REPORT

OF THE

SIXTY-SIXTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

HELD AT

LIVERPOOL IN SEPTEMBER 1896.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
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[*An asterisk * indicates that the title only is given. The mark † indicates the same, but a reference is given to the journal or newspaper where it is published* in extenso.]

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PLATE.

OBJECTS AND RULES

OF

THE ASSOCIATION.

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 not less than two years in advance [1]; 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 Assistant General 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.[2]

1. Delegates nominated by the Corresponding Societies under the conditions hereinafter explained. *Claims under this Rule to be sent to the Assistant General 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.[3]

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,[4] and of preparing Reports

[1] Revised by the General Committee, Liverpool, 1896.

[2] Revised, Montreal, 1884.

[3] Passed, Edinburgh, 1871.

[4] *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

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 Sectional 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, and on the following Thursday, Friday, Saturday,[4] Monday, and Tuesday, for the objects stated in the Rules of the Association. The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and the Sectional Committee except for Thursday and Saturday.[5]

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

necessary, in order to give an opportunity to the Committees of doing justice to 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 Assistant General Secretary *before the conclusion of the Meeting.*

[1] Sheffield, 1879. [2] Swansea, 1880. [3] Edinburgh, 1871.
[4] The meeting on Saturday is optional, Southport, 1883. [5] Nottingham, 1893.

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 Assistant General Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxix), 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 Assistant General 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.

Notices regarding Grants of Money.[2]

1. No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the Rules of the Association.
2. In grants of money to Committees the Association does not contemplate the payment of personal expenses to the Members.
3. Committees to which grants of money are entrusted by the Association for the prosecution of particular Researches in Science are appointed for one year only. If the work of a Committee cannot be completed in the year, and if the Sectional Committee desire the work to be continued, application for the reappointment of the Committee for another year must be made at the next meeting of the Association.
4. Each Committee is required to present a Report, whether final or interim, at the next meeting of the Association after their appointment or reappointment. Interim Reports must be submitted in writing, though not necessarily for publication.

[1] Revised by the General Committee, Bath, 1888.
[2] Revised by the General Committee at Ipswich, 1895.

5. In each Committee the Chairman is the only person entitled to call on the Treasurer, Professor A. W. Rücker, F.R.S., for such portion of the sums granted as may from time to time be required.
6. Grants of money sanctioned at a meeting of the Association expire on June 30 following. The Treasurer is not authorised after that date to allow any claims on account of such grants.
7. The Chairman of a Committee must, before the meeting of the Association next following after the appointment or reappointment of the Committee, forward to the Treasurer a statement of the sums which have been received and expended, with vouchers. The Chairman must also return the balance of the grant, if any, which has been received and not spent; or, if further expenditure is contemplated, he must apply for leave to retain the balance.
8. When application is made for a Committee to be reappointed, and to retain the balance of a former grant which is in the hands of the Chairman, and also to receive a further grant, the amount of such further grant is to be estimated as being additional to, and not inclusive of, the balance proposed to be retained.
9. 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.
10. Members and Committees who may be entrusted with sums of money for collecting specimens of Natural History are requested to reserve the specimens so obtained to be dealt with by authority of the Association.
11. Committees are requested to furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and to state whether the apparatus will be useful for continuing the research in question, or for other scientific purposes.
12. All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association when not employed in scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation shortly before the meeting commences. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At the time appointed the Chair will be taken,[1] and the reading of communications, in the order previously made public, commenced.

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.

[1] The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and Sectional Committee, except for Thursday and Saturday.

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 Assistant General 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.

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]

If the President of a Section is 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.[3]

[1] Passed by the General Committee at Newcastle, 1863.
[2] Passed by the General Committee at Birmingham, 1865.
[3] Passed by the General Committee at Leeds, 1890.

Corresponding Societies.[1]

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 Assistant General 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 Assistant General Secretary of the Association, a schedule, properly filled up, which will be issued by him, 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 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

[1] Passed by the General Committee, 1884.

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

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

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 the 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.

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, 831.	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, Esq.
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.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
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.
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., F.R.S.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.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
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.
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 Glong, 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.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S., F.R.S.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., F.R.S.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., F.R.S.E. Professor Allen Thomson, M.D., LL.D., F.R.S., F.R.S.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., F.R.S.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.
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., F.R.S.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.

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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., LL.D., F.R.S.L. & E. 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., F.R.S.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., F.R.S.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.
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 Marquess 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. Colonel R. P. Laurie, C.B., M.P. E. R. Wodehouse, Esq., M.P. Jerom Murch, Esq., J.P., D.L.	W. Pumphrey, Esq. J. L. Stothert, Esq., M.Inst.C.E. B. H. Watts, Esq.

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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. The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., F.R.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. The Right Hon. W. L. Jackson, M.P. The Mayor of Leeds Sir James Kitson, Bart., M.Inst.C.E. Sir Andrew Fairbairn, M.A.	J. Rawlinson Ford, Esq. Sydney Lupton, Esq., M.A. Professor L. C. Miall, F.L.S., F.G.S. Professor A. Smithells, B.Sc.
WILLIAM HUGGINS, Esq., D.C.L., LL.D., Ph.D., F.R.S., F.R.A.S., Hon. F.R.S.E. CARDIFF, August 19, 1891.	The Right Hon. Lord Windsor, Lord-Lieutenant of Glamorganshire The Most Hon. the Marquess of Bute, K.T. The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S. The Right Hon. Lord Tredegar The Right Hon. Lord Aberdare, G.C.B., F.R.S., F.R.G.S. Sir J. T. D. Llewelyn, Bart., F.Z.S. Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., Pres.G.S. Sir Robert Ball, LL.D., F.R.S., F.R.A.S., Royal Astronomer of Ireland	R. W. Atkinson, Esq., B.Sc., F.C.S., F.I.C. Professor H. W. Lloyd Tanner, M.A., F.R.A.S.
SIR ARCHIBALD GEIKIE, LL.D., D.Sc., For. Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom EDINBURGH, August 3, 1892.	The Right Hon. the Lord Provost of Edinburgh The Most Hon. the Marquess of Lothian, K.T. The Right Hon. the Earl of Rosebery, LL.D., F.R.S., F.R.S.E. The Right Hon. J. H. A. Macdonald, C.B., LL.D., F.R.S., F.R.S.E. Principal Sir William Muir, K.C.S.I., D.C.L. Professor Sir Douglas Maclagan, M.D., Pres.R.S.E. Professor Sir William Turner, F.R.S., F.R.S.E. Professor P. G. Tait, M.A., F.R.S.E. Professor A. Crum Brown, M.D., F.R.S., F.R.S.E., Pres.C.S.	Professor G. F. Armstrong, M.A., M.Inst.C.E., F.R.S.E., F.G.S. F. Grant Ogilvie, Esq., M.A., B.Sc., F.R.S.E. John Harrison, Esq.

DR. J. S. BURDON SANDERSON, M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford NOTTINGHAM, September 13, 1893.	His Grace the Duke of St. Albans, Lord-Lieut. of Nottinghamshire His Grace the Duke of Devonshire, K.G., Chancellor of the University of Cambridge His Grace the Duke of Portland. His Grace the Duke of Newcastle The Right Hon. Lord Belper. The Mayor of Nottingham The Right Hon. Sir W. R. Grove, F.R.S. Sir John Turney, J.P. Professor Michael Foster, M.A., Sec.R.S. W. H. Ransom, Esq., M.D., F.R.S.	Professor F. Clowes, D.Sc. Professor W. H. Heaton, M.A. Arthur Williams, Esq.
The MOST HON. THE MARQUIS OF SALISBURY, K.G., D.C.L., F.R.S., Chancellor of the University of Oxford. OXFORD, August 8, 1894.	The Right Hon. the Earl of Jersey, G.C.M.G., Lord-Lieutenant of the County of Oxford The Right Hon. Lord Wantage, K.C.B., V.C., Lord-Lieutenant of Berkshire The Right Hon. the Earl of Rosebery, K.G., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Oxford, D.D. The Right Hon. Lord Rothschild, Lord-Lieutenant of Buckinghamshire. The Right Hon. Lord Kelvin, D.C.L., Pres.R.S. The Rev. the Vice-Chancellor of the University of Oxford. The Mayor of Oxford. Sir W. R. Anson, D.C.L., Warden of All Souls College Sir Bernhard Samuelson, Bart., M.P., F.R.S. Sir Henry Dyke Acland, Bart., M.D., F.R.S., Regius Professor of Medicine. The Rev. the Master of Pembroke College, Sedleian Professor of Natural Philosophy Dr. J. J. Sylvester, F.R.S., Savilian Professor of Geometry.	Gilbert C. Bourne, Esq., M.A. G. C. Druce, Esq., M.A. D. H. Nagel, Esq., M.A.
CAPTAIN SIR DOUGLAS GALTON, K.C.B., D.C.L., LL.D., F.R.S., F.R.G.S., F.G.S. IPSWICH, September 11, 1895	The Most Hon. the Marquis of Bristol, M.A., Lord.-Lieutenant of the County of Suffolk The Right Hon. Lord Walsingham, LL.D., F.R.S., High Steward of the University of Cambridge The Right Hon. Lord Rayleigh, Sec.R.S., Lord-Lieutenant of Essex The Right Hon. Lord Gwydyr, M.A., High Steward of Ipswich The Right Hon. Lord Henniker F.S.A. The Right Hon. Lord Rendlesham J. H. Bartlet, Esq., Mayor of Ipswich Sir G. G. Stokes, Bart., D.C.L., F.R.S. Dr. E. Frankland, D.C.L., F.R.S. Professor G. H. Darwin, M.A., F.R.S. Felix T. Cobbold, Esq., M.A.	G. H. Hewetson, Esq. S. A. Notcutt, Esq., B.A., LL.M., B. c. E. P. Ridley, Esq.
SIR JOSEPH LISTER, BART, D.C.L., LL.D., President of the Royal Society LIVERPOOL, September 16, 1896.	The Right Hon. the Earl of Derby, G.C.B., Lord Mayor of Liverpool. The Right Hon. the Earl of Sefton, K.G., Lord-Lieutenant of Lancashire. Sir W. B. Forwood, J.P. Sir Henry E. Roscoe. D.C.L., F.R.S. The Principal of University College, Liverpool W. Rathbone, Esq., LL.D. W. Crookes, Esq., F.R.S., V.P.C.S. T. H. Ismay, Esq., J.P., D.L. Professor A. Liversidge, F.R.S.	Professor W. A. Herdman, F.R.S. Isaac C. Thompson, Esq., F.L.S. W. E. Willink, Es

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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., F.R.S.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., F.R.S.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, Dr. O. J. Lodge, D. MacAlister, Rev. W. Routh.
1882. Southampton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Dr. 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, A. Johnson, O. J. Lodge, 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, A. Lodge, W. N. Shaw, 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.
1891. Cardiff......	Prof. O. J. Lodge, D.Sc., LL.D., F.R.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Prof. A. L. Selby.
1892. Edinburgh	Prof. A. Schuster, Ph.D., F.R.S., F.R.A.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1893. Nottingham	R. T. Glazebrook, M.A., F.R.S.	W. T. A. Emtage, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1894. Oxford	Prof. A. W. Rücker, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, J. Walker.
1895. Ipswich ...	Prof. W. M. Hicks, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, G. T. Walker, W. Watson.
1896. Liverpool...	Prof. J. J. Thomson, M.A., D.Sc., F.R.S.	Prof. W. H. Heaton, J. L. Howard, Prof. A. Lodge, G. T. Walker, W. Watson.

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, R. 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.

Date and Place	Presidents	Secretaries
1846. Southampton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
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. H. Miller, M.A., 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.	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.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.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.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.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............. ..	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.

Date and Place	Presidents	Secretaries
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S.	H. S. Bell, W. Chandler Roberts, J. M. Thomson.
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. P. Bedson, H. B. Dixon, W. R. E. Hodgkinson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, F.R.S.	P. P. 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.	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, H. Forster Morley, R. E. Moyle, W W. J. Nicol.
1889. Newcastle-upon-Tyne	Sir I. Lowthian Bell, Bart., D.C.L., F.R.S.	H. Forster Morley, D. H. Nagel, 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, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1891. Cardiff......	Prof. W. C. Roberts-Austen, C.B., F.R.S.	C. H. Bothamley, H. Forster Morley, W. W. J. Nicol, G. S. Turpin.
1892. Edinburgh	Prof. H. McLeod, F.R.S.	J. Gibson, H. Forster Morley, D. H. Nagel, W. W. J. Nicol.
1893. Nottingham	Prof. J. Emerson Reynolds, M.D., D.Sc., F.R.S.	J. B. Coleman, M. J. R. Dunstan, D. H. Nagel, W. W. J. Nicol.
1894. Oxford......	Prof. H. B. Dixon, M.A., F.R.S.	A. Colefax, W. W. Fisher, Arthur Harden, H. Forster Morley.

SECTION B (*continued*).—CHEMISTRY.

1895. Ipswich ...	Prof. R. Meldola, F.R.S.	E. H. Fison, Arthur Harden, C. A. Kohn, J. W. Rodger.
1896. Liverpool...	Dr. Ludwig Mond, F.R.S.	Arthur Harden, C. A. Kohn

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	J. Phillips, T. J. 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.—*Geog.*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geog.*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Capt. 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.—*Geog.*, G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.

Date and Place	Presidents	Secretaries
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.
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, Pres. G. S.	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....	J. 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.

[1] The subject of Geography was separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section" in 1850; for Presidents and Secretaries of which see page lxii.

Date and Place	Presidents	Secretaries
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.
1867. Dundee ...	Archibald Geikie, F.R.S.	E. Hull, W. Pengelly, H. 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. T. 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. M. Duncan, F.R.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, 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.
1891. Cardiff	Prof. T. Rupert Jones, F.R.S., F.G.S.	W. Galloway, J. E. Marr, Clement Reid, W. W. Watts.
1892. Edinburgh	Prof. C. Lapworth, LL.D., F.R.S., F.G.S.	H. M. Cadell, J. E. Marr, Clement Reid, W. W. Watts.
1893. Nottingham	J. J. H. Teall, M.A., F.R.S., F.G.S.	J. W. Carr, J. E. Marr, Clement Reid, W. W. Watts.
1894. Oxford......	L. Fletcher, M.A., F.R.S.	F. A. Bather, A. Harker, Clement Reid, W. W. Watts.
1895. Ipswich ...	W. Whitaker, B.A., F.R.S. ...	F. A. Bather, G. W. Lamplugh, H. A. Miers, Clement Reid.
1896. Liverpool...	J. E. Marr, M.A., F.R.S., Sec. G.S.	J. Lomas, Prof. H. A. Miers, Clement Reid.

BIOLOGICAL SCIENCES.

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

Date and Place	Presidents	Secretaries
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.

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. lxi.]

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.

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

Date and Place	Presidents	Secretaries
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.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham[1]	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.

1866. Nottingham	Prof. Huxley, F.R.S.—*Dep. of Physiol.*, Prof. Humphry, F.R.S.—*Dep. of Anthropol.*, A. R. Wallace.	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.

[1] The title of Section D was changed to Biology; and for the word 'Subsection,' in the rules for conducting the business of the Sections, the word 'Department' was substituted.

Date and Place	Presidents	Secretaries
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, F.R.S.—*Dep. of Anthropol.*, Prof. Rolleston, 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.
1876. Glasgow ...	A. Russel Wallace, F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, 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, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister.—*Dep. of Anthropol.*, F. Galton, 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., F.R.S. —*Dep. of Anthropol.*, Prof. W. H. Flower, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, 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.[1]	Prof. A. Gamgee, M.D., F.R.S. —*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, F.L.S. —*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport[2]	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 ...	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. M'Intosh, M.D., LL.D., F.R.S. F.R.S.E.	W. Heape, J. McGregor-Robertson, J. Duncan Matthews, Howard Saunders, H. Marshall Ward.

[1] The Departments of Zoology and Botany and of Anatomy and Physiology were amalgamated.

[2] Anthropology was made a separate Section, see p. lxviii.

Date and Place	Presidents	Secretaries
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.
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, S. J. Hickson, F. W. Oliver, H. Wager, H. Marshall Ward.
1891. Cardiff	Francis Darwin, M.A., M.B., F.R.S., F.L.S.	F. E. Beddard, Prof. W. A. Herdman, Dr. S. J. Hickson, G. Murray, Prof. W. N. Parker, H. Wager.
1892. Edinburgh	Prof. W. Rutherford, M.D., F.R.S., F.R.S.E.	G. Brook, Prof. W. A. Herdman, G. Murray, W. Stirling, H. Wager.
1893. Nottingham[1]	Rev. Canon H. B. Tristram, M.A., LL.D., F.R.S.	G. C. Bourne, J. B. Farmer, Prof. W. A. Herdman, S. J. Hickson, W. B. Ransom, W. L. Sclater.
1894. Oxford[2] ...	Prof. I. Bayley Balfour, M.A., F.R.S.	W. W. Benham, Prof. J. B. Farmer, Prof. W A. Herdman, Prof. S. J. Hickson, G. Murray, W. L. Sclater.

SECTION D (*continued*).—ZOOLOGY.

1895. Ipswich ...	Prof. W. A. Herdman, F.R.S.	G. C. Bourne, H. Brown, W. E. Hoyle, W. L. Sclater.
1896. Liverpool...	Prof. E. B. Poulton, F.R.S.	H. O. Forbes, W. Garstang, W. E. Hoyle.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. J. Haviland..................	Dr. H. J. H. Bond, Mr. G. E. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

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

1835. Dublin	Dr. J. C. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. P. M. 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.

[1] Physiology was made a separate Section, see p. lxviii.
[2] The title of Section D was changed to Zoology.

Date and Place	Presidents	Secretaries
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.
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.[2]	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. lv.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. J. C. 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.

[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. lviii.). Section E, being then vacant, was assigned in 1851 to Geography.

[2] *Vide* note on page lix.

Date and Place	Presidents	Secretaries
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.
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.

Date and Place	Presidents	Secretaries
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.	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., F.R.S.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.	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.

Date and Place	Presidents	Secretaries
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.
1891. Cardiff......	E. G. Ravenstein, F.R.G.S., F.S.S.	John Coles, J. S. Keltie, H. J. Mackinder, A. Silva White, Dr. Yeats.
1892. Edinburgh	Prof. J. Geikie, D.C.L., F.R.S., V.P.R.Scot.G.S.	J. G. Bartholomew, John Coles, J. S. Keltie, A. Silva White.
1893. Nottingham	H. Seebohm, Sec. R.S., F.L.S., F.Z.S.	Col. F. Bailey, John Coles, H. O. Forbes, Dr. H. R. Mill.
1894. Oxford......	Capt. W. J. L. Wharton, R.N., F.R.S.	John Coles, W. S. Dalgleish, H. N. Dickson, Dr. H. R. Mill.
1895. Ipswich ...	H. J. Mackinder, M.A., F.R.G.S.	John Coles, H. N. Dickson, Dr. H. R. Mill, W. A. Taylor.
1896. Liverpool...	Major L. Darwin, Sec. R.G.S.	Col. F. Bailey, H. N. Dickson, Dr. H. R. Mill, E. C. DuB. Phillips.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

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

SECTION F.—STATISTICS.

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.

Date and Place	Presidents	Secretaries
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.

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.
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, Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, 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	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.

Date and Place	Presidents	Secretaries
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, 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, 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.
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.
1891. Cardiff......	Prof. W. Cunningham, D.D., D.Sc., F S.S.	Prof. J. Brough, E. Cannan, Prof. E. C. K. Gonner, H. Ll. Smith, Prof. W. R. Sorley.
1892. Edinburgh	Hon. Sir C. W. Fremantle, K.C.B.	Prof. J. Brough, J. R. Findlay, Prof. E. C. K. Gonner, H. Higgs, L. L. F. R. Price.
1893. Nottingham	Prof. J. S. Nicholson, D.Sc., F.S.S.	Prof. E. C. K. Gonner, H. de B. Gibbins, J. A. H. Green, H. Higgs, L. L. F. R. Price.
1894. Oxford......	Prof. C. F. Bastable, M.A., F.S.S.	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.
1895. Ipswich ...	L. L. Price, M.A.	E. Cannan, Prof. E. C. K. Gonner, H. Higgs.
1896. Liverpool...	Rt. Hon. L. Courtney, M.P....	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.

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. South'mpt'n	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. Birmingh'm	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.

Date and Place	Presidents	Secretaries
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, F.R.S.	J. Oldham, J. Thomson, W. S. Ward.
1854. Liverpool...	John Scott Russell, F.R.S. ...	J. Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. M. Rankine, F.R.S. ...	L. Hill, W. Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton. B. Jones, 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	William Fairbairn, 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.
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, A. 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 ...	J. Abernethy, 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	J. Brunlees, 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.

Date and Place	Presidents	Secretaries
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.
1891. Cardiff......	T. Forster Brown, M.Inst.C.E.,	C. W. Cooke, Prof. A. C. Elliott, W. B. Marshall, E. Rigg.
1892. Edinburgh	Prof. W. C. Unwin, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, W. C. Popplewell, E. Rigg.
1893. Nottingham	Jeremiah Head, M.Inst.C.E., F.C.S.	C. W. Cooke, W. B. Marshall, E. Rigg, H. Talbot.
1894. Oxford......	Prof. A. B. W. Kennedy, F.R.S., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, Rev. F. J. Smith.
1895. Ipswich ...	Prof. L. F. Vernon-Harcourt, M.A., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, P. G. M. Stoney.
1896. Liverpool...	Sir Douglas Fox, V.P.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, S. Dunkerley, W. B. Marshall.

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.
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.
1891. Cardiff......	Prof. F. Max Müller, M.A. ...	G. W. Bloxam, Prof. R. Howden, H. Ling Roth, E. Seward.
1892. Edinburgh	Prof. A. Macalister, M.A., M.D., F.R.S.	G. W. Bloxam, Dr. D. Hepburn, Prof. R. Howden, H. Ling Roth.
1893. Nottingham	Dr. R. Munro, M.A., F.R.S.E.	G. W. Bloxam, Rev. T. W. Davies, Prof. R. Howden, F. B. Jevons, J. L. Myres.
1894. Oxford......	Sir W. H. Flower, K.C.B., F.R.S.	H. Balfour, Dr. J. G. Garson, H. Ling Roth.
1895. Ipswich ...	Prof. W. M. Flinders Petrie, D.C.L.	J. L. Myres, Rev. J. J. Raven, H. Ling Roth.
1896. Liverpool...	Arthur J. Evans, F.S.A.	Prof. A. C. Haddon, J. L. Myres, Prof. A. M. Paterson.

SECTION I.—PHYSIOLOGY (including Experimental Pathology and Experimental Psychology).

1894. Oxford......	Prof. E. A. Schäfer, F.R.S., M.R.C.S.	Prof. F. Gotch, Dr. J. S. Haldane, M. S. Pembrey.
1896. Liverpool...	Dr. W. H. Gaskell, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington.

SECTION K.—BOTANY.

1895. Ipswich ...	W. T. Thiselton-Dyer, F.R.S.	A. C. Seward, Prof. F. E. Weiss.
1896 Liverpool...	Dr. D. H. Scott, F.R.S.	Prof. Harvey Gibson, A. C. Seward, Prof. F. E. Weiss.

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.
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.

Date and Place	Lecturer	Subject of Discourse
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.	The 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.
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.

Date and Place	Lecturer	Subject of Discourse
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	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.	Galvanic 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	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.
1891. Cardiff	Prof. L. C. Miall, F.L.S., F.G.S.	Some Difficulties in the Life of Aquatic Insects.
	Prof. A. W. Rücker, M.A., F.R.S.	Electrical Stress.
1892. Edinburgh	Prof. A. M. Marshall, F.R.S.	Pedigrees.
	Prof. J. A. Ewing, M.A., F.R.S.	Magnetic Induction.
1893. Nottingham	Prof. A. Smithells, B.Sc.	Flame.
	Prof. Victor Horsley, F.R.S.	The Discovery of the Physiology of the Nervous System.
1894. Oxford......	J. W. Gregory, D.Sc., F.G.S.	Experiences and Prospects of African Exploration.
	Prof. J. Shield Nicholson, M.A.	Historical Progress and Ideal Socialism.
1895. Ipswich ...	Prof. S. P. Thompson, F.R.S.	Magnetism in Rotation.
	Prof. Percy F. Frankland, F.R.S.	The Work of Pasteur and its various Developments.
1896. Liverpool...	Dr. F. Elgar, F.R.S.	Safety in Ships.
	Prof. Flinders Petrie, D.C.L.	Man before Writing.

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.
1891. Cardiff	Prof. S. P. Thompson, F.R.S.	Electricity in Mining.
1892. Edinburgh	Prof. C. Vernon Boys, F.R.S.	Electric Spark Photographs.
1893. Nottingham	Prof. Vivian B. Lewes	Spontaneous Combustion.
1894. Oxford	Prof. W. J. Sollas, F.R.S. ...	Geologies and Deluges.
1895. Ipswich ...	Dr. A. H. Fison	Colour.
1896. Liverpool...	Prof. J. A. Fleming, F.R.S....	The Earth a Great Magnet.

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[1] Mr. Courtney was unable to attend the Meeting.

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1895–96.

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				£	s.	d.
Balance brought forward				1621	19	11
Life Compositions				200	0	0
New Annual Members' Subscriptions				76	0	0
Annual Subscriptions				541	0	0
Sale of Associates' Tickets				487	0	0
Sale of Ladies' Tickets				261	0	0
Sale of Index, 1861–90				18	13	9
Sale of other Publications				136	18	8
Interest on Deposit at Ipswich Bank				10	4	0
Interest on Exchequer Bills				9	13	4
Dividends on Consols				200	7	4
Dividends on India 3 per Cents				104	8	0
Unexpended Balances of Grants returned :—						
Committee on North-Western Tribes of Canada	£76	15	0			
Committee on New Sections of Stonesfield Slate	26	7	6			
Committee on Erratic Blocks	2	10	6			
Committee for Comparison of Magnetic Standards	0	4	3			
				105	17	3
				£3773	2	3

Investments

		£	s.	d.
June 29, 1895:	Consols	7537	3	5
	India 3 per Cents	3600	0	0
		£11,137	3	5

LUDWIG MOND, E. FRANKLAND, } *Auditors.*

from July 1, 1895, to June 30, 1896. *Cr.*

1895–96. PAYMENTS.

	£	s.	d.	£	s.	d.
Expenses of Ipswich Meeting, including Printing, Advertising, Payment of Clerks, &c.				148	10	5
Rent and Office Expenses				50	5	2
Salaries				505	0	0
Printing, Binding, &c.				1007	5	4
Payment of Grants made at Ipswich:						
Photographs of Meteorological Phenomena	15	0	0			
Seismological Observations	80	0	0			
Abstracts of Physical Papers	100	0	0			
Calculation of Certain Integrals	10	0	0			
Uniformity of Size of Pages of Transactions, &c.	5	0	0			
Wave-length Tables of the Spectra of the Elements	10	0	0			
Action of Light upon Dyed Colours	2	6	1			
Electrolytic Quantitative Analysis	10	0	0			
The Carbohydrates of Barley Straw	50	0	0			
Reprinting Discussion on the Relation of Agriculture to Science	5	0	0			
Erratic Blocks	10	0	0			
Palæozoic Phyllopoda	5	0	0			
Shell-bearing Deposits at Clava, &c.	10	0	0			
Eurypterids of the Pentland Hills	2	0	0			
Investigation of a Coral Reef by Boring and Sounding	10	0	0			
Examination of Locality where the Cetiosaurus in the Oxford Museum was found	25	0	0			
Palæolithic Deposits at Hoxne	25	0	0			
Fauna of Singapore Caves	40	0	0			
Age and Relation of Rocks near Moreseat, Aberdeen	10	0	0			
Table at the Zoological Station at Naples	100	0	0			
Table at the Biological Laboratory, Plymouth	15	0	0			
Zoology, Botany, and Geology of the Irish Sea	50	0	0			
Zoology of the Sandwich Islands	100	0	0			
African Lake Fauna	100	0	0			
Oysters under Normal and Abnormal Environment	40	0	0			
Climatology of Tropical Africa	10	0	0			
Calibration and Comparison of Measuring Instruments	20	0	0			
Small Screw Gauge	10	0	0			
North-Western Tribes of Canada	100	0	0			
Lake Village at Glastonbury	30	0	0			
Ethnographical Survey	40	0	0			
Mental and Physical Condition of Children	10	0	0			
Physiological Applications of the Phonograph	25	0	0			
Corresponding Societies Committee	30	0	0			
				1104	6	1
In hands of General Treasurer:						
At Bank of England, Western Branch £481 10 5						
Less Cheques not presented 25 0 0						
	456	10	5			
Exchequer Bills	500	0	0			
Cash	1	4	10			
				957	15	3
				£3773	2	3

Account.

	£	s.	d.
June 30, 1896: Consols	7537	3	5
India 3 per Cents	3600	0	0
	£11,137	3	5

ARTHUR W. RÜCKER, *General Treasurer.*

July 10, 1896.

Table showing the Attendance and Receipts

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, DD.	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
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S. ...	330	31

* 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 8 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	1855 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	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896

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

REPORT OF THE COUNCIL.

Report of the Council for the Year 1895–96, *presented to the General Committee at Liverpool on Wednesday, September* 16, 1896.

The Council have received reports from the General Treasurer during the past year, and his accounts from July 1, 1895, to June 30, 1896, which have been audited, will be presented to the General Committee.

Of the Auditors appointed last year, Dr. Ludwig Mond alone was able to act. Dr. Thorpe was incapacitated by a severe accident, and Mr. J. Head was in America at the time of the audit. The President therefore requested Dr. Frankland to act in conjunction with Dr. Mond, which he consented to do.

The Council received an invitation from the Committee charged with the arrangements for celebrating the Jubilee of the appointment of the Right Hon. Lord Kelvin as Professor of Natural Philosophy in the University of Glasgow, to appoint two representatives to take part in the celebration.

They appointed Sir Douglas Galton, President, and Professor A. W. Rücker, General Treasurer, to be their representatives, and asked them to convey to Lord Kelvin the following letter of congratulation :—

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
BURLINGTON HOUSE, LONDON, W.

TO THE RIGHT HONOURABLE LORD KELVIN, D.C.L., LL.D., F.R.S., &c. &c.

MY LORD,—The Council of the British Association for the Advancement of Science desire to offer to you their sincere congratulations on your attainment of the fiftieth year of your tenure of the Professorship of Natural Philosophy in the University of Glasgow.

It is unnecessary to recount the triumphs you have won during the last half-century in mastering the difficulties which beset the advance of scientific theory and experiment, and in applying scientific principles to the practical service of man. The record of your achievements is fresh in the minds of those who address you, and can never be effaced from the history of the development of Mathematical and Experimental Physics, of Engineering, and of Navigation.

We would rather, therefore, recall to your recollection the long and close connection which has existed between the British Association and yourself.

As a regular attendant at our meetings, you have not only enriched our Transactions with many important papers, but have encouraged the efforts of younger men by never-failing sympathy and interest in their work.

You have been President of the Mathematical and Physical Section of the Association no less than five times. You were President of the Association at Edinburgh in 1871, and are now a Life-Member of our Council.

As colleagues, then, we wish to tell you of the pride with which we, in common with all your fellow-countrymen, regard your distinguished career, and of the feelings of personal attachment with which we express the hope that you may long be spared to enjoy, in health and strength, the honours you have so nobly won.

Signed on behalf of the Council,
DOUGLAS GALTON, President.

June, 1896.

The Council have nominated Mr. T. H. Ismay, J.P., D.L., and Professor Archibald Liversidge, F.R.S., Vice-Presidents of the Association; and Mr. C. Booth, jun., Assistant Local Treasurer.

The Council had also nominated as a Vice-President of the Association Mr. George Holt. They deeply regret the loss which the Association has sustained by the death of Mr. Holt, one of the most munificent of the promoters of Science in the City of Liverpool.

The Council have elected the following Foreign Men of Science Corresponding Members:—

Professor Dr. Emil C. Hansen, Copenhagen.
Professor F. Paschen, Hanover.
Professor Ira Remsen, Baltimore.
Professor C. Runge, Hanover.

An invitation to hold the Annual Meeting of the Association in 1898 at Bristol has been received. An invitation has also been received to hold the Annual Meeting of the Association at Glasgow in 1898. These invitations will be presented to the General Committee on Monday.

The Council received a proposal from M. Gariel, Secretary of the Council of the Association Française pour l'Avancement des Sciences, that in 1898 or 1899 the French Association should meet at Boulogne, and our Association at some town on the opposite coast, such as would allow an interchange of visits between the two Associations. This proposal was cordially welcomed by the Council, and inquiries were instituted as to the possibility of a meeting of our Association at Dover, which seemed to be the most suitable town on the English side of the Straits. A favourable report was received of the accommodation at Dover, and of the welcome which the Association might expect; and a reply was sent to M. Gariel thanking him for his suggestion, and expressing a hope that we should be able to do our part towards its accomplishment. Since then an invitation has been received from the Corporation of Dover to hold our meeting in 1899 in that town. The Council of the French Association, which ordinarily meets earlier than ours, wish to settle their place of meeting in 1899 before the date of our meeting at Toronto. It thus becomes expedient for the General Committee to consider the invitation from Dover at their meeting on Monday next; and, to enable them to do so, the Council propose that, in the rule for fixing the place of meeting, the words 'not less than two years in advance' be substituted for the words 'two years in advance.' If this proposal be adopted, the invitation from Dover will come before the General Committee on Monday next.

The President has received from the Mayor of San Francisco the following resolution, which had been passed by the Board of Supervisors of that city:—

'Resolved that his honour the Mayor be, and is hereby empowered and requested to invite the American and Australasian Associations for the Advancement of Science to meet in this city in 1897; also, to invite the British Association of the same character to meet said Associations in this city as invited guests, and to that end to take such action as may be proper to arrange for their comfort and accommodation on that occasion.

'And the clerk is hereby directed to advertise this resolution as required by law.

'Board of Supervisors, San Francisco, October 28, 1895.'

The President was requested by the Council to inform the Mayor of

San Francisco that his communication would be laid before the General Committee at Liverpool.

Since the above resolution was adopted the Council have been informed that it has been decided to hold the meeting of the American Association in 1897 at Detroit. It is not, therefore, possible, to make arrangements for a joint meeting in San Francisco, or for the Association to visit that city. It is proposed, therefore, to reply in this sense to the invitation of the Mayor of San Francisco, and to request him to convey to the Board of Supervisors the best thanks of the Association for their cordial invitation.

The Council recommend that on the occasion of the Meeting of the Association at Toronto, the President, Vice-Presidents, and Officers of the American Association be invited to attend as Honorary Members for the year; and further that all Fellows and Members of the American Association be admitted Members of the British Association on the same terms as old Annual Members, namely, on payment of 1*l.*, without the payment of an admission fee.

The Council recommend that the arrangements made for the Meetings of the General Committee at Montreal, in 1884, be adopted for the Meeting next year—viz.: That two Meetings be held at Toronto, and that an adjourned Meeting be held in London at the beginning of the month of November, for the election of the President and Officers for 1898, and for fixing the date of the Meeting in that year.

The Council have received the following communication from the Secretary of the Corporation of the McGill University, Montreal:—

TO THE PRESIDENT AND MEMBERS OF THE COUNCIL OF THE BRITISH ASSOCIATION.

McGill University, Montreal,
January 11, 1896.

GENTLEMEN,—I have been directed by the Corporation of the University to lay before the Council of the British Association a proposal giving the Faculty of Applied Science the liberty of substituting for the British Association Gold Medal one or more Bronze Medals, together with an exhibition or prizes in such cases as the Faculty might recommend.

The British Association Gold Medal was generously founded by the members of the British Association in the year 1885, and, apart from its intrinsic value, the medal has always been regarded as the highest prize obtainable in the Faculty of Applied Science.

The desire of the Faculty has been to require a very high standard from those who are candidates for the medal. A difficulty has, however, often arisen, owing to the fact that there are five distinct departments in the Faculty, namely, the departments of Civil Engineering, Electrical Engineering, Mechanical Engineering, Mining, and Chemistry. The practice has been to award the medal in the several departments in rotation; but of course it often happens that in more than one department there are to be found students worthy of the medal. It has also happened that the best student is not in the department in which the medal falls in order of rotation.

After long consideration, and after the experience of the ten years which have passed since the foundation of the medal, the Faculty is of the opinion that it would be advisable to ask the permission of the Council to substitute for the Gold Medal a B.A. Exhibition, or B.A. Prizes, together with one or more B.A. Bronze Medals. The Faculty is convinced that the change would rather add to than diminish the value of the foundation.

The Council informed the Corporation of the McGill University that they were willing to advise the General Committee to accept the proposed changes, and they have asked for information as to the number of Prizes and Bronze Medals which would probably be awarded annually under the revised regulations.

The following resolutions referred to the Council by the General Committee for consideration and action if desirable were dealt with as follows:—

(1) That the Council be requested to consider whether it be desirable to take steps in order to bring the following resolution under the notice of H.M. Government and the Trustees of the British Museum:—

'That in view of the importance of preserving the remains of the various civilisations of this Empire which are fast disappearing, and in order to prevent the loss and dispersion of collections of ancient and modern Anthropology which may be offered to the nation, it is highly desirable to acquire less costly and far more extended storehouse space than can be provided in London.'

The Council appointed a Committee to report on this resolution, and were informed that, in accordance with the suggestion made by Mr. Charles Read, Keeper of Antiquities and Ethnography at the British Museum, and with the concurrence of Professor Flinders Petrie, the proposal to establish a Repository for preserving Anthropological or other objects will be again discussed at the Liverpool Meeting; and that therefore no further action need be taken by the Council at present.

(2) That the Council be requested to bring before the Government the importance of securing for the National Collections the type collection of preparations of Fossil Plants left by the late Professor W. C. Williamson.

This resolution was communicated by the President, Sir Douglas Galton, to the Trustees of the British Museum, and the Council have been informed that the Collection of Fossils has been purchased by them for the Museum.

(3) That it is desirable to reprint collections of the Addresses delivered by the Presidents of Sections in separate volumes for sale.

The Council, having considered this proposal, resolved that no action be taken.

(4) That the Council be requested to provide the Geological Survey Maps and Sections of the district in which the Association meets each year, to be placed in a conspicuous position in the Meeting Room of Section C.

The Officers have been empowered to carry out this proposal.

The Report of the Corresponding Societies Committee for the past year, consisting of the list of the Corresponding Societies and the titles of the more important papers, and especially those referring to Local Scientific Investigations, published by those Societies during the year ending June 1, 1896, has been received.

The Corresponding Societies Committee, consisting of Mr. Francis Galton, Professor R. Meldola, Sir Douglas Galton, Sir Rawson Rawson, Dr. J. G. Garson, Sir J. Evans, Mr. J. Hopkinson, Mr. W. Whitaker, Mr. G. J. Symons, Professor T. G. Bonney, Mr. T. V. Holmes, Professor E. B. Poulton, Mr. Cuthbert Peek, and the Rev. Canon Tristram, is hereby nominated for reappointment by the General Committee.

The Council nominate Dr. J. G. Garson, Chairman, and Mr. T. V.

Holmes, Secretary, to the Conference of Delegates of Corresponding Societies to be held during the Meeting at Liverpool.

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

Professor W. E. Ayrton.
Sir Benjamin Baker.
Sir John Evans.
Sir Clements R. Markham.
Mr. W. Whitaker.

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

Anderson, Dr. W., C.B., F.R.S.
Boys, Professor C. Vernon, F.R.S.
*Creak, Captain E. W., F.R.S.
Edgeworth, Professor F. Y., M.A.
Foxwell, Professor H. S., M.A.
Harcourt, Professor L. F. Vernon, M.A., M.Inst.C.E.
Herdman, Professor W. A., F.R.S.
*Hopkinson, Dr. J., F.R.S.
Horsley, Victor, Esq., F.R.S.
Lodge, Professor Oliver J., F.R.S.
*Marr, J. E., Esq., F.R.S.
Meldola, Professor R., F.R.S.
Poulton, Professor E. B., F.R.S.
*Preece, W. H., Esq., C.B., F.R.S.
Ramsay, Professor W., F.R.S.
Reynolds, Professor J. Emerson, M.D., F.R S.
Shaw, W. N., Esq., F.R.S.
Symons, G. J., Esq., F.R.S.
Teall, J. J. H., Esq., F.R.S.
Thiselton-Dyer, W. T., Esq., C.M.G., F.R.S.
Thomson, Professor J. M., F.R.S.E.
*Tylor, Professor E. B., F.R.S.
Unwin, Professor W. C., F.R.S.
Vines, Professor S. H., F.R.S.
Ward, Professor Marshall, F.R.S

Committees appointed by the General Committee at the Liverpool Meeting in September 1896.

1. *Receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee	Grants
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements. [Last year's grant renewed, and the unexpended balance in the hands of the Chairman.]	*Chairman.*—Professor G. Carey Foster. *Secretary.*—Mr. R. T. Glazebrook. Lord Kelvin, Professors W. E. Ayrton, J. Perry, W. G. Adams, and Oliver J. Lodge, Lord Rayleigh, Dr. John Hopkinson, Dr. A. Muirhead, Messrs. W. H. Preece and Herbert Taylor, Professors J. D. Everett and A. Schuster, Dr. J. A. Fleming, Professors G. F. FitzGerald, G. Chrystal, and J. J. Thomson, Mr. W. N. Shaw, Dr. J. T. Bottomley, Rev. T. C. Fitzpatrick, Professor J. Viriamu Jones, Dr. G. Johnstone Stoney, Professor S. P. Thompson, Mr. G. Forbes, Mr. J. Rennie, Mr. E. H. Griffiths, and Professor A. W. Rücker.	£ s. d. 5 0 0
The Application of Photography to the Elucidation of Meteorological Phenomena.	*Chairman.*—Mr. G. J. Symons. *Secretary.*—Mr. A. W. Clayden. Professor R. Meldola, Mr. John Hopkinson, and Mr. H. N. Dickson.	10 0 0
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.*—Lieut.-Colonel Allan Cunningham. Lord Kelvin, Professor B. Price, Dr. J. W. L. Glaisher, Professor A. G. Greenhill, Professor W. M. Hicks, Major P. A. Macmahon, and Professor A. Lodge.	25 0 0
Seismological Observations.	*Chairman.*—Mr. G. J. Symons. *Secretaries.*—Mr. C. Davison and Professor J. Milne. Lord Kelvin, Professor W. G. Adams, Dr. J. T. Bottomley, Sir F. J. Bramwell, Professor G. H. Darwin, Mr. Horace Darwin, Major L. Darwin, Mr. G. F. Deacon, Professor J. A. Ewing, Professor C. G. Knott, Professor G. A. Lebour, Professor R. Meldola, Professor J. Perry, Professor J. H. Poynting, and Dr. Isaac Roberts.	100 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
To assist the Physical Society in bringing out Abstracts of Physical Papers.	*Chairman.*—Dr. E. Atkinson. *Secretary.* — Professor A. W. Rücker.	100 0 0
To co-operate with Professor Karl Pearson in the Calculation of certain Integrals. [5*l.* renewed.]	*Chairman.*—Rev. Robert Harley. *Secretary.*—Dr. A. R. Forsyth. Dr. J. W. L. Glaisher, Professor A. Lodge, and Professor Karl Pearson.	20 0 0
Considering the best Methods of Recording the Direct Intensity of Solar Radiation.	*Chairman.*—Sir G. G. Stokes. *Secretary.*—Professor H. McLeod. Professor A. Schuster, Dr. G. Johnstone Stoney, Sir H. E. Roscoe, Captain W. de W. Abney, Dr. C. Chree, Mr. G. J. Symons, Mr. W. E. Wilson, and Professor A. A. Rambaut.	10 0 0
The present state of our Knowledge in Electrolysis and Electro-chemistry.	*Chairman.*—Mr. W. N. Shaw. *Secretary.*—Mr. W. C. D. Whetham. Rev. T. C. Fitzpatrick and Mr. E. H. Griffiths.	50 0 0
Preparing a new Series of Wave-length Tables of the Spectra of the Elements.	*Chairman.*—Sir H. E. Roscoe. *Secretary.*—Dr. Marshall Watts. Mr. J. N. Lockyer, Professors J. Dewar, G. D. Liveing, A. Schuster, W. N. Hartley, and Wolcott Gibbs, and Captain Abney.	10 0 0
To inquire into the Proximate Chemical Constituents of the various kinds of Coal.	*Chairman.*—Sir I. Lowthian Bell. *Secretary.*—Professor P. Phillips Bedson. Professor F. Clowes, Dr. Ludwig Mond, Professors Vivian B. Lewes and E. Hull, and Messrs. J. W. Thomas and H. Bauerman.	10 0 0
The Electrolytic Methods of Quantitative Analysis.	*Chairman.*—Professor J. Emerson Reynolds. *Secretary.*—Dr. C. A. Kohn. Professor Frankland, Professor F. Clowes, Dr. Hugh Marshall, Mr. A. E. Fletcher, and Professor W. Carleton Williams.	10 0 0
Isomeric Naphthalene Derivatives.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Professor H. E. Armstrong.	50 0 0
To investigate the Erratic Blocks of the British Isles and to take measures for their preservation.	*Chairman.*—Professor E. Hull. *Secretary.*—Mr. P. F. Kendall. Professor T. G. Bonney, Mr. C. E. De Rance, Professor W. J. Sollas, Mr. R. H. Tiddeman, Rev. S. N. Harrison, Mr. J. Horne, Mr. Dugald Bell, Mr. F. M. Burton, and Mr. J. Lomas.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
The Investigation of the Eurypterid-bearing Deposits of the Pentland Hills. [The unexpended balance in the hands of the Chairman renewed.]	*Chairman.*—Dr. R. H. Traquair. *Secretary.*—Mr. M. Laurie. Professor T. Rupert Jones.	
To consider a project for investigating the Structure of a Coral Reef by Boring and Sounding.	*Chairman.*—Professor T. G. Bonney. *Secretary.*—Professor W. J. Sollas. Sir Archibald Geikie, Professors J. W. Judd, C. Lapworth, A. C. Haddon, Boyd Dawkins, G. H. Darwin, S. J. Hickson, and A. Stewart, Admiral W. J. L. Wharton, Drs. H. Hicks, J. Murray, W. T. Blanford, Le Neve Foster, and H. B. Guppy, Messrs. F. Darwin, H. O. Forbes, G. C. Bourne, A. R. Binnie, J. W. Gregory, and J. C. Hawkshaw, and Hon. P. Fawcett.	40 0 0
To examine the ground from which the remains of *Cetiosaurus* in the Oxford Museum were obtained, with a view to determining whether other parts of the same animal remain in the rock. [Unexpended balance.]	*Chairman.*—Professor H.G. Seeley. *Secretary.*—Mr. James Parker. Earl of Ducie, Professor E. Ray Lankester, and Lord Valentia.	
To explore certain Caves in the Neighbourhood of Singapore, and to collect their living and extinct Fauna. [Last year's grant of 40*l.* unexpended.]	*Chairman.*—Sir W. H. Flower. *Secretary.*—Mr. H. N. Ridley. Dr. R. Hanitsch, Mr. Clement Reid, and Mr. A. Russel Wallace.	
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor J. Geikie. *Secretary.*—Mr. W. W. Watts. Professor T. G. Bonney, Dr. T. Anderson, and Messrs. A. S. Reid, E. J. Garwood, W. Gray, H. B. Woodward, J. E. Bedford, R. Kidston, R. H. Tiddeman, J. J. H. Teall, J. G. Goodchild, and O. W. Jeffs.	15 0 0
To study Life-zones in the British Carboniferous Rocks.	*Chairman.*—Mr. J. E. Marr. *Secretary.*—Mr. E. J. Garwood. Mr. F. A. Bather, Mr. G. C. Crick, Mr. A. H. Foord, Mr. H. Fox, Dr. Wheelton Hind, Dr. G. J. Hinde, Mr. P. F. Kendall, Mr. J. W. Kirkley, Mr. R. Kidston, Mr. G. W. Lamplugh, Professor G. A. Lebour, Mr. G. H. Morton, Professor H. A. Nicholson, Mr. B. N. Peach, Mr. A. Strahan, and Dr. H. Woodward.	15 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
To examine the Conditions under which remains of the Irish Elk are found in the Isle of Man.	*Chairman.*—Professor W. Boyd Dawkins. *Secretary.*—Mr. P. C. Kermode. His Honour Deemster Gill, Mr. G. W. Lamplugh, and Mr. W. B. Savage.	15 0 0
To enable Professor W. F. R. Weldon to investigate the phenomena of variation in Crustacea, or, failing this, to appoint some other competent investigator to carry on a definite piece of work at the Zoological Station at Naples.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Mr. Percy Sladen. Professor E. Ray Lankester, Professor W. F. R. Weldon, Professor S. J. Hickson, Mr. A. Sedgwick, Professor W. C. M'Intosh, and Mr. W. E. Hoyle.	100 0 0
To enable Mr. Walter Garstang to occupy a Table at the Laboratory of the Marine Biological Association at Plymouth, for an experimental investigation as to the extent and character of selection occurring among certain crabs and fishes, and to cover the cost of certain apparatus.	*Chairman.*—Mr. G. C. Bourne. *Secretary.* — Professor E. Ray Lankester. Professor Sydney H. Vines, Mr. A. Sedgwick, and Professor W. F. R. Weldon.	40 0 0
Zoological Bibliography and Publication.	*Chairman.*—Sir W. H. Flower. *Secretary.*—Mr. F. A. Bather. Professor W. A. Herdman, Mr. W. E. Hoyle, Dr. P. Lutley Sclater, Mr. Adam Sedgwick, Dr. D. Sharp, Mr. C. D. Sherborn, Rev. T. R. R. Stebbing, and Professor W. F. R. Weldon.	5 0 0
Compilation of an Index Generum et Specierum Animalium.	*Chairman.*—Sir W. H. Flower. *Secretary.*—Mr. F. A. Bather. Dr. P. L. Sclater, Dr. H. Woodward, Rev. T. R. R. Stebbing, and Mr. R. McLachlan.	100 0 0
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.*—Dr. P. L. Sclater. *Secretary.*—Mr. G. Murray. Mr. W. Carruthers, Dr. A. C. Günther, Dr. D. Sharp, Mr. F. Du Cane Godman, and Professor A. Newton.	40 0 0
To work out the details of the Observations on the Migration of Birds at Lighthouses and Lightships, 1880–87.	*Chairman.*—Professor A. Newton. *Secretary.*—Mr. John Cordeaux. Mr. John A. Harvie-Brown, Mr. R. M. Barrington, Mr. W. E. Clarke, Rev. E. P. Knubley, and Dr. H. O. Forbes.	40 0 0
Climatology of Tropical Africa.	*Chairman.*—Mr. E. G. Ravenstein. *Secretary.*—Mr. H. N. Dickson. Sir John Kirk, Dr. H. R. Mill, and Mr. G. J. Symons.	20 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
State Monopolies in other Countries.	*Chairman.*— *Secretary.*—Mr. H. Higgs. Mr. W. M. Acworth, the Rt. Hon. L. H Courtney, Professor H. S. Foxwell, and Professor H. Sidgwick. [The Chairman to be appointed by the Council.]	15 0 0
Future Dealings in Raw Produce.	*Chairman.*—Mr. L. L. Price. *Secretaries.*—Professor Gonner and Mr. E. Helm., Mr. Hugh Bell, Major P. G. Craigie, Professor W. Cunningham, Professor Edgeworth, Mr. R. H. Hooker, and Mr. H. R. Rathbone.	10 0 0
To consider means by which better practical effect can be given to the Introduction of the Screw Gauge proposed by the Association in 1884.	*Chairman.*—Mr. W. H. Preece. *Secretary.*—Mr. Conrad W. Cooke. Lord Kelvin, Sir F. J. Bramwell, Sir H. Trueman Wood, Maj.-Gen. Webber, Mr. R. E. Crompton, Mr. A. Stroh, Mr. A. Le Neve Foster, Mr. C. J. Hewitt, Mr. G. K. B. Elphinstone, Mr. T. Buckney, Col. Watkin, Mr. E. Rigg, and Mr. W. A. Price.	10 0 0
The Physical Characters, Languages, and Industrial and Social Condition of the North-Western Tribes of the Dominion of Canada. [And unexpended balance in hands of Chairman.]	*Chairman.*—Professor E. B. Tylor. *Secretary.*—Mr. Cuthbert E. Peek. Dr. G. M. Dawson, Mr. R. G. Haliburton, and Mr. H. Hale.	75 0 0
The Lake Village at Glastonbury.	*Chairman.*—Dr. R. Munro. *Secretary.*—Mr. A. Bulleid. Professor W. Boyd Dawkins, General Pitt-Rivers, Sir John Evans, and Mr. Arthur J. Evans.	30 0 0
To organise an Ethnographical Survey of the United Kingdom.	*Chairman.*—Mr. E. W. Brabrook. *Secretary.*—Mr. E. Sidney Hartland. Mr. Francis Galton, Dr. J. G. Garson, Professor A. C. Haddon, Dr. Joseph Anderson, Mr. J. Romilly Allen, Dr. J. Beddoe, Professor D. J. Cunningham, Professor W. Boyd Dawkins, Mr. Arthur J. Evans, Mr. F. G. Hilton Price, Sir H. Howorth, Professor R. Meldola, General Pitt-Rivers, and Mr. E. G. Ravenstein.	40 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
To co-operate with the Committee appointed by the International Congress of Hygiene and Demography in the investigation of the Mental and Physical Condition of Children.	*Chairman.*—Sir Douglas Galton. *Secretary.*—Dr. Francis Warner. Mr. E. W. Brabrook, Dr. J. G. Garson, and Mr. White Wallis.	10 0 0
Linguistic and Anthropological Characteristics of the North Dravidians—the Ura-ons.	*Chairman.*—Mr. E. Sidney Hartland. *Secretary.*—Mr. Hugh Raynbird, jun. Professor A. C. Haddon and Mr. J. L. Myres.	5 0 0
To co-operate with the Silchester Excavation Fund Committee in their Explorations.	*Chairman.*—Mr. A. J. Evans. *Secretary.*—Mr. John L. Myres. Mr. E. W. Brabrook.	20 0 0
Physiological Applications of the Phonograph.	*Chairman.*—Professor J. G. McKendrick. *Secretary.*—Professor J. G. McKendrick. Professor G. G. Murray and Mr. David S. Wingate.	15 0 0
Oysters and Typhoid: the infectivity of the Oyster, and the diseases of the Oyster.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Professor R. Boyce. Mr. G. C. Bourne and Professor C. S. Sherrington.	30 0 0
To investigate the changes which are associated with the functional activity of Nerve Cells and their peripheral extensions.	*Chairman.*—Dr. W. H. Gaskell. *Secretary.*—Dr. W. H. Gaskell. Professor Burdon Sanderson, Professor E. A. Schäfer, Professor J. G. McKendrick, Professor W. D. Halliburton, Professor J. B. Haycraft, Professor F. Gotch, Dr. A. Waller, Dr. J. N. Langley, and Dr. Mann.	190 0 0
The physiological effects of Peptone and its Precursors.	*Chairman.*—Professor E. A. Schäfer. *Secretary.*—Professor W. H. Thompson. Professor R. Boyce and Professor C. S. Sherrington.	20 0 0
Fertilisation in Phæophyceæ.	*Chairman.*—Professor J. B. Farmer. *Secretary.*—Professor R. W. Phillips. Professor F. O. Bower and Professor Harvey Gibson.	20 0 0
Corresponding Societies Committee for the preparation of their Report.	*Chairman.*—Professor R. Meldola. *Secretary.*—Mr. T. V. Holmes. Mr. Francis Galton, Sir Douglas Galton, Sir Rawson Rawson, Mr. G. J. Symons, Dr. J. G. Garson, Sir John Evans, Mr. J. Hopkinson, Professor T. G. Bonney, Mr. W. Whitaker, Professor E. B. Poulton, Mr. Cuthbert Peek, and Rev. Canon H. B. Tristram.	25 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee
To confer with British and Foreign Societies publishing Mathematical and Physical Papers as to the desirability of securing Uniformity in the size of the pages of their Transactions and Proceedings.	*Chairman.*—Professor S. P. Thompson. *Secretary.*—Mr. J. Swinburne. Mr. G. H. Bryan, Mr. C. V. Burton, Mr. R. T. Glazebrook, Professor A. W. Rücker, and Dr. G. Johnstone Stoney.
Co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.	*Chairman.*—Lord McLaren. *Secretary.*—Professor Crum Brown. Mr. John Murray, Dr. A. Buchan, Professor R. Copeland, and Hon. R. Abercromby.
To confer with the Astronomer Royal and the Superintendents of other Observatories with reference to the Comparison of Magnetic Standards with a view of carrying out such comparison.	*Chairman.*—Professor A. W. Rücker. *Secretary.*—Mr. W. Watson. Professor A. Schuster and Professor H. H. Turner.
Comparing and Reducing Magnetic Observations.	*Chairman.*—Professor W. G. Adams. *Secretary.*—Dr. C. Chree. Lord Kelvin, Professor G. H. Darwin, Professor G. Chrystal, Professor A. Schuster, Captain E. W. Creak, the Astronomer Royal, Mr. William Ellis, and Professor A. W. Rücker.
The Collection and Identification of Meteoric Dust.	*Chairman.*—Mr. John Murray. *Secretary.*—Mr. John Murray. Professor A. Schuster, Lord Kelvin, the Abbé Renard, Dr. A. Buchan, the Hon. R. Abercromby, Dr. M. Grabham, Mr. John Aitken, Mr. L. Fletcher, and Mr. A. Ritchie Scott.
The Rate of Increase of Underground Temperature downwards in various Localities of dry Land and under Water.	*Chairman.*—Professor J. D. Everett. *Secretary.*—Professor J. D. Everett. Professor Lord Kelvin, Mr. G. J. Symons, Sir A. Geikie, Mr. J. Glaisher, Professor Edward Hull, Dr. C. Le Neve Foster, Professor A. S. Herschel, Professor G. A. Lebour, Mr. A. B. Wynne, Mr. W. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, Mr. A. Strahan, and Professor Michie Smith.
That Mr. John Brill be requested to draw up a Report on Non-commutative Algebras.	—
That Professor S. P. Thompson and Professor A. W. Rücker be requested to draw up a Report on the State of our Knowledge concerning Resultant Tones.	—

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

Subject for Investigation or Purpose	Members of the Committee
The mode of Teaching Geometrical Drawing in Schools.	*Chairman.*—Professor O. Henrici. *Secretary.*—Professor O. Henrici. Captain Abney, Dr. J. H. Gladstone, Mr. R. B. Hayward, Professor Karl Pearson, and Professor W. Cawthorne Unwin.
The Action of Light upon Dyed Colours.	*Chairman.*—Dr. T. E. Thorpe. *Secretary.*—Professor J. J. Hummel. Dr. W. H. Perkin, Professor W. J. Russell, Captain Abney, Professor W. Stroud, and Professor R. Meldola.
The Investigation of the direct Formation of Haloids from pure Materials.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Mr. W. A. Shenstone. Professor W. R. Dunstan and Mr. C. H. Bothamley.
The Properties of Solutions.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Dr. W. W. J. Nicol. Professor W. Ramsay.
Reporting on the Bibliography of Solution.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Dr. W. W. J. Nicol. Professors H. McLeod, S. U. Pickering, W. Ramsay, and S. Young.
The Continuation of the Bibliography of Spectroscopy.	*Chairman.*—Professor H. McLeod. *Secretary.*—Professor Roberts-Austen. Mr. H. G. Madan and Mr. D. H. Nagel.
The Action of Light on the Hydracids of the Halogens in presence of Oxygen.	*Chairman.*—Dr. W. J. Russell. *Secretary.*—Dr. A. Richardson. Captain Abney, Professor W. Noel Hartley and Professor W. Ramsay.
The Carbohydrates of Barley Straw.	*Chairman.*—Professor R. Warington. *Secretary.*—Mr. C. F. Cross. Mr. Manning Prentice.
The Teaching of Natural Science in Elementary Schools.	*Chairman.*—Dr. J. H. Gladstone. *Secretary.*—Professor H. E. Armstrong. Mr. George Gladstone, Mr. W. R. Dunstan, Sir J. Lubbock, Sir Philip Magnus, Sir H. E. Roscoe, and Dr. Silvanus P. Thompson.
The Description and Illustration of the Fossil Phyllopoda of the Palæozoic Rocks.	*Chairman.*—Rev. Professor T. Wiltshire. *Secretary.*—Professor T. R. Jones. Dr. H. Woodward.
To ascertain the Age and Relations of the Rocks in which Secondary Fossils have been found near Moreseat, Aberdeenshire.	*Chairman.*—Mr. T. F. Jamieson. *Secretary.*—Mr. J. Milne. Mr. A. J. Jukes-Browne.
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. Rev. G. F. Whidborne, Mr. R. Kidston, Professor H. G. Seeley, and Mr. H. Woods.

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

Subject for Investigation or Purpose	Members of the Committee
The Investigation of the African Lake Fauna by Mr. J. E. Moore.	*Chairman.*—Dr. P. L. Sclater. *Secretary.*—Professor G. B. Howes. Dr. John Murray, Professor E. Ray Lankester, and Professor W. A. Herdman.
To continue the investigation of the Zoology of the Sandwich Islands, with power to co-operate with the Committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance in their investigations as may be offered by the Hawaiian Government or the Trustees of the Museum at Honolulu. The Committee to have power to dispose of specimens where advisable.	*Chairman.*—Professor A. Newton. *Secretary.*—Dr. David Sharp. Dr. W. T. Blanford, Professor S. J. Hickson, Mr. O. Salvin, Dr. P. L. Sclater, and Mr. Edgar A. Smith.
The Necessity for the immediate investigation of the Biology of Oceanic Islands.	*Chairman.*—Sir W. H. Flower. *Secretary.*—Professor A. C. Haddon. Mr. G. C. Bourne, Dr. H. O. Forbes, Professor W. A. Herdman, Professor S. J. Hickson, Dr. John Murray, Professor A. Newton, and Mr. A. E. Shipley.
The position of Geography in the Educational System of the Country.	*Chairman.*—Mr. H. J. Mackinder. *Secretary.*—Mr. A. J. Herbertson. Mr. J. S. Keltie, Dr. H. R. Mill, Mr. E. G. Ravenstein, and Mr. Eli Sowerbutts.
To organise an Ethnological Survey of Canada.	*Chairman.*—Dr. George Dawson. *Secretary.*—Dr. George Dawson. Mr. E. W. Brabrook, Professor A. C. Haddon, Mr. E. S. Hartland, Mr. Horatio Hale, Dr. J. G. Bourinot, Abbé Cuoq, Mr. B. Sullé, Abbé Tanquay, Mr. C. Hill-Tout, Mr. David Boyle, Rev. Dr. Scadding, Rev. Dr. J. Maclean, Dr. Merée Beauchemin, Rev. Dr. G. Patterson, Professor D. P. Penhallow, and Mr. C. M. Bell.
Anthropometric Measurements in Schools.	*Chairman.*—Professor A. Macalister. *Secretary.*—Professor B. Windle. Mr. E. W. Brabrook, Professor J. Cleland, and Dr. J. G. Garson.
The best methods of preserving Vegetable Specimens for Exhibition in Museums.	*Chairman.*—Dr. D. H. Scott. *Secretary.*—Professor J. B. Farmer. Professor Bayley Balfour, Professor Errera, Mr. W. Gardiner, Professor J. R. Green, Professor M. C. Potter, Professor J. W. H. Trail, and Professor F. E. Weiss.

Communications ordered to be printed in extenso.

Mr. G. F. Lyster's paper on 'The Physical and Engineering Features of the River Mersey and the Port of Liverpool.'

Mr. Francis Darwin's paper on 'The Ascent of Sap.'

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

That the Council be requested to take such steps as they think best to bring before the Government the question of the establishment of a National Physical Laboratory in general accordance with the recommendations contained in the Report appended hereto,* and to invite the co-operation of the Royal Society of London, the Royal Society of Edinburgh, the Royal Astronomical Society, the Physical Society, and other kindred Societies, in securing its foundation.

That it is of urgent importance to press upon the Government the necessity of establishing a Bureau of Ethnology for Greater Britain, which, by collecting information with regard to the native races within, and on the borders of, the Empire, will prove of immense value to science and to the Government itself.

* See Report, p. 82.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Liverpool Meeting, September 1896. The Names of the Members entitled to call on the General Treasurer for the respective Grants are prefixed.

Mathematics and Physics.

	£	s.	d.
*Foster, Professor Carey—Electrical Standards (Last year's grant renewed)	5	0	0
*Symons, Mr. G. J.—Photographs of Meteorological Phenomena	10	0	0
*Rayleigh, Lord—Mathematical Tables	25	0	0
*Symons, Mr. G. J.—Seismological Observations	100	0	0
*Atkinson, Dr. E.—Abstracts of Physical Papers	100	0	0
*Harley, Rev. R.—Calculation of Certain Integrals (5*l.* renewed)	20	0	0
*Stokes, Sir G. G.—Solar Radiation	10	0	0
*Shaw, Mr. W. N.—Electrolysis and Electro-chemistry	50	0	0
Chemistry.			
*Roscoe, Sir H. E.—Wave-length Tables of the Spectra of the Elements	10	0	0
*Bell, Sir I. Lowthian.—Chemical Constituents of Coal	10	0	0
*Reynolds, Professor J. Emerson.—Electrolytic Quantitative Analysis	10	0	0
*Tilden, Professor W. A.—Isometric Naphthalene Derivatives	50	0	0
Geology.			
*Hull, Professor E.—Erratic Blocks	10	0	0
*Bonney, Professor T. G.—Investigation of a Coral Reef	40	0	0
*Seeley, Professor H. G.—Examination of Locality where the Cetiosaurus in the Oxford Museum was found (Unexpended balance in hand)	—		
*Flower, Sir W. H.—Fauna of Singapore Caves (Unexpended balance in hand, 40*l.*)	—		
*Geikie, Professor J.—Photographs of Geological Interest	15	0	0
*Marr, Mr. J. E.—Life-zones in British Carboniferous Rocks	15	0	0
Dawkins, Professor W. Boyd.—Remains of the Irish Elk in the Isle of Man	15	0	0
Zoology.			
*Herdman, Professor W. A.—Table at the Zoological Station, Naples	100	0	0
*Bourne, Mr. G. C.—Table at the Biological Laboratory, Plymouth	40	0	0
*Flower, Sir W. H.—Zoological Bibliography and Publication	5	0	0
*Flower, Sir W. H.—Index Generum et Specierum Animalium	100	0	0
Carried forward	£740	0	0

* Reappointed.

	£	s.	d.
Brought forward	740	0	0
*Sclater, Dr. P. L.—Zoology and Botany of the West India Islands	40	0	0
*Newton, Professor.—To work out Details of Observations on the Migration of Birds	40	0	0
Geography.			
*Ravenstein, Mr. E. G.—Climatology of Tropical Africa	20	0	0
Economic Science and Statistics.			
.—State Monopolies in other Countries	15	0	0
Price, Mr. L. L.—Future Dealings in Raw Produce	10	0	0
Mechanical Science.			
*Preece, Mr. W. H.—Small Screw Gauge	10	0	0
Anthropology.			
*Tylor, Professor E. B.—North-Western Tribes of Canada	75	0	0
*Munro, Dr. R.—Lake Village at Glastonbury	30	0	0
*Brabrook, Mr. E. W.—Ethnographical Survey	40	0	0
*Galton, Sir Douglas.—Mental and Physical Condition of Children	10	0	0
*Hartland, Mr. E. S.—Linguistic and Anthropological Characteristics of the North Dravidians	5	0	0
Evans, Mr. A. J.—Silchester Excavation	20	0	0
Physiology.			
*McKendrick, Professor J. G.—Physiological Applications of the Phonograph	15	0	0
Herdman, Professor W. A.—Oysters under Normal and Abnormal Conditions of Environment	30	0	0
Gaskell, Dr. W. H.—Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	190	0	0
Schäfer, Professor.—Physiological Effects of Peptone and its Precursors	20	0	0
Botany.			
Farmer, Professor J. B.—Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies.			
*Meldola, Professor R.—Preparation of Report	25	0	0
	£1,355	0	0

* Reappointed.

The Annual Meeting in 1897.

The Meeting at Toronto, Canada, will commence on Wednesday, August 18.

The Annual Meeting in 1898.

The Annual Meeting of the Association in 1898 will be held at Bristol.

The Annual Meeting in 1899.

The Annual Meeting of the Association in 1899 will be held at Dover.

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

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

	£	s.	d.
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0

1836.

	£	s.	d.
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.

	£	s.	d.
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.

	£	s.	d.
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.

	£	s.	d.
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	0
Cast-iron Experiments	103	0	7
Railway Constants	28	7	0
Land and Sea Level	274	1	2
Steam-vessels' Engines	100	0	4
Stars in Histoire Céleste	171	18	0
Stars in Lacaille	11	0	6
Stars in R.A.S. Catalogue	166	16	0
Animal Secretions	10	10	6
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.

	£	s.	d.
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.

	£	s.	d.
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
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, Firth 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

	£	s.	d.
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 at 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 at 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

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.

	£	s.	d.
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

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

	£	s.	d.
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.

	£	s.	d.
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
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 at 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 at 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 Coasts	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
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 at 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 at 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 at 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 at 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
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 at 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 at 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 at 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

	£	s.	d.
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 at 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
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 at 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 at 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	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 Meteorology	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	30	0	0
Chemistry Record	100	0	0
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	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
Naples 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 Acid 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
Dipterocarpeæ, Report on	20	0	0
Mechanical Equivalent of Heat	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperature	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 Electricity 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 Siphon 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 for 4th Million	100	0	0
Anthropometric Committee	66	0	0
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
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
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
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 Kilimanjaro	25	0	0
Recent Polyzoa	10	0	0
Granton Biological Station	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
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
Caves in North Wales	25	0	0
Volcanic Phenomena of Vesuvius	30	0	0
Geological Record	100	0	0
Palæozoic Phyllopoda	15	0	0
Zoological Literature Record	100	0	0
Granton Biological Station	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
Cae Gwyn Cave, N. 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
Underground Waters	5	0	0
'Manure' Gravels of Wexford	10	0	0
Provincial Museums Reports	5	0	0
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
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
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
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
Palæozoic Phyllopoda	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	100	0	0
North-Western Tribes of Canada	150	0	0
Nomad Tribes of Asia Minor	30	0	0
Corresponding Societies	20	0	0
Marine Biological Association	200	0	0
'Baths Committee,' Bath	100	0	0
	£1417	0	11

1890.

	£	s.	d.
Electrical Standards	12	17	0
Electrolysis	5	0	0
Electro-optics	50	0	0
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
Palæozoic Phyllopoda	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 Northampton	25	0	0
Botanical Station at Peradeniya	25	0	0

	£	s.	d.
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

1891.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	100	0	0
Electrolysis	5	0	0
Seismological Phenomena of Japan	10	0	0
Temperatures of Lakes	20	0	0
Photographs of Meteorological Phenomena	5	0	0
Discharge of Electricity from Points	10	0	0
Ultra Violet Rays of Solar Spectrum	50	0	0
International Standard for Analysis of Iron and Steel	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Formation of Haloids	25	0	0
Action of Light on Dyes	17	10	0
Geological Record	100	0	0
Volcanic Phenomena of Vesuvius	10	0	0
Fossil Phyllopoda	10	0	0
Photographs of Geological Interest	9	5	0
Lias of Northamptonshire	25	0	0
Registration of Type-Specimens of British Fossils	5	5	0
Investigation of Elbolton Cave	25	0	0
Botanical Station at Peradeniya	50	0	0
Experiments with a Tow-net	40	0	0
Marine Biological Association	12	10	0
Disappearance of Native Plants	5	0	0
Action of Waves and Currents in Estuaries	125	0	0
Anthropometric Calculations	10	0	0
New Edition of 'Anthropological Notes and Queries'	50	0	0
North-Western Tribes of Canada	200	0	0
Corresponding Societies	25	0	0
	£1,029	10	0

1892.

	£	s.	d.
Observations on Ben Nevis	50	0	0
Photographs of Meteorological Phenomena	15	0	0
Pellian Equation Tables	10	0	0
Discharge of Electricity from Points	50	0	0
Seismological Phenomena of Japan	10	0	0
Formation of Haloids	12	0	0
Properties of Solutions	10	0	0
Action of Light on Dyed Colours	10	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	20	0	0
Underground Waters	10	0	0
Investigation of Elbolton Cave	25	0	0
Excavations at Oldbury Hill	10	0	0
Cretaceous Polyzoa	10	0	0
Naples Zoological Station	100	0	0
Marine Biological Association	17	10	0
Deep-sea Tow-net	40	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	100	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Anthropometric Laboratory	5	0	0
Anthropological Notes and Queries	20	0	0
Prehistoric Remains in Mashonaland	50	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	25	0	0
	£864	10	0

1893.

	£	s.	d.
Electrical Standards	25	0	0
Observations on Ben Nevis	150	0	0
Mathematical Tables	15	0	0
Intensity of Solar Radiation	2	8	6
Magnetic Work at the Falmouth Observatory	25	0	0
Isomeric Naphthalene Derivatives	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	5	0	0
Underground Waters	5	0	0
Shell-bearing Deposits at Clava, Chapelhall, &c.	20	0	0
Eurypterids of the Pentland Hills	10	0	0
Naples Zoological Station	100	0	0
Marine Biological Association	30	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	50	0	0

	£	s.	d.
Exploration of Irish Sea	30	0	0
Physiological Action of Oxygen in Asphyxia	20	0	0
Index of Genera and Species of Animals	20	0	0
Exploration of Karakoram Mountains	50	0	0
Scottish Place-names	7	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Economic Training	3	7	0
Anthropometric Laboratory	5	0	0
Exploration in Abyssinia	25	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	30	0	0
	£907	15	6

1894.

	£	s.	d.
Electrical Standards	25	0	0
Photographs of Meteorological Phenomena	10	0	0
Tables of Mathematical Functions	15	0	0
Intensity of Solar Radiation	5	5	6
Wave-length Tables	10	0	0
Action of Light upon Dyed Colours	5	0	0
Erratic Blocks	15	0	0
Fossil Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	20	0	0
Eurypterids of the Pentland Hills	5	0	0
New Sections of Stonesfield Slate	14	0	0
Observations on Earth-tremors	50	0	0
Exploration of Calf-Hole Cave	5	0	0
Naples Zoological Station	100	0	0
Marine Biological Association	5	0	0
Zoology of the Sandwich Islands	100	0	0
Zoology of the Irish Sea	40	0	0
Structure and Function of the Mammalian Heart	10	0	0
Exploration in Abyssinia	30	0	0
Economic Training	9	10	0
Anthropometric Laboratory Statistics	5	0	0
Ethnographical Survey	10	0	0
The Lake Village at Glastonbury	40	0	0
Anthropometrical Measurements in Schools	5	0	0
Mental and Physical Condition of Children	20	0	0.
Corresponding Societies	25	0	0
	£583	15	6

1895.

	£	s.	d.
Electrical Standards	25	0	0
Photographs of Meteorological Phenomena	10	0	0
Earth Tremors	75	0	0
Abstracts of Physical Papers	100	0	0
Reduction of Magnetic Observations made at Falmouth Observatory	50	0	0
Comparison of Magnetic Standards	25	0	0
Meteorological Observations on Ben Nevis	50	0	0
Wave-length Tables of the Spectra of the Elements	10	0	0
Action of Light upon Dyed Colours	4	6	1
Formation of Haloids from Pure Materials	20	0	0
Isomeric Naphthalene Derivatives	30	0	0
Electrolytic Quantitative Analysis	30	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Photographs of Geological Interest	10	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills	3	0	0
New Sections of Stonesfield Slate	50	0	0
Exploration of Calf Hole Cave	10	0	0
Nature and Probable Age of High-level Flint-drifts	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea	35	9	4
Zoology and Botany of the West India Islands	50	0	0
Index of Genera and Species of Animals	50	0	0
Climatology of Tropical Africa	5	0	0
Exploration of Hadramut	50	0	0
Calibration and Comparison of Measuring Instruments	25	0	0
Anthropometric Measurements in Schools	5	0	0
Lake Village at Glastonbury	30	0	0
Exploration of a Kitchen-midden at Hastings	10	0	0
Ethnographical Survey	10	0	0
Physiological Applications of the Phonograph	25	0	0
Corresponding Societies	30	0	0
	£977	15	5

1896.	£	s.	d.
Photographs of Meteorological Phenomena	15	0	0
Seismological Observations	80	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Uniformity of Size of Pages of Transactions, &c.	5	0	0
Wave-length Tables of the Spectra of the Elements	10	0	0
Action of Light upon Dyed Colours	2	6	1
Electrolytic Quantitative Analysis	10	0	0
The Carbohydrates of Barley Straw	50	0	0
Reprinting Discussion on the Relation of Agriculture to Science	5	0	0
Erratic Blocks	10	0	0
Palæozoic Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	10	0	0
Eurypterids of the Pentland Hills	2	0	0
Investigation of a Coral Reef by Boring and Sounding	10	0	0
Examination of Locality where the Cetiosaurus in the Oxford Museum was found	25	0	0
Palæolithic Deposits at Hoxne	25	0	0
Fauna of Singapore Caves	40	0	0
Age and Relation of Rocks near Moreseat, Aberdeen	10	0	0
Table at the Zoological Station at Naples	100	0	0
Table at the Biological Laboratory, Plymouth	15	0	0
Zoology, Botany, and Geology of the Irish Sea	50	0	0
Zoology of the Sandwich Islands	100	0	0
African Lake Fauna	100	0	0
Oysters under Normal and Abnormal Environment	40	0	0
Climatology of Tropical Africa	10	0	0
Calibration and Comparison of Measuring Instruments	20	0	0
Small Screw Gauge	10	0	0
North-Western Tribes of Canada	100	0	0
Lake Village at Glastonbury	30	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Physiological Applications of the Phonograph	25	0	0
Corresponding Societies Committee	30	0	0
	£1,104	6	1

General Meetings.

On Wednesday, September 16, at 8 P.M., in the Philharmonic Hall, Liverpool, Captain Sir Douglas Galton, K.C.B., D.C.L., LL.D., F.R.S., F.R.G.S., F.G.S., resigned the office of President to Sir Joseph Lister, Bart., D.C.L., LL.D., President of the Royal Society, who took the Chair, and delivered an Address, for which see page 3.

On Thursday, September 17, at 8.30 P.M., a Soirée took place at the Town Hall.

On Friday, September 18, at 8.30 P.M., in the Philharmonic Hall, Dr. Francis Elgar, F.R.S., delivered a discourse on 'Safety in Ships.'

On Monday, September 21, at 8.30 P.M., in the Philharmonic Hall, Professor Flinders Petrie, D.C.L., delivered a discourse on 'Man before Writing.'

On Tuesday, September 22, at 8.30 P.M., a Soirée took place at the Museum and Art Gallery.

On Wednesday, September 23, at 2.30 P.M., in the small Concert Room, St. George's 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 Toronto. [The Meeting is appointed to commence on Wednesday, August 18, 1897.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

SIR JOSEPH LISTER, Bart., D.C.L., LL.D., P.R.S.,

PRESIDENT.

My Lord Mayor, my Lords, Ladies, and Gentlemen, I have first to express my deep sense of gratitude for the great honour conferred upon me by my election to the high office which I occupy to-day. It came upon me as a great surprise. The engrossing claims of surgery have prevented me for many years from attending the meetings of the Association, which excludes from her sections medicine in all its branches. This severance of the art of healing from the work of the Association was right and indeed inevitable. Not that medicine has little in common with science. The surgeon never performs an operation without the aid of anatomy and physiology; and in what is often the most difficult part of his duty, the selection of the right course to follow, he, like the physician, is guided by pathology, the science of the nature of disease, which, though very difficult from the complexity of its subject matter, has made during the last half-century astonishing progress; so that the practice of medicine in every department is becoming more and more based on science as distinguished from empiricism. I propose on the present occasion to bring before you some illustrations of the interdependence of science and the healing art; and the first that I will take is perhaps the most astonishing of all results of purely physical inquiry—the discovery of the Röntgen rays, so called after the man who first clearly revealed them to the world. Mysterious as they still are, there is one of their properties which we can all appreciate—their power of passing through substances opaque to ordinary light. There seems to be no relation whatever between transparency in the common sense of the term and penetrability to these emanations. The glasses of a pair of spectacles may arrest them while their wooden and leathern case allows them to pass almost unchecked. Yet they produce, whether directly or indirectly, the same effects as light upon a photographic plate. As a general rule the denser any object is the greater obstacle does it oppose to the rays. Hence, as bone is denser than flesh, if the hand or other part of the body is placed above the sensitive film enclosed in a case of wood or other light material at a suitable distance from the source of the rays, while they pass with the utmost facility through the uncovered parts of the lid of the box and powerfully affect the plate beneath, they are arrested to a large extent by the bones, so that the plate is little acted upon in the parts opposite to them, while the portions corresponding to the muscles and other soft parts are influenced in an intermediate degree. Thus a picture is obtained in which the bones stand out in sharp relief among the flesh, and anything abnormal in their shape or position is clearly displayed.

I need hardly point out what important aid this must give to the surgeon. As an instance, I may mention a case which occurred in the practice of Mr. Howard Marsh. He was called to see a severe injury of the elbow, in which the swelling was so great as to make it impossible for him by ordinary means of examination to decide whether he had to deal with a fracture or a dislocation. If it were the latter, a cure would be effected by the exercise of violence which would be not only useless but most injurious if a bone was broken. By the aid of the Röntgen rays a photograph was taken in which the bone of the upper arm was clearly seen displaced forwards on those of the forearm. The diagnosis being thus established, Mr. Marsh proceeded to reduce the dislocation; and his success was proved by another photograph which showed the bones in their natural relative position.

The common metals, such as lead, iron, and copper, being still denser than the osseous structures, these rays can show a bullet embedded in a bone or a needle lodged about a joint. At the last conversazione of the Royal Society a picture produced by the new photography displayed with perfect distinctness through the bony framework of the chest a halfpenny low down in a boy's gullet. It had been there for six months, causing uneasiness at the pit of the stomach during swallowing; but whether the coin really remained impacted, and if so, what was its position, was entirely uncertain till the Röntgen rays revealed it. Dr. Macintyre of Glasgow, who was the photographer, informs me that when the presence of the halfpenny had been thus demonstrated, the surgeon in charge of the case made an attempt to extract it, and although this was not successful in its immediate object, it had the effect of dislodging the coin; for a subsequent photograph by Dr. Macintyre not only showed that it had disappeared from the gullet, but also, thanks to the wonderful penetrating power which the rays had acquired in his hands, proved that it had not lodged further down in the alimentary passage. The boy has since completely recovered.

The Röntgen rays cause certain chemical compounds to fluoresce, and emit a faint light plainly visible in the dark; and if they are made to fall upon a translucent screen impregnated with such a salt, it becomes beautifully illuminated. If a part of the human body is interposed between the screen and the source of the rays, the bones and other structures are thrown in shadow upon it, and thus a diagnosis can be made without the delay involved in taking a photograph. It was in fact in this way that Dr. Macintyre first detected the coin in the boy's gullet. Mr. Herbert Jackson, of King's College, London, early distinguished himself in this branch of the subject. There is no reason to suppose that the limits of the capabilities of the rays in this way have yet been reached. By virtue of the greater density of the heart than the adjacent lungs with their contained air, the form and dimensions of that organ in the living body may be displayed on the fluorescent screen, and even its movements have been lately seen by several different observers.

Such important applications of the new rays to medical practice have strongly attracted the interest of the public to them, and I venture to think that they have even served to stimulate the investigations of physicists. The eminent Professor of Physics in the University College of this city (Professor Lodge) was one of the first to make such practical applications, and I was able to show to the Royal Society at a very early period a photograph, which he had the kindness to send me, of a bullet embedded in the hand. His interest in the medical aspect of the subject remains unabated, and at the same time he has been one of the most distinguished investigators of its purely physical side.

There is another way in which the Röntgen rays connect themselves with physiology, and may possibly influence medicine. It is found that if the skin is long exposed to their action it becomes very much irritated, affected with a sort of aggravated sun-burning. This suggests the idea that the transmission of the rays through the human body may be not altogether a matter of indifference to internal organs, but may, by long-continued action, produce, according to the condition of the part concerned, injurious irritation or salutary stimulation.

This is the jubilee of Anæsthesia in surgery. That priceless blessing to mankind came from America. It had, indeed, been foreshadowed in the first year of this century by Sir Humphry Davy, who, having found a toothache from which he was suffering relieved as he inhaled laughing gas (nitrous oxide), threw out the suggestion that it might perhaps be used for preventing pain in surgical operations. But it was not till, on September 30, 1846, Dr. W. T. G. Morton, of Boston, after a series of experiments upon himself and the lower animals, extracted a tooth painlessly from a patient whom he had caused to inhale the vapour of sulphuric ether, that the idea was fully realised. He soon afterwards publicly exhibited his method at the Massachusetts General Hospital, and after that event the great discovery spread rapidly over the civilised world. I witnessed the first operation in England under ether. It was performed by Robert Liston in University College Hospital, and it was a complete success. Soon afterwards I saw the same great surgeon amputate the thigh as painlessly, with less complicated anæsthetic apparatus, by aid of another agent, chloroform, which was being powerfully advocated as a substitute for ether by Dr. (afterwards Sir James Y.) Simpson, who also had the great merit of showing that confinements could be conducted painlessly, yet safely, under its influence. These two agents still hold the field as general anæsthetics for protracted operations, although the gas originally suggested by Davy, in consequence of its rapid action and other advantages, has taken their place in short operations, such as tooth extraction. In the birthplace of anæsthesia ether has always maintained its ground; but in Europe it was to a large extent displaced by chloroform till recently, when many have returned to ether, under the idea that, though less convenient, it is safer. For my own part, I believe that chloroform, if carefully administered on right principles, is, on the average, the safer agent of the two.

The discovery of anæsthesia inaugurated a new era in surgery. Not only was the pain of operations abolished, but the serious and sometimes mortal shock which they occasioned to the system was averted, while the patient was saved the terrible ordeal of preparing to endure them. At the same time the field of surgery became widely extended, since many procedures in themselves desirable, but before impossible from the protracted agony they would occasion, became matters of routine practice. Nor have I by any means exhausted the list of the benefits conferred by this discovery.

Anæsthesia in surgery has been from first to last a gift of science. Nitrous oxide, sulphuric ether, and chloroform are all artificial products of chemistry, their employment as anæsthetics was the result of scientific investigation, and their administration, far from being, like the giving of a dose of medicine, a matter of rule of thumb, imperatively demands the vigilant exercise of physiological and pathological knowledge.

While rendering such signal service to surgery, anæsthetics have thrown light upon biology generally. It has been found that they exert their soporific influence not only upon vertebrata, but upon animals so remote in structure from man as bees and other insects. Even the functions of vegetables are suspended by their agency. They thus afford strong confirmation of the great generalisation that living matter is of the same essential nature wherever it is met with on this planet, whether in the animal or vegetable kingdom. Anæsthetics have also, in ways to which I need not here refer, powerfully promoted the progress of physiology and pathology.

My next illustration may be taken from the work of Pasteur on fermentation. The prevailing opinion regarding this class of phenomena when they first engaged his attention was that they were occasioned primarily by the oxygen of the air acting upon unstable animal or vegetable products, which, breaking up under its influence, communicated disturbance to other organic materials in their vicinity, and thus led to their decomposition. Cagniard-Latour had indeed shown several years before that yeast consists essentially of the cells of a microscopic fungus which grows as the sweetwort ferments; and he had attributed the breaking up of the sugar into alcohol and carbonic acid to the growth of the micro-organism. In Germany Schwann, who independently discovered the yeast plant, had published very striking experiments in support of analogous ideas regarding the putrefaction of meat. Such views had also found other advocates, but they had become utterly discredited, largely through the great authority of Liebig, who bitterly opposed them.

Pasteur, having been appointed as a young man Dean of the Faculty of Sciences in the University of Lille, a town where the products of alcoholic fermentation were staple articles of manufacture, determined to study that process thoroughly; and as a result he became firmly convinced of the correctness of Cagniard-Latour's views regarding it. In the case of other fermentations, however, nothing fairly comparable to the formation of yeast had till then been observed. This was now done by Pasteur for that fermentation in which sugar is resolved into lactic acid. This lactic fermentation was at that time brought about by adding some animal substance, such as fibrin, to a solution of sugar, together with chalk that should combine with the acid as it was formed. Pasteur saw, what had never before been noticed, that a fine grey deposit was formed, differing little in appearance from the decomposing fibrin, but steadily increasing as the fermentation proceeded. Struck by the analogy presented by the increasing deposit to the growth of yeast in sweetwort, he examined it with the microscope, and found it to consist of minute particles of uniform size. Pasteur was not a biologist, but although these particles were of extreme minuteness in comparison with the constituents of the yeast plant, he felt convinced that they were of an analogous nature, the cells of a tiny microscopic fungus. This he regarded as the essential ferment, the fibrin or other so-called ferment serving, as he believed, merely the purpose of supplying to the growing plant certain chemical ingredients essential to its nutrition not contained in the sugar. And the correctness of this view he confirmed in a very striking manner, by doing away with the fibrin or other animal material altogether, and substituting for it mineral salts containing the requisite chemical elements. A trace of the grey deposit being applied to a solution of sugar containing these salts in addition to the chalk, a brisker lactic fermentation ensued than could be procured in the ordinary way.

I have referred to this research in some detail because it illustrates

Pasteur's acuteness as an observer and his ingenuity in experiment, as well as his almost intuitive perception of truth.

A series of other beautiful investigations followed, clearly proving that all true fermentations, including putrefaction, are caused by the growth of micro-organisms.

It was natural that Pasteur should desire to know how the microbes which he showed to be the essential causes of the various fermentations took their origin. It was at that period a prevalent notion, even among many eminent naturalists, that such humble and minute beings originated *de novo* in decomposing organic substances; the doctrine of spontaneous generation, which had been chased successively from various positions which it once occupied among creatures visible to the naked eye, having taken its last refuge where the objects of study were of such minuteness that their habits and history were correspondingly difficult to trace. Here again Pasteur at once saw, as if by instinct, on which side the truth lay; and, perceiving its immense importance, he threw himself with ardour into its demonstration. I may describe briefly one class of experiments which he performed with this object. He charged a series of narrow-necked glass flasks with a decoction of yeast, a liquid peculiarly liable to alteration on exposure to the air. Having boiled the liquid in each flask, to kill any living germs it might contain, he sealed its neck with a blow-pipe during ebullition; after which, the flask being allowed to cool, the steam within it condensed, leaving a vacuum above the liquid. If, then, the neck of the flask were broken in any locality, the air at that particular place would rush in to fill the vacuum, carrying with it any living microbes that might be floating in it. The neck of the flask having been again sealed, any germs so introduced would in due time manifest their presence by developing in the clear liquid. When any of such a series of flasks were opened and re-sealed in an inhabited room, or under the trees of a forest, multitudes of minute living forms made their appearance in them; but if this was done in a cellar long unused, where the suspended organisms, like other dust, might be expected to have all fallen to the ground, the decoction remained perfectly clear and unaltered. The oxygen and other gaseous constituents of the atmosphere were thus shown to be of themselves incapable of inducing any organic development in yeast-water.

Such is a sample of the many well-devised experiments by which he carried to most minds the conviction that, as he expressed it, '*la génération spontanée est une chimère*,' and that the humblest and minutest living organisms can only originate by parentage from beings like themselves.

Pasteur pointed out the enormous importance of these humble organisms in the economy of nature. It is by their agency that the dead bodies of plants and animals are resolved into simpler compounds fitted for assimilation by new living forms. Without their aid the world would be, as Pasteur said, *encombré de cadavres.* They are essential not only to our well-being, but to our very existence. Similar microbes must have discharged the same necessary function of removing refuse and providing food for successive generations of plants and animals during the past periods of the world's history; and it is interesting to think that organisms as simple as can well be conceived to have existed when life first appeared upon our globe have, in all probability, propagated the same lowly but most useful offspring during the ages of geological time.

Pasteur's labours on fermentation have had a very important influence upon surgery. I have been often asked to speak on my share in this matter before a public audience; but I have hitherto refused to do so, partly because the details are so entirely technical, but chiefly because I have felt an invincible repugnance to what might seem to savour of self-advertisement. The latter objection now no longer exists, since advancing years have indicated that it is right for me to leave to younger men the practice of my dearly loved profession. And it will perhaps be expected that, if I can make myself intelligible, I should say something upon the subject on the present occasion.

Nothing was formerly more striking in surgical experience than the difference in the behaviour of injuries according to whether the skin was implicated or not. Thus, if the bones of the leg were broken and the skin remained intact, the surgeon applied the necessary apparatus without any other anxiety than that of maintaining a good position of the fragments, although the internal injury to bones and soft parts might be very severe. If, on the other hand, a wound of the skin was present communicating with the broken bones, although the damage might be in other respects comparatively slight, the compound fracture, as it was termed, was one of the most dangerous accidents that could happen. Mr. Syme, who was, I believe, the safest surgeon of his time, once told me that he was inclined to think that it would be, on the whole, better if all compound fractures of the leg were subjected to amputation, without any attempt to save the limb. What was the cause of this astonishing difference? It was clearly in some way due to the exposure of the injured parts to the external world. One obvious effect of such exposure was indicated by the odour of the discharge, which showed that the blood in the wound had undergone putrefactive change by which the bland nutrient liquid had been converted into highly irritating and poisonous substances. I have seen a man with compound fracture of the leg die within two days of the accident, as plainly poisoned by the products of putrefaction as if he had taken a fatal dose of some potent toxic drug.

An external wound of the soft parts might be healed in one of two ways. If its surfaces were clean cut and could be brought into accurate apposition, it might unite rapidly and painlessly 'by the first intention.' This, however, was exceptional. Too often the surgeon's efforts to obtain primary union were frustrated: the wound inflamed and the retentive stitches had to be removed, allowing it to gape; and then, as if it had been left open from the first, healing had to be effected in the other way which it is necessary for me briefly to describe. An exposed raw surface became covered in the first instance with a layer of clotted blood or certain of its constituents, which invariably putrefied ; and the irritation of the sensitive tissues by the putrid products appeared to me to account sufficiently for the inflammation which always occurred in and around an open wound during the three or four days which elapsed before what were termed 'granulations' had been produced. These constituted a coarsely granular coating of very imperfect or embryonic structure, destitute of sensory nerves and prone to throw off matter or pus, rather than absorb, as freshly divided tissues do, the products of putrefaction. The granulations thus formed a beautiful living plaster, which protected the sensitive parts beneath from irritation, and the system generally from poisoning and consequent febrile disturbance. The granulations had other useful properties of which I may mention their tendency to shrink as they grew, thus gradually reducing the dimensions of the sore. Meanwhile, another cause of its diminution was in operation. The cells of the epidermis or scarf-skin of the cutaneous margins were perpetually producing a crop of young cells of similar nature, which gradually spread over the granulations till they covered them entirely, and a complete cicatrix or scar was the result. Such was the other mode of healing, that by granulation and cicatrisation ; a process which, when it proceeded unchecked to its completion, commanded our profound admiration. It was, however, essentially tedious compared with primary union, while, as we have seen, it was always preceded by more or less inflammation and fever, sometimes very serious in their effects. It was also liable to unforeseen interruptions. The sore might become larger instead of smaller, cicatrisation giving place to ulceration in one of its various forms, or even to the frightful destruction of tissue which, from the circumstance that it was most frequently met with in hospitals, was termed hospital gangrene. Other serious and often fatal complications might arise, which the surgeon could only regard as untoward accidents and over which he had no efficient control.

It will be readily understood from the above description that the inflammation which so often frustrated the surgeon's endeavours after primary union was in my opinion essentially due to decomposition of blood within the wound.

These and many other considerations had long impressed me with the greatness of the evil of putrefaction in surgery. I had done my best to mitigate it by scrupulous ordinary cleanliness and the use of various deodorant lotions. But to prevent it altogether appeared hopeless while we believed with Liebig that its primary cause was the atmospheric oxygen which, in accordance with the researches of Graham, could not fail to be perpetually diffused through the porous dressings which were used to absorb the blood discharged from the wound. But when Pasteur had shown that putrefaction was a fermentation caused by the growth of microbes, and that these could not arise *de novo* in the decomposable substance, the problem assumed a more hopeful aspect. If the wound could be treated with some substance which, without doing too serious mischief to the human tissues, would kill the microbes already contained in it and prevent the future access of others in the living state, putrefaction might be prevented, however freely the air with its oxygen might enter. I had heard of carbolic acid as having a remarkable deodorising effect upon sewage, and having obtained from my colleague Dr. Anderson, Professor of Chemistry in the University of Glasgow, a sample which he had of this product, then little more than a chemical curiosity in Scotland, I determined to try it in compound fractures. Applying it undiluted to the wound, with an arrangement for its occasional renewal, I had the joy of seeing these formidable injuries follow the same safe and tranquil course as simple fractures, in which the skin remains unbroken.

At the same time we had the intense interest of observing in open wounds what had previously been hidden from human view, the manner in which subcutaneous injuries are repaired. Of special interest was the process by which portions of tissue killed by the violence of the accident were disposed of, as contrasted with what had till then been invariably witnessed. Dead parts had been always seen to be gradually separated from the living by an inflammatory process and thrown off as sloughs. But when protected by the antiseptic dressing from becoming putrid and therefore irritating, a structure deprived of its life caused no disturbance in its vicinity ; and, on the contrary, being of a nutritious nature, it served as pabulum for the growing elements of the neighbouring living structures, and these became in due time entirely substituted for it. Even dead bone was seen to be thus replaced by living osseous tissue.

This suggested the idea of using threads of dead animal structures for tying blood-vessels ; and this was realised by means of catgut, which is made from the intestine of the sheep. If deprived of living microbes, and otherwise properly prepared, catgut answers its purpose completely ; the knot holding securely, while the ligature around the vessel becomes gradually absorbed and replaced by a ring of living tissue. The threads, instead of being left long as before, could now be cut short, and the tedious process of separation of the ligature, with its attendant serious danger of bleeding, was avoided.

Undiluted carbolic acid is a powerful caustic ; and although it might be employed in compound fracture, where some loss of tissue was of little moment in comparison with the tremendous danger to be averted, it was altogether unsuitable for wounds made by the surgeon. It soon appeared, however, that the acid would answer the purpose aimed at, though used in diluted forms devoid of caustic action, and therefore applicable to operative surgery. According to our then existing knowledge, two essential points had to be aimed at : to conduct the operation so that on its completion the wound should contain no living microbes, and to apply a dressing capable of preventing the access of other living organisms till the time should have arrived for changing it.

Carbolic acid lent itself well to both these objects. Our experience with this agent brought out what was, I believe, a new principle in pharmacology—namely, that the energy of action of any substance upon the human tissues depends not only upon the proportion in which it is contained in the material used as a vehicle for its administration, but also upon the degree of tenacity with which it is held by its solvent. Water dissolves carbolic acid sparingly and holds it extremely lightly, leaving it free to act energetically on other things for which it has greater affinity, while various organic substances absorb it greedily and hold it tenaciously. Hence its watery solution seemed admirably suited for a detergent lotion to be used for destroying any microbes that might fall upon the wound during the operation, and for purifying the surrounding skin and also the surgeon's hands and instruments. For the last-named purpose it had the further advantage that it did not act on steel.

For an external dressing the watery solution was not adapted, as it soon lost the acid it contained, and was irritating while it lasted. For this purpose some organic substances were found to answer well. Large proportions of the acid could be blended with them in so bland a form as to be unirritating; and such mixtures, while perpetually giving off enough of the volatile salt to prevent organic development in the discharges that flowed past them, served as a reliable store of the antiseptic for days together.

The appliances which I first used for carrying out the antiseptic principle were both rude and needlessly complicated. The years that have since passed have witnessed great improvements in both respects. Of the various materials which have been employed by myself and others, and their modes of application, I need say nothing except to express my belief, as a matter of long experience, that carbolic acid, by virtue of its powerful affinity for the epidermis and oily matters associated with it, and also its great penetrating power, is still the best agent at our disposal for purifying the skin around the wound. But I must say a few words regarding a most important simplification of our procedure. Pasteur, as we have seen, had shown that the air of every inhabited room teems with microbes; and for a long time I employed various more or less elaborate precautions against the living atmospheric dust, not doubting that, as all wounds except the few which healed completely by the first intention, underwent putrefactive fermentation, the blood must be a peculiarly favourable soil for the growth of putrefactive microbes. But I afterwards learnt that such was by no means the case. I had performed many experiments in confirmation of Pasteur's germ theory, not indeed in order to satisfy myself of its truth, but in the hope of convincing others. I had observed that uncontaminated milk, which would remain unaltered for an indefinite time if protected from dust, was made to teem with microbes of different kinds by a very brief exposure to the atmosphere, and that the same effect was produced by the addition of a drop of ordinary water. But when I came to experiment with blood drawn with antiseptic precautions into sterilised vessels, I saw to my surprise that it might remain free from microbes in spite of similar access of air or treatment with water. I even found that if very putrid blood was largely diluted with sterilised water, so as to diffuse its microbes widely and wash them of their acrid products, a drop of such dilution added to pure blood might leave it unchanged for days at the temperature of the body, although a trace of the septic liquid undiluted caused intense putrefaction within twenty-four hours. Hence I was led to conclude that it was the grosser forms of septic mischief, rather than microbes in the attenuated condition in which they existed in the atmosphere, that we had to dread in surgical practice. And at the London Medical Congress in 1881, I hinted, when describing the experiments I have alluded to, that it might turn out possible to disregard altogether the atmospheric dust. But greatly as I should have rejoiced at such a simplification of our procedure, if justifiable, I did not then venture to test it in practice. I knew that with the safeguards which we then employed I could ensure the safety of my patients, and I did not dare to imperil it by relaxing them. There is one golden rule for all experiments upon our fellow-men. Let the thing tried be that which, according to our best judgment, is the most likely to promote the welfare of the patient. In other words, Do as you would be done by.

Nine years later, however, at the Berlin Congress in 1890, I was able to bring forward what was, I believe, absolute demonstration of the harmlessness of the atmospheric dust in surgical operations. This conclusion has been justified by subsequent experience : the irritation of the wound by antiseptic irrigation and washing may therefore now be avoided, and nature left quite undisturbed to carry out her best methods of repair, while the surgeon may conduct his operations as simply as in former days, provided always that, deeply impressed with the tremendous importance of his object, and inspiring the same conviction in all his assistants, he vigilantly maintains from first to last, with a care that, once learnt, becomes instinctive, but for the want of which nothing else can compensate, the use of the simple means which will suffice to exclude from the wound the coarser forms of septic impurity.

Even our earlier and ruder methods of carrying out the antiseptic principle soon produced a wonderful change in my surgical wards in the Glasgow Royal Infirmary, which, from being some of the most unhealthy in the kingdom, became, as I believe I may say without exaggeration, the healthiest in the world ; while other wards, separated from mine only by a passage a few feet broad, where former modes of treatment were for a while continued, retained their former insalubrity. This result, I need hardly remark, was not in any degree due to special skill on my part, but simply to the strenuous endeavour to carry out strictly what seemed to me a principle of supreme importance.

Equally striking changes were afterwards witnessed in other institutions. Of these I may give one example. In the great Allgemeines Krankenhaus of Munich, hospital gangrene had become more and more rife from year to year, till at length the frightful condition was reached that 80 per cent. of all wounds became affected by it. It is only just to the memory of Professor von Nussbaum, then the head of that establishment, to say that he had done his utmost to check this frightful scourge; and that the evil was not caused by anything peculiar in his management was shown by the fact that in a private hospital under his care there was no unusual unhealthiness. The larger institution seemed to have become hopelessly infected, and the city authorities were contemplating its demolition and reconstruction. Under these circumstances, Professor von Nussbaum despatched his chief assistant, Dr. Lindpaintner, to Edinburgh, where I at that time occupied the chair of clinical surgery, to learn the details of the antiseptic system as we then practised it. He remained until he had entirely mastered them, and after his return all the cases were on a certain day dressed on our plan. From that day forward not a single case of hospital gangrene occurred in the Krankenhaus. The fearful disease pyæmia likewise disappeared, and erysipelas soon followed its example.

But it was by no means only in removing the unhealthiness of hospitals that the antiseptic system showed its benefits. Inflammation being suppressed, with attendant pain, fever, and wasting discharge, the sufferings of the patient were, of course, immensely lessened; rapid primary union being now the rule, convalescence was correspondingly curtailed; while as regards safety and the essential nature of the mode of repair, it became a matter of indifference whether the wound had clean-cut surfaces which could be closely approximated, or whether the injury inflicted had been such as to cause destruction of tissue. And operations which had been regarded from time immemorial as unjustifiable were adopted with complete safety.

It pleases me to think that there is an ever-increasing number of practitioners throughout the world to whom this will not appear the language of exaggeration. There are cases in which, from the situation of the part concerned or other unusual circumstances, it is impossible to carry out the antiseptic system completely. These, however, are quite exceptional; and even in them much has been done to mitigate the evil which cannot be altogether avoided.

I ask your indulgence if I have seemed to dwell too long upon matters in which I have been personally concerned. I now gladly return to the labours of others.

The striking results of the application of the germ theory to Surgery acted as a powerful stimulus to the investigation of the nature of the micro-organisms concerned; and it soon appeared that putrefaction was by no means the only evil of microbic origin to which wounds were liable. I had myself very early noticed that hospital gangrene was not necessarily attended by any unpleasant odour; and I afterwards made a similar observation regarding the matter formed in a remarkable epidemic of erysipelas in Edinburgh obviously of infective character. I had also seen a careless dressing followed by the occurrence of suppuration without putrefaction. And as these non-putrefactive disorders had the same self-propagating property as ferments, and were suppressed by the same antiseptic agencies which were used for combating the putrefactive microbes, I did not doubt that they were of an analogous origin; and I ventured to express the view that, just as the various fermentations had each its special microbe, so it might be with the various complications of wounds. This surmise was afterwards amply verified. Professor Ogston, of Aberdeen, was an early worker in this field, and showed that in acute abscesses, that is to say those which run a rapid course, the matter, although often quite free from unpleasant odour, invariably contains micro-organisms belonging to the group which, from the spherical form of their elements, are termed micrococci; and these he classed as streptococci or staphylococci, according as they were arranged in chains or disposed in irregular clusters like bunches of grapes. The German pathologist, Fehleisen, followed with a beautiful research, by which he clearly proved that erysipelas is caused by a streptococcus. A host of earnest workers in different countries have cultivated the new science of Bacteriology, and, while opening up a wide fresh domain of Biology, have demonstrated in so many cases the causal relation between special micro-organisms and special diseases, not only in wounds but in the system generally, as to afford ample confirmation of the induction which had been made by Pasteur that all infective disorders are of microbic origin.

Not that we can look forward with anything like confidence to being able ever to see the *materies morbi* of every disease of this nature. One of the latest of such discoveries has been that by Pfeiffer of Berlin of the bacillus of influenza, perhaps the most minute of all micro-organisms ever yet detected. The bacillus of anthrax, the cause of a plague common among cattle in some parts of Europe, and often communicated to sorters of foreign wool in this country, is a giant as compared with this tiny being; and supposing the microbe of any infectious fever to be as much smaller than the influenza bacillus as this is less than that of anthrax, a by no means unlikely hypothesis, it is probable that it would never be visible to man. The improvements of the microscope, based on the principle established by my father in the earlier part of the century, have apparently nearly reached the limits of what is possible. But that such parasites are really the causes of all this great class of diseases can no longer be doubted.

The first rational step towards the prevention or cure of disease is to know its cause; and it is impossible to over-estimate the practical value of researches such as those to which I am now referring. Among their many achievements is what may be fairly regarded as the most important discovery ever made in pathology, because it revealed the true nature of the disease which causes more sickness and death in the human race than any other. It was made by Robert Koch, who greatly distinguished himself, when a practitioner in an obscure town in Germany, by the remarkable combination of experimental acuteness and skill, chemical and optical knowledge and successful micro-photography which he brought to bear upon the elucidation of infective diseases of wounds in the lower animals; in recognition of which service the enlightened Prussian Government at once appointed him to an official position of great importance in Berlin. There he conducted various important researches; and at the London Congress in 1881 he showed to us for the first time the bacillus of tubercle. Wonderful light was thrown by this discovery upon a great group of diseases which had before been rather guessed than known to be of allied nature; a precision and efficacy never before possible was introduced into their surgical treatment, while the physician became guided by new and sure light as regards their diagnosis and prevention.

At that same London Congress Koch demonstrated to us his 'plate culture' of bacteria, which was so important that I must devote a few words to its description. With a view to the successful study of the habits and effects of any particular microbe outside the living body, it is essential that it should be present unmixed in the medium in which it is cultivated. It can be readily understood how difficult it must have been to isolate any particular micro-organism when it existed mixed, as was often the case, with a multitude of other forms. In fact, the various ingenious attempts made to effect this object had often proved entire failures. Koch, however, by an ingenious procedure converted what had been before impossible into a matter of the utmost facility. In the broth or other nutrient liquid which was to serve as food for the growing microbe he dissolved, by aid of heat, just enough gelatine to ensure that, while it should become a solid mass when cold, it should remain fluid though reduced in temperature so much as to be incapable of killing living germs. To the medium thus partially cooled was added some liquid containing, among others, the microbe to be investigated; and the mixture was thoroughly shaken so as to diffuse the bacteria and separate them from each other. Some of the liquid was then poured out in a thin layer upon a glass plate and allowed to cool so as to assume the solid form. The various microbes, fixed in the gelatine and so prevented from intermingling, proceeded to develop each its special progeny, which in course of time showed itself as an opaque speck in the transparent film. Any one of such specks could now be removed and transferred to another vessel in which the microbe composing it grew in perfect isolation.

Pasteur was present at this demonstration, and expressed his sense of the great progress effected by the new method. It was soon introduced into his own institute and other laboratories throughout the world; and it has immensely facilitated bacteriological study.

One fruit of it in Koch's own hands was the discovery of the microbe of cholera in India, whither he went to study the disease. This organism was termed by Koch from its curved form the 'comma bacillus,' and by the French the cholera vibrio. Great doubts were for a long time felt regarding this discovery. Several other kinds of bacteria were found of the same shape, some of them producing very similar appearances in culture media. But bacteriologists are now universally agreed that, although various other conditions are necessary to the production of an attack of cholera besides the mere presence of the vibrio, yet it is the essential *materies morbi*; and it is by the aid of the diagnosis which its presence in any case of true cholera enables the bacteriologist to make, that threatened invasions of this awful disease have of late years been so successfully repelled from our shores. If bacteriology had done nothing more for us than this, it might well have earned our gratitude.

I have next to invite your attention to some earlier work of Pasteur. There is a disease known in France under the name of *choléra des poules*, which often produced great havoc among the poultry yards of Paris. It had been observed that the blood of birds that had died of this disease was peopled by a multitude of minute bacteria, not very dissimilar in form and size to the microbe of the lactic ferment to which I have before referred. And Pasteur found that, if this bacterium was cultivated outside the body for a protracted period under certain conditions, it underwent a remarkable diminution of its virulence; so that, if inoculated into a healthy fowl, it no longer caused the death of the bird, as it would have done in its original condition, but produced a milder form of the disease which was not fatal. And this altered character of the microbe, caused by certain conditions, was found to persist in successive generations cultivated in the ordinary way. Thus was discovered the great fact of what Pasteur termed the *atténuation des virus*, which at once gave the clue to understanding what had before been quite mysterious, the difference in virulence of the same disease in different epidemics.

But he made the further very important observation that a bird which had gone through the mild form of the complaint had acquired immunity against it in its most virulent condition. Pasteur afterwards succeeded in obtaining mitigated varieties of microbes for some other diseases; and he applied with great success the principle which he had discovered in fowl-cholera for protecting the larger domestic animals against the plague of anthrax. The preparations used for such preventive inoculations he termed 'vaccins' in honour of our great countryman, Edward Jenner. For Pasteur at once saw the analogy between the immunity to fowl-cholera produced by its attenuated virus and the protection afforded against small-pox by vaccination. And while pathologists still hesitated, he had no doubt of the correctness of Jenner's expression *variolæ vaccinæ*, or small-pox in the cow.

It is just a hundred years since Jenner made the crucial experiment of inoculating with small-pox a boy whom he had previously vaccinated, the result being, as he anticipated, that the boy was quite unaffected. It may be remarked that this was a perfectly legitimate experiment, involving no danger to the subject of it. Inoculation was at that time the established practice; and if vaccination should prove nugatory, the inoculation would be only what would have been otherwise called for; while it would be perfectly harmless if the hoped-for effect of vaccination had been produced.

We are a practical people, not much addicted to personal commemorations: although our nation did indeed celebrate with fitting splendour the jubilee of the reign of our beloved Queen; and at the invitation of Glasgow the scientific world has lately marked in a manner, though different, as imposing, the jubilee of the life-work of a sovereign in science (Lord Kelvin). But while we cannot be astonished that the centenary of Jenner's immortal discovery should have failed to receive general recognition in this country, it is melancholy to think that this year should, in his native county, have been distinguished by a terrible illustration of the results which would sooner or later inevitably follow the general neglect of his prescriptions.

I have no desire to speak severely of the Gloucester Guardians. They are not sanitary authorities, and had not the technical knowledge necessary to enable them to judge between the teachings of true science and the declamations of misguided, though well-meaning, enthusiasts. They did what they believed to be right; and when roused to a sense of the greatness of their mistake, they did their very best to repair it, so that their city is said to be now the best vaccinated in Her Majesty's dominions. But though by their praiseworthy exertions they succeeded in promptly checking the raging epidemic, they cannot recall the dead to life, or restore beauty to marred features, or sight to blinded eyes. Would that the entire country and our Legislature might take duly to heart this object-lesson!

How completely the medical profession were convinced of the efficacy of vaccination in the early part of this century was strikingly illustrated by an account given by Professor Crookshank, in his interesting history of this subject, of several eminent medical men in Edinburgh meeting to see the to them unprecedented fact of a vaccinated person having taken small-pox. It has, of course, since become well known that the milder form of the disease, as modified by passing through the cow, confers a less permanent protection than the original human disorder. This it was, of course, impossible for Jenner to foresee. It is, indeed, a question of degree, since a second attack of ordinary small-pox is occasionally known to occur, and vaccination, long after it has ceased to give perfect immunity, greatly modifies the character of the disorder and diminishes its danger. And, happily, in re-vaccination after a certain number of years we have the means of making Jenner's work complete. I understand that the majority of the Commissioners, who have recently issued their report upon this subject, while recognising the value and importance of re-vaccination, are so impressed with the difficulties that would attend making it compulsory by legislation that they do not recommend that course; although it is advocated by two of their number who are of peculiarly high authority on such a question. I was lately told by a Berlin professor that no serious difficulty is experienced in carrying out the compulsory law that prevails in Germany. The masters of the schools are directed to ascertain in the case of every child attaining the age of twelve whether re-vaccination has been practised. If not, and the parents refuse to have it done, they are fined one mark. If this does not prove effectual, the fine is doubled: and if even the double penalty should not prove efficacious, a second doubling of it would follow, but, as my informant remarked, it is very seldom that it is called for. The result is that small-pox is a matter of extreme rarity in that country; while it is almost unknown in the huge German army, in consequence of the rule that every soldier is re-vaccinated on entering the service. Whatever view our Legislature may take on this question, one thing seems to me clear: that it will be the duty of Government to encourage by every available means the use of calf lymph, so as to exclude the possibility of the communication of any human disease to the child, and to institute such efficient inspection of vaccination institutes as shall ensure careful antiseptic arrangements, and so prevent contamination by extraneous microbes. If this were done, 'conscientious objections' would cease to have any rational basis. At the same time, the administration of the regulations on vaccination should be transferred (as advised by the Commissioners) to competent sanitary authorities.

But to return to Pasteur. In 1880 he entered upon the study of that terrible but then most obscure disease, Hydrophobia or Rabies, which from its infective character he was sure must be of microbic origin, although no micro-organism could be detected in it. He early demonstrated the new pathological fact that the virus had its essential seat in the nervous system. This proved the key to his success in this subject. One result that flowed from it has been the cause of unspeakable consolation to many. The foolish practice is still too prevalent of killing the dog that has bitten any one, on the absurd notion that, if it were mad, its destruction would prevent the occurrence of Hydrophobia in the person bitten. The idea of the bare possibility of the animal having been so affected causes an agony of suspense during the long weeks or months of possible incubation of the disease. Very serious nervous symptoms aping true Hydrophobia have been known tc result from the terror thus inspired. Pasteur showed that if a little of the brain or spinal cord of a dog that had been really mad was inoculated in an appropriate manner into a rabbit, it infallibly caused rabies in that animal in a few days. If therefore such an experiment was made with a negative result, the conclusion might be drawn with certainty that the dog had been healthy. It is perhaps right that I should say that the inoculation is painlessly done under an anæsthetic, and that in the rabbit rabies does not assume the violent form that it does in the dog, but produces gradual loss of power with little if any suffering.

This is the more satisfactory because rabbits in which the disease has been thus artificially induced are employed in carrying out what was Pasteur's greatest triumph, the preventive treatment of Hydrophobia in the human subject. We have seen that Pasteur discovered that microbes might under some circumstances undergo mitigation of their virulence. He afterwards found that under different conditions they might have it exalted, or, as he expressed it, there might be a *renforcement du virus.* Such proved to be the case with rabies in the rabbit; so that the spinal cords of animals which had died of it contained the poison in a highly intensified condition. But he also found that if such a highly virulent cord was suspended under strict antiseptic precautions in a dry atmosphere at a certain temperature, it gradually from day to day lost in potency, till in course of time it became absolutely inert. If now an emulsion of such a harmless cord was introduced under the skin of an animal, as in the subcutaneous administration of morphia, it might be followed without harm another day by a similar dose of a cord still rather poisonous; and so from day to day stronger and stronger injections might be used, the system becoming gradually accustomed to the poison, till a degree of virulence had been reached far exceeding that of the bite of a mad dog. When this had been attained, the animal proved incapable of taking the disease in the ordinary way; and more than that, if such treatment was adopted after an animal had already received the poison, provided that too long a time had not elapsed, the outbreak of the disease was prevented. It was only after great searching of heart that Pasteur, after consultation with some trusted medical friends, ventured upon trying this practice upon man. It has since been extensively adopted in various parts of the world with increasing success as the details of the method were improved. It is not of course the case that every one bitten by a really rabid animal takes the disease; but the percentage of those who do so, which was formerly large, has been reduced almost to zero by this treatment, if not too long delayed.

While the intensity of rabies in the rabbit is undoubtedly due to a peculiarly virulent form of the microbe concerned, we cannot suppose that the daily diminishing potency of the cord suspended in dry warm air is an instance of attenuation of virus, using the term 'virus' as synonymous with the microbe concerned. In other words, we have no reason to believe that the special micro-organism of hydrophobia continues to develop in the dead cord and produce successively a milder and milder progeny; since rabies cannot be cultivated in the nervous system of a dead animal. We must rather conclude that there must be some chemical poison present which gradually loses its potency as time passes. And this leads me to refer to another most important branch of this large subject of bacteriology, that of the poisonous products of microbes.

It was shown several years ago by Roux and Yersin, working in the *Institut Pasteur*, that the crust or false membrane which forms upon the throats of patients affected with diphtheria contains bacteria which can be cultivated outside the body in a nutrient liquid, with the result that it acquires poisonous qualities of astonishing intensity, comparable to that of the secretion of the poison-glands of the most venomous serpents. And they also ascertained that the liquid retained this property after the microbes had been removed from it by filtration, which proved that the poison must be a chemical substance in solution, as distinguished from the living element which had produced it. These poisonous products of bacteria, or toxins as they have been termed, explain the deadly effects of some microbes, which it would otherwise be impossible to understand. Thus, in diphtheria itself the special bacillus which was shown by Löffler to be its cause, does not become propagated in the blood, like the microbe of chicken cholera, but remains confined to the surface on which it first appeared: but the toxin which it secretes is absorbed from that surface into the blood, and so poisons the system. Similar observations have been made with regard to the microbes of some other diseases, as, for example, the bacillus of tetanus or lockjaw. This remains localised in the wound, but forms a special toxin of extreme potency, which becomes absorbed and diffused through the body.

Wonderful as it seems, each poisonous microbe appears to form its own peculiar toxin. Koch's tuberculin was of this nature; a product of the growth of the tubercle bacillus in culture media. Here, again, great effects were produced by extremely minute quantities of the substance; but here a new peculiarity showed itself, viz. that patients affected with tubercular disease, in any of its varied forms, exhibited inflammation in the affected part and general fever after receiving under the skin an amount of the material which had no effect whatever upon healthy persons. I witnessed in Berlin some instances of these effects, which were simply astounding. Patients affected with a peculiar form of obstinate ulcer of the face showed, after a single injection of the tuberculin, violent inflammatory redness and swelling of the sore and surrounding skin; and, what was equally surprising, when this disturbance subsided the disease was found to have undergone great improvement. By repetitions of such procedures, ulcers which had previously been steadily advancing, in spite of ordinary treatment, became greatly reduced in size, and in some instances apparently cured. Such results led Koch to believe that he had obtained an effectual means of dealing with tubercular disease in all its forms. Unhappily, the apparent cure proved to be only of transient duration, and the high hopes which had been inspired by Koch's great reputation were dashed. It is but fair to say that he was strongly urged to publish before he was himself disposed to do so, and we cannot but regret that he yielded to the pressure put upon him.

But though Koch's sanguine anticipations were not realised, it would be a great mistake to suppose that his labours with tuberculin have been fruitless. Cattle are liable to tubercle, and, when affected with it, may become a very serious source of infection for human beings, more especially when the disease affects the udders of cows, and so contaminates the milk. By virtue of the close affinity that prevails between the lower animals and ourselves, in disease as well as in health, tuberculin produces fever in tubercular cows in doses which do not affect healthy beasts. Thus, by the subcutaneous use of a little of the fluid, tubercle latent in internal organs of an apparently healthy cow can be with certainty revealed, and the slaughter of the animal after this discovery protects man from infection.

It has been ascertained that glanders presents a precise analogy with tubercle as regards the effects of its toxic products. If the microbe which has been found to be the cause of this disease is cultivated in appropriate media, it produces a poison which has received the name of mallein, and the subcutaneous injection of a suitable dose of this fluid into a glandered horse causes striking febrile symptoms which do not occur in a healthy animal. Glanders, like tubercle, may exist in insidious latent forms which there was formerly no possibility of detecting, but which are at once disclosed by this means. If a glandered horse has been accidentally introduced into a large stable, this method of diagnosis surely tells if it has infected others. All receive a little mallein. Those which become affected with fever are slaughtered, and thus not only is the disease prevented from spreading to other horses, but the grooms are protected from a mortal disorder.

This valuable resource sprang from Koch's work on tuberculin, which has also indirectly done good in other ways. His distinguished pupil, Behring, has expressly attributed to those researches the inspiration of the work which led him and his since famous collaborateur, the Japanese Kitasato, to their surprising discovery of anti-toxic serum. They found that if an animal of a species liable to diphtheria or tetanus received a quantity of the respective toxin, so small as to be harmless, and afterwards, at suitable intervals, successively stronger and stronger doses, the creature, in course of time, acquired such a tolerance for the poison as to be able to receive with impunity a quantity very much greater than would at the outset have proved fatal. So far, we have nothing more than seems to correspond with the effects of the increasingly potent cords in Pasteur's treatment of rabies. But what was entirely new in their results was that, if blood was drawn from an animal which had acquired this high degree of artificial immunity, and some of the clear fluid or serum which exuded from it after it had clotted was introduced under the skin of another animal, this second animal acquired a strong, though more transient, immunity against the particular toxin concerned. The serum in some way counteracted the toxin or was antitoxic. But, more than that, if some of the antitoxic serum was applied to an animal after it had already received a poisonous dose of the toxin, it preserved the life of the creature, provided that too long a time had not elapsed after the poison was introduced. In other words, the antitoxin proved to be not only preventive but curative.

Similar results were afterwards obtained by Ehrlich, of Berlin, with some poisons not of bacterial origin, but derived from the vegetable kingdom; and quite recently the independent labours of Calmette of Lille and Fraser of Edinburgh have shown that antidotes of wonderful efficacy against the venom of serpents may be procured on the same principle. Calmette has obtained antitoxin so powerful that a quantity of it only a 200,000th part of the weight of an animal will protect it perfectly against a dose of the secretion of the poison-glands of the most venomous serpents known to exist, which without such protection would have proved fatal in four hours. For curative purposes larger quantities of the remedy are required, but cases have been already published by Calmette in which death appears to have been averted in the human subject by this treatment.

Behring's darling object was to discover means of curing tetanus and diphtheria in man. In tetanus the conditions are not favourable; because the specific bacilli lurk in the depths of the wound, and only declare their presence by symptoms caused by their toxin having been already in a greater or less amount diffused through the system; and in every case of this disease there must be a fear that the antidote may be applied too late to be useful. But in diphtheria the bacilli very early manifest their presence by the false membrane which they cause upon the throat, so that the antitoxin has a fair chance; and here we are justified in saying that Behring's object has been attained.

The problem, however, was by no means so simple as in the case of some mere chemical poison. However effectual the antitoxin might be against the toxin, if it left the bacilli intact, not only would repeated injections be required to maintain the transient immunity to the poison perpetually secreted by the microbes, but the bacilli might by their growth and extension cause obstruction of the respiratory passages.

Roux, however, whose name must always be mentioned with honour in relation to this subject, effectually disposed of this difficulty. He showed by experiments on animals that a diphtheritic false membrane, rapidly extending and accompanied by surrounding inflammation, was brought to a stand by the use of the antitoxin, and soon dropped off, leaving a healthy surface. Whatever be the explanation, the fact was thus established that the antitoxic serum, while it renders the toxin harmless, causes the microbe to languish and disappear.

No theoretical objection could now be urged against the treatment;

and it has during the last two years been extensively tested in practice in various parts of the world, and it has gradually made its way more and more into the confidence of the profession. One important piece of evidence in its favour in this country is derived from the report of the six large hospitals under the management of the London Asylums Board. The medical officers of these hospitals at first naturally regarded the practice with scepticism : but as it appeared to be at least harmless, they gave it a trial ; and during the year 1895 it was very generally employed upon the 2,182 cases admitted ; and they have all become convinced of its great value. In the nature of things, if the theory of the treatment is correct, the best results must be obtained when the patients are admitted at an early stage of the attack, before there has been time for much poisoning of the system : and accordingly we learn from the report that, comparing 1895 with 1894, during which latter year the ordinary treatment had been used, the percentage of mortality, in all the six hospitals combined, among the patients admitted on the first day of the disease, which in 1894 was 22·5, was only 4·6 in 1895 ; and for those admitted on the second day the numbers are 27 for 1894 and 14·8 for 1895. Thus for cases admitted on the first day the mortality was only one-fifth of what it was in the previous year, and for those entering on the second it was halved. Unfortunately in the low parts of London which furnish most of these patients the parents too often delay sending in the children till much later : so that on the average no less than 67·5 per cent. were admitted on the fourth day of the disease or later. Hence the aggregate statistics of all cases are not nearly so striking. Nevertheless, taking it altogether, the mortality in 1895 was less than had ever before been experienced in those hospitals. I should add that there was no reason to think that the disease was of a milder type than usual in 1895 ; and no change whatever was made in the treatment except as regards the antitoxic injections.

There is one piece of evidence recorded in the report which, though it is not concerned with high numbers, is well worthy of notice. It relates to a special institution to which convalescents from scarlet fever are sent from all the six hospitals. Such patients occasionally contract diphtheria, and when they do so the added disease has generally proved extremely fatal. In the five years preceding the introduction of the treatment with antitoxin the mortality from this cause had never been less than 50 per cent., and averaged on the whole 61·9 per cent. During 1895, under antitoxin, the deaths among the 119 patients of this class were only 7·5 per cent., or one-eighth of what had been previously experienced. This very striking result seems to be naturally explained by the fact that these patients being already in hospital when the diphtheria appeared, an unusually early opportunity was afforded for dealing with it.

There are certain cases of so malignant a character from the first that no treatment will probably ever be able to cope with them. But taking all cases together it seems probable that Behring's hope that the mortality may be reduced to 5 per cent. will be fully realised when the public become alive to the paramount importance of having the treatment commenced at the outset of the disease.

There are many able workers in the field of Bacteriology whose names time does not permit me to mention, and to whose important labours I cannot refer; and even those researches of which I have spoken have been, of course, most inadequately dealt with. I feel this especially with regard to Pasteur, whose work shines out more brightly the more his writings are perused.

I have lastly to bring before you a subject which, though not bacteriological, has intimate relations with bacteria. If a drop of blood is drawn from the finger by a prick with a needle and examined microscopically between two plates of glass, there are seen in it minute solid elements of two kinds, the one pale orange bi-concave discs, which, seen in mass, give the red colour to the vital fluid, the other more or less granular spherical masses of the soft material called protoplasm, destitute of colour, and therefore called the colourless or white corpuscles. It has been long known that if the microscope was placed at such a distance from a fire as to have the temperature of the human body, the white corpuscles might be seen to put out and retract little processes or pseudopodia, and by their means crawl over the surface of the glass, just like the extremely low forms of animal life termed, from this faculty of changing their form, amœbæ. It was a somewhat weird spectacle, that of seeing what had just before been coursing through our veins moving about like independent creatures. Yet there was nothing in this inconsistent with what we knew of the fixed components of the animal frame. For example, the surface of a frog's tongue is covered with a layer of cells, each of which is provided with two or more lashing filaments or cilia, and those of all the cells acting in concert cause a constant flow of fluid in a definite direction over the organ. If we gently scrape the surface of the animal's tongue, we can detach some of these ciliated cells; and on examining them with the microscope in a drop of water, we find that they will contiuue for an indefinite time their lashing movements, which are just as much living or vital in their character as the writhings of a worm. And, as I observed many years ago, these detached cells behave under the influence of a stimulus just like parts connected with the body, the movements of the cilia being excited to greater activity by gentle stimulation, and thrown into a state of temporary inactivity when the irritation was more severe. Thus each constituent element of our bodies may be regarded as in one sense an independent living being, though all work together in marvellous harmony for the good of the body politic. The independent movements of the white corpuscles outside the body were therefore not astonishing: but they long remained matters of mere curiosity. Much interest was called to them by the observation of the German pathologist Cohnheim that in some inflammatory conditions they passed through the pores in the walls of the finest blood-vessels, and thus escaped into the interstices of the surrounding tissues. Cohnheim attributed their transit to the pressure of the blood. But why it was that, though larger than the red corpuscles, and containing a nucleus which the red ones have not, they alone passed through the pores of the vessels, or why it was that this emigration of the white corpuscles occurred abundantly in some inflammations and was absent in others, was quite unexplained.

These white corpuscles, however, have been invested with extraordinary new interest by the researches of the Russian naturalist and pathologist, Metchnikoff. He observed that, after passing through the walls of the vessels, they not only crawl about like amœbæ, but, like them, receive nutritious materials into their soft bodies and digest them. It is thus that the effete materials of a tadpole's tail are got rid of; so that they play a most important part in the function of absorption.

But still more interesting observations followed. He found that a microscopic crustacean, a kind of water-flea, was liable to be infested by a fungus which had exceedingly sharp-pointed spores. These were apt to penetrate the coats of the creature's intestine, and project into its body-cavity. No sooner did this occur with any spore than it became surrounded by a group of the cells which are contained in the cavity of the body and correspond to the white corpuscles of our blood. These proceeded to attempt to devour the spore; and if they succeeded, in every such case, the animal was saved from the invasion of the parasite. But if the spores were more than could be disposed of by the devouring cells (phagocytes, as Metchnikoff termed them), the water-flea succumbed.

Starting from this fundamental observation, he ascertained that the microbes of infective diseases are subject to this same process of devouring and digestion, carried on both by the white corpuscles and by cells that line the blood-vessels. And by a long series of most beautiful researches he has, as it appears to me, firmly established the great truth that phagocytosis is the main defensive means possessed by the living body against the invasions of its microscopic foes. The power of the system to produce antitoxic substances to counteract the poisons of microbes is undoubtedly in its own place of great importance. But in the large class of cases in which animals are naturally refractory to particular infective diseases the blood is not found to yield any antitoxic element by which the natural immunity can be accounted for. Here phagocytosis seems to be the sole defensive agency. And even in cases in which the serum does possess antitoxic, or, as it would seem in some cases, germicidal properties, the bodies of the dead microbes must at last be got rid of by phagocytosis, and some recent observations would seem to indicate that the useful elements of the serum may be, in part at least, derived from the digestive juices of the phagocytes. If ever there was a romantic chapter in pathology, it has surely been that of the story of phagocytosis.

I was myself peculiarly interested by these observations of Metchnikoff's, because they seemed to me to afford clear explanation of the healing of wounds by first intention under circumstances before incomprehensible. Complete primary union was sometimes seen to take place in wounds treated with water-dressing, that is to say, a piece of wet lint covered with a layer of oiled-silk to keep it moist. This, though cleanly when applied, was invariably putrid within twenty-four hours. The layer of blood between the cut surfaces was thus exposed at the outlet of the wound to a most potent septic focus. How was it prevented from putrefying, as it would have done under such influence if, instead of being between divided living tissues, it had been between plates of glass or other indifferent material? Pasteur's observations pushed the question a step further. It now was, How were the bacteria of putrefaction kept from propagating in the decomposable film? Metchnikoff's phagocytosis supplied the answer. The blood between the lips of the wound became rapidly peopled with phagocytes, which kept guard against the putrefactive microbes and seized them as they endeavoured to enter.

If phagocytosis was ever able to cope with septic microbes in so concentrated and intense a form, it could hardly fail to deal effectually with them in the very mitigated condition in which they are present in the air. We are thus strongly confirmed in our conclusion that the atmospheric dust may safely be disregarded in our operations: and Metchnikoff's researches, while they have illumined the whole pathology of infective diseases, have beautifully completed the theory of antiseptic treatment in surgery.

I might have taken equally striking illustrations of my theme from other departments in which microbes play no part. In fact any attempt to speak of all that the art of healing has borrowed from science and contributed to it during the past half-century would involve a very extensive dissertation on pathology and therapeutics. I have culled specimens from a wide field; and I only hope that in bringing them before you I have not overstepped the bounds of what is fitting before a mixed company. For many of you my remarks can have had little if any novelty: for others they may perhaps possess some interest as showing that Medicine is no unworthy ally of the British Association—that, while her practice is ever more and more based on science, the ceaseless efforts of her votaries to improve what have been fittingly designated *Quæ prosunt omnibus artes,* are ever adding largely to the sum of abstract knowledge.

REPORTS

ON THE

STATE OF SCIENCE.

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Corresponding Societies.—Report of the Committee, consisting of Professor R. MELDOLA (*Chairman*), Mr. T. V. HOLMES (*Secretary*), Mr. FRANCIS GALTON, Sir DOUGLAS GALTON, Sir RAWSON RAWSON, Mr. G. J. SYMONS, Dr. J. G. GARSON, Sir JOHN EVANS, Mr. J. HOPKINSON, Professor T. G. BONNEY, Mr. W. WHITAKER, Professor E. B. POULTON, Mr. CUTHBERT PEEK, *and* Rev. Canon H. B. TRISTRAM.

THE Corresponding Societies Committee of the British Association beg leave to submit the following Report of the Conference held at Liverpool.

The Council intended to nominate Mr. W. Whitaker, F.R.S., Chairman of the Liverpool Conference, but, owing to serious illness, Mr. Whitaker was unable to be present, and Dr. Garson was nominated in his place. Mr. T. V. Holmes was nominated Secretary to the Conference.

The meetings of the Conference were held in St. George's Hall, in the Small Concert Room, on Thursday, September 17, and in the Crown Court on Tuesday, September 22, at 3.30 P.M. The following Corresponding Societies nominated as delegates to represent them at the Liverpool meeting:—

Belfast Naturalists' Field Club . . .	William Gray, M.R.I.A.
Belfast Natural History and Philosophical Society	Alexander Tate, M.Inst.C.E.
Berwickshire Naturalists' Club . . .	Wm. T. Hindmarsh, F.L.S.
Birmingham Natural History and Philosophical Society	Charles Pumphrey.
Bristol Naturalists' Society . . .	Professor S. Young, F.R.S.
Buchan Field Club	John Gray, B.Sc.
Burton-on-Trent Natural History and Archæological Society	Philip B. Mason, F.L.S.
Caradoc and Severn Valley Field Club .	W. W. Watts, M.A., F.G.S.
Cardiff Naturalists' Society . . .	E. W. Small.
Chester Society of Natural Science and Literature	Osmund W. Jeffs.
Chesterfield and Midland Counties Institution of Engineers	M. H. Mills, F.G.S.

Cornwall, Royal Geological Society of .	T. R. Polwhele, F.G.S.
Dorset Natural History and Antiquarian Field Club	N. M. Richardson.
Dublin Naturalists' Field Club . . .	Professor T. Johnson, D.Sc.
East Kent Natural History Society . .	Henry Coates, F.R.S.E.
East of Scotland Union of Naturalists' Societies	A. M. Rodger, M.A.
Essex Field Club	T. V. Holmes, F.G.S.
Federated Institution of Mining Engineers	M. H. Mills, M.Inst.C.E.
Glasgow Geological Society . . .	J. Barclay Murdoch.
Glasgow Natural History Society . .	Professor F. O. Bower, F.R.S.
Glasgow Philosophical Society . . .	W. W. Blackie, B.Sc.
Hampshire Field Club	Rev. A. G. Joyce.
Hertfordshire Natural History Society .	Sir John Evans, K.C.B.
Holmesdale Natural History Club . .	Miss M. C. Crosfield.
Ireland, Statistical and Social Inquiry Society of	Professor Bastable, M.A.
Isle of Man Natural History and Antiquarian Society	A. W. Moore, M.A.
Leeds Geological Association . . .	Professor P. F. Kendall, F.G.S.
Leeds Naturalists' Club and Scientific Association	Harold Wager, F.L.S.
Leicester Literary and Philosophical Society	Montagu Browne, F.L.S.
Liverpool Engineering Society . . .	Arthur J. Maginnis, M.Inst.N.A.
Liverpool Geographical Society .	Horace Walker.
Liverpool Geological Society . . .	E. Dickson, F.G.S.
Malton Field Naturalists' and Scientific Society	Dr. E. Colby, M.A.
Manchester Geographical Society . .	Eli Sowerbutts, F.R.G.S.
Manchester Geological Society . . .	Mark Stirrup, F.G.S.
Manchester Microscopical Society . .	F. W. Hembry.
Norfolk and Norwich Naturalists' Society .	Clement Reid, F.G.S.
North Staffordshire Naturalists' Field Club	C. E. De Rance, F.G.S.
North of England Institute of Mining Engineers	J. H. Merivale, M.A.
Nottingham Naturalists' Society . .	Professor J. W. Carr, M.A.
Perthshire Society of Natural Science .	Sir Robert Pullar.
Rochdale Literary and Scientific Society .	J. R. Heape.
Scotland, Mining Institute of . . .	James Barrowman.
Somersetshire Archæological and Natural History Society	F. T. Elworthy.
Tyneside Geographical Society. . .	G. E. T. Smithson.
Warwickshire Naturalists' and Archæologists' Field Club	Wm. Andrews, F.G.S.
Woolhope Naturalists' Field Club . .	Rev. J. O. Bevan, M.A.
Yorkshire Geological and Polytechnic Society	Wm. Cash, F.G.S.
Yorkshire Naturalists' Union . . .	Rev. E. P. Knubley, M.A.

First Conference, September 17, 1896.

The first meeting of the Conference took place in the Crown Court, adjoining the Reception Room, St. George's Hall.

The Chairman, Dr. Garson, opened the proceedings by expressing his regret that serious illness prevented Mr. Whitaker from being present, though he was glad to be able to add that the latest accounts of him were that he was progressing satisfactorily. He was pleased to see a larger number of delegates than usual, as a sign that the connection of the Corresponding Societies with the British Association was becoming more and more appreciated. He hoped the delegates would attend regularly, so that they might the better explain to their respective Societies on their return home the nature of the work in which they were asked to co-operate.

Mr. George Abbott, M.R.C.S., General Secretary of the South Eastern Union of Scientific Societies, then read a short paper entitled 'District Unions of Natural History Societies.' Mr. Abbott remarked that while local Natural History Societies had done much good work, yet that in many cases their efforts had been weak, irregular, and desultory. He thought the chief cause of failure had been want of organisation. A step in the right direction had been taken by the Unions of Scientific Societies already existing, such as those of Yorkshire and the East of Scotland, but he considered that the British Association did not sufficiently foster such unions. He therefore felt that a plan was necessary which would organise the local societies under the guidance of the British Association, which should help to bring these unions into being through the agency of an organising secretary. He submitted the following plan for the consideration of the Conference :—

Districts.—The United Kingdom should be divided into fifteen or twenty districts, in each of which all Natural History Societies should be affiliated for mutual aid, counsel, and work. Existing unions should perhaps be imitated, at any rate not disturbed.

Geographical lines should decide their size, which might vary in extent and be dependent, in some measure, on railway facilities. From time to time these areas might be subject to review, and necessary changes made.

Congress.—Each of such unions would have its annual congress attended by delegates and members from its affiliated societies. This would be held in a fresh town every year, with a new president, somewhat after the manner of the British Association itself. The congresses would probably take place in spring, but two should never be held on the same day.

These unions would render important help to local societies, would bring isolated workers together, assist schools, colleges, and technical institutes and museums, start new societies, and revive waning ones. Through these annual meetings local and petty jealousies would lessen or turn to friendly rivalries—each society trying to excel in real work, activity, and good science teaching.

Further, economy of labour would be accomplished by a precise demarcation of area for each local society. This would be understood as its sphere of work and influence ; in this portion of country it would have a certain amount of responsibility in such matters as observation, research, and vigilance against encroachments on footpaths, commons, and wayside wastes.

These unions might also, through their Central Committees, bring about desirable improvements in publication, but it would perhaps not be desirable, in all cases, to go in for joint publication. In this, as in other matters connected with the unions, *co-operation and not uniformity* must be our aim.

Union Committees.—Each union would need a general secretary and a committee, all of whom should be intimately acquainted with methods of work and the best ambitions of local societies.

Corresponding Members.—This is another necessary development. Each local society should appoint in every village in its district a corresponding member with some distinctive title, and certain privileges and advantages.

The work asked of him would be to—

1. Forward surplus Natural History specimens to their Society's Museum.
2. Supply prompt information on the following subjects :—

  (*a*) New geological sections.
  (*b*) Details of wells, borings, springs, &c.
  (*c*) Finds of geological and antiquarian interest.

3. Answer such questions as the British Association or the local society may require.
4. Keep an eye on historic buildings.
5. Assist the Selborne Society in carrying out its objects.

No mean occupation—certainly a useful, attractive, and honourable post—worthy of any man's acceptance.

In return he should be offered—

1. Assistance in naming specimens, and with the formation of school museums.
2. Free admission to lectures and excursions.
3. Copies of transactions.
4. Free use of the Society's library.

Every village would soon, under this scheme, possess an agent, registrar, or whatever you like to call him, who would be more and more able, as he gained experience, to further the aims of this association.

Expenses or Ways and Means.—This cannot be ignored, but would not form a sufficient barrier to prevent the adoption of the scheme.

The unions would be self-supporting, by means of small contributions from the affiliated societies. Money is only wanting for the expenses of an organising secretary. I do not attempt to estimate the cost of this, but with objects so desirable and far-reaching in view, the price cannot be considered excessive, and the British Association would soon be repaid by obtaining prompt and direct communication with all the towns and villages in Great Britain, by greater assistance in its research work and in all other branches which the British Association was established sixty-five years ago to promote.

The Chairman was sure that they all felt much obliged to Mr. Abbott for his paper on this important subject. He invited discussion.

The Rev. E. P. Knubley remarked that he would give briefly the results of the experience of the Yorkshire Naturalists' Union during the twenty years of its existence. It was, he believed, the largest union of scientific societies in England, having thirty-six affiliated associations. There were 500 members and 2,500 associates, making a total of 3,000 workers. He thought they owed much to their geographical position and to the great variety of rocks, scenery, soil, and climate in Yorkshire. As to the organisation of the Union, it was based to a considerable extent on that of the British Association. Their president, a distinguished Yorkshireman, was elected annually. There were general secretaries, an executive of twelve members, and a general committee. Their work came under five sections—those of geology, botany, zoology, conchology, and entomology. In addition, much work was carried on by means of research committees, which were in direct communication with the British Association. Eight such committees were then in existence : a Boulder Committee ; a Sea Coast Erosion Committee ; a Fossil Flora Committee ; a Geological Photographs Committee ; a Marine Biology Committee ; a Micro-zoological and Micro-botanical Committee ; a Wild Birds and Eggs Protection Committee ; and a Mycological Committee. All these Committees reported annually, and their Reports were presented to the British Association. An annual meeting of the Union was held in one of the Yorkshire towns. For excursion purposes Yorkshire was divided into five parts, and a meeting was held in each of them. One meeting every year took place on the sea coast. Great care was taken by the secretaries before each excursion to get all the geological, botanical, and other information obtainable about the place to be visited, and, when there, every endeavour was made to get each member to do some special work. In short, every effort was made to train workers in the various departments of natural science. It has been found necessary to discourage the offering of hospitality, on account of the loss of time involved. He would only add that the success of the Yorkshire Naturalists' Union was largely due to the energy and perseverance of their general secretary, Mr. W. D. Roebuck.

The Chairman asked Mr. Knubley how many of the Yorkshire Scientific Associations which were on the list of the Corresponding Societies of the British Association were also on that of the Yorkshire Union. Mr. Knubley replied that the Leeds Naturalists' Club, Leeds Geological Association, and Malton Naturalists' Society were affiliated to the Union, but not the Yorkshire Geological and Polytechnic Society, nor the Yorkshire Philosophical Society.

Mr. M. H. Mills then gave some account of the organisation of the Federated Institution of Mining Engineers. He said that the rules of the Federation had been carefully considered by the secretaries and councils of the various societies composing it, and it had been found that the best kind of federation was that which touched only the publication of their papers. Each society did its work independently, as before the existence of the Federation, but now they had one publication instead of many. In answer to questions from Sir Douglas Galton, Mr. Mills added that he thought it would be a good thing that societies doing the same kind of work should be federated together ; he also stated that members of the societies composing the Federation paid but one subscription, a portion of it only being given to the Federation for printing the publication.

Mr. Montagu Browne gave some details as to the present constitution of the Leicester Literary and Philosophical Society. With regard to payments for printing, he said that usually each section was self-supporting, but that in the case of papers of exceptional interest and expense, the parent society made a special grant, if necessary.

Mr. C. E. De Rance was glad to learn that the Yorkshire Union had established a Coast Erosion Committee to carry on the work in Yorkshire, which had been done for so many years by a British Association Committee for the country generally. As regards Mr. Abbott's plan, he fully concurred with him as to the need for an organising secretary, without whose aid he felt sure that scarcely any federation would be accomplished.

Mr. W. T. Hindmarsh said that while the Berwickshire Naturalists' Club had a large area for its field of work, extending not only over Berwickshire, but over Northumberland, outside Newcastle there was no large town or University within its boundaries. The district was sparsely populated, and there was no other Naturalists' Club in it with which they could unite.

Mr. J. H. Merivale thought, from some remarks of the last speaker, that he did not quite realise that federation did not imply the slightest loss of independence on the part of any local society joining a union. The great advantage was that the transactions of all the local societies were to be found in one publication. He was certain that if the Natural History Societies throughout the kingdom would unite as the societies composing the Federated Mining Engineers had done, the result would be excellent.

Professor T. Johnson mentioned that in Ireland they had a good example of a Union. It comprised four clubs, one in Dublin, another in Belfast, a third in Cork, and a fourth in Limerick, which combined to form the Irish Field Club Union. A yearly meeting was held in various parts of the country, and they had a publication which was common property—the 'Irish Naturalist.' There was a poll-tax of twopence from each member to defray the expenses of the Union, and there was a committee formed of the president and secretaries of the four societies. They had an arrangement by which a specialist belonging to one club could have his expenses paid if he lectured to another club. They were also forming a directory, so that students coming to Ireland would shortly be able to learn who was working at any given subject and where he might be found. They made a point of sending their specimens to museums. In addition, they had short courses of lectures to arouse the interest of amateurs, with occasional excursions. The Union had been originated by Mr. Praeger, secretary of the Dublin Club.

In answer to a question from the Chairman, Professor Johnson added that the fees received from persons attending the lectures were put into a common fund and used for excursion purposes, the lecturer himself receiving nothing from the course.

Mr. Eli Sowerbutts thought that while in some respects federation must commend itself to all, there were some questions of great delicacy involved in it which made him hesitate to come to any decision at that meeting. He felt sure that a society would not submit to be controlled by another society as regards the publication of its papers. There were also many other matters needing careful discussion before any decision could be safely arrived at.

Much discussion then arose as to the possibility of arranging for a meeting for the further consideration of Mr. Abbott's paper before the second meeting of the Conference. In this the Chairman, Sir Douglas Galton, Professor Johnson, Mr. Abbott, Mr. Watts, Mr. Tate, and others took part. At length the following motion was proposed by Mr. Abbott, seconded by the Rev. E. P. Knubley, and carried unanimously :—

'That Mr. Montagu Browne, Professor Johnson, the Rev. E. P. Knubley, Mr. Hindmarsh, Mr. W. W. Watts, and Mr. Abbott be nominated to form a sub-committee (with power to add to their number) to consider this question, and report to the Conference of Delegates of Corresponding Societies.'

Mr. W. Watts inquired whether anything was being done to preserve the publications of the local societies. The Chairman replied that many pounds had been spent in binding those sent to the British Association Office, and that it was proposed to index them if funds could be obtained for that purpose.

The meeting then terminated.

Meeting of the Sub-committee.

A meeting of the sub-committee was held in the Crown Court on Monday, September 21. The Rev. T. R. R. Stebbing and Mr. O. W. Jeffs were added to the sub-committee.

Report of Sub-committee appointed at Meeting of Delegates of Corresponding Societies, September 17, 1896 (*Chairman*, Rev. T. R. R. Stebbing, *F.R.S.*).

The following resolutions have been unanimously agreed to :—

(1) That Mr. G. Abbott's paper on 'District Unions of Natural History Societies' be distributed by the Committee of the Corresponding Societies amongst *all* the Natural History Societies in the United Kingdom, with the request that their opinion on the feasibility of the plan advocated in the paper be communicated as early as possible to the Corresponding Societies Committee for their report to the next Conference of Delegates.

(2) That the formation of District Unions of Natural History Societies is highly desirable, and would be of general advantage.

(3) That the Committee of the Corresponding Societies be requested to take steps to encourage the formation of District Unions of Natural History Societies.

(4) That it should be distinctly understood that the formation of Unions would not in any way prevent the affiliation of individual Societies of such Unions to the British Association as at present.

Liverpool, Second Conference, September 22, 1896.

The Second Conference was held in the Small Concert Room, St. George's Hall, Dr. Garson in the chair.

The Chairman called upon Mr. Abbott to read the Report of the subcommittee appointed at the last Conference. [Mr. Abbott then read the resolutions given above.]

Mr. De Rance expressed his satisfaction with the outcome of the Subcommittee's deliberation. The more our local societies could combine for purposes of publication the better. He moved that the Report be received.

Mr. Hembry seconded the motion.

After some discussion, in which the Chairman, Mr. Sowerbutts, the Rev. J. O. Bevan, and others took part, the Report was received. Some further discussion took place as to the adoption of the Report, which was moved by Mr. Abbott and seconded by Mr. Hembry. The Report was at length adopted, and a resolution was also passed referring the Report to the Corresponding Societies Committee.

A delegate having inquired when the next Conference would take place, the Chairman replied that it would be next year at Toronto.

The following Paper by Professor Flinders Petrie was then read :—

On a Federal Staff for Local Museums.

The present suggestions only affect a distribution of labour, and will rather economise than require extra expenditure.

In all local museums the main difficulty of the management is that there is neither money nor work enough for a highly trained and competent man. It is in any case impossible to get a universal genius who can deal with every class of object equally well, and hardly any local museum can afford to pay for a first-class curator on any one subject. These difficulties are entirely the result of a want of co-operation.

According to the report of the Committee in 1887, there are fifty-six 1st class, fifty-five 2nd class, sixty-three 3rd class, and thirty 4th class museums in the kingdom. Setting aside the last two classes as mostly too poor to pay except for mere caretaking, there are 111 in the other classes; and deducting a few of the 1st class museums as being fully provided, there are 100 museums, all of which endeavour to keep up to the mark by spending perhaps 30*l.* to 200*l.* a year on a curator.

The practical course would seem to be their union, in providing a federal staff, to circulate for all purposes requiring skilled knowledge; leaving the permanent attention to each place to devolve on a mere caretaker. If half of these 1st and 2nd class museums combined in paying 30*l.* a year each, there would be enough to pay three first-rate men 500*l.* a year apiece, and each museum would have a week of attention in the year from a geologist, and the same from a zoologist and an archæologist.

The duties of such a staff would be to arrange and label the new specimens acquired in the past year, taking sometimes a day, or perhaps a fortnight, at one place; to advise on alterations and improvements; to recommend purchases required to fill up gaps; to note duplicates and promote exchanges between museums; and to deliver a lecture on the principal novelties of their own subject in the past year. Such visitants, if well selected, would probably be welcome guests at the houses of some of those interested in the museum in each place.

The effect at the country museums would be that three times in the year a visitant would arrive for one of the three sections, would work everything up to date, stir the local interests by advice and a lecture, stimulate the caretaker, and arrange routine work that could be carried out before the next year's visit, and yet would not cost more than having down three lecturers for the local institution or society, apart from this work.

To many, perhaps most, museums 30*l.* for skilled work, and 30*l.* or 40*l.* for a caretaker, would be an economy on their present expenditure, while they would get far better attention. Such a system could not be suddenly started; but if there were an official base for it, curators could interchange work according to their specialities, and as each museum post fell vacant it might be placed in commission among the best curators in that district, until by gradual selection the most competent men were attached to forty or fifty museums to be served in rotation. It is not impossible that the highest class of the local museums might be glad to subscribe, so as to get special attention on subjects outside of the studies of their present curators.

The Chairman was sure that the meeting felt much obliged to Professor Petrie for this very suggestive paper. He hoped that gentlemen wishing to discuss it would be as brief as possible in their comments, as they had much business before them.

Mr. W. E. Hoyle said that he had no legal *locus standi* there, but had come on the suggestion of the Assistant General Secretary, who had sent him a copy of Professor Petrie's paper, and asked him to take part in the discussion. He hoped no action would be taken in this matter in such a way as to prevent co-operation with the Museums Association. Professor Petrie's scheme seemed to him a most simple and practical one, and he thought it would be a good thing for those specially interested in it to confer with the officials of the Museums Association with regard to it. The chief difficulty which he foresaw in carrying it out was the almost incredible inertia of museum committees. The Museums Association met once a year, and everyone who had attended its meetings had admitted their value in enabling curators to exchange ideas upon all museum questions. It had been in existence about six years, but hitherto very few societies had cared to go to the expense of sending their curators to its meetings. In the museum over which he had the honour to preside there were four assistant curators who were doing good work. It was probably not in Professor Petrie's mind when he drew up his scheme for a Federal staff. Yet he was quite prepared to urge upon his Committee the adoption of Professor Petrie's plan.

Mr. M. H. Mills could testify to the thoroughness with which museum questions were discussed at meetings of the Museums Association. If his proposition were in order, he would move that this question be referred to the Museums Association.

The Chairman thought Mr. Mills' proposition inadmissible.

Mr. G. Abbott cordially supported Professor Petrie's suggestions, and thought that an increase in the number of Unions of Naturalists' Societies would greatly tend towards their general adoption.

Mr. N. M. Richardson did not think there could be any doubt as to the advantages of Professor Petrie's scheme, though he was afraid that the Committee of the Dorset County Museum were hardly in a position to incur the expense.

Professor Johnson thought it would be a good thing if the Museums Association could become a Corresponding Society of the British Association, so that one or more of its chief officials might be present at discussions of this kind. He had listened with considerable interest to Professor Petrie's paper, but he would protest strongly against the suggestion that the curators of our local museums should be converted into mere caretakers, as he thought the tendency should be in the opposite direction. It would be well to urge our local societies to employ as their curator a specialist of some kind, and to give him a chance of rising above the position he held at first, rather than to make him feel that he would always be a mere caretaker dependent wholly on some one who came down occasionally from some centre of enlightenment. He knew an admirable curator in the north of Ireland, seventy years of age, and a specialist in three or four branches, who was then living on a salary of 70*l.* per annum, and had to dust the tables, open the door, and act in general as a mere caretaker. This was a disgrace to the great town in which the museum was situated. Local museums should have a grant of 50*l*. to 100*l*., or even 150*l*. for the payment of specialists.

Professor J. W. Carr was inclined to regret that Professor Petrie's paper had not been read before the Museums Association. Mr. Hoyle (who, like the speaker, was a member of the Council of the Museums Association) had not mentioned that some years ago a sub-committee was appointed by that Association to report upon a suggestion much resembling that of Professor Petrie. No definite result had, however, been arrived at. He thought that if Professor Petrie were now to bring this paper before the notice of the Museums Association the weight of his authority might produce more important effects. He regretted the absence of delegates from the Museums Association to discuss this question.

The Chairman remarked that any society might apply to be placed on the list of Corresponding Societies. He hoped the delegates would give a full account of this discussion to the societies they represented. He called upon Professor Petrie to reply.

Professor Petrie said that this was to a great extent a money question. He did not think that his suggestions necessarily involved additional expense. He thought it would be better that the money should be divided between the mere caretaker and the specialists, rather than that an attempt should be made to combine them by employing one man who could not posslbly be a specialist on all points. Indeed, those curators who were more than mere caretakers would by his plan receive a larger amount of money than before by rendering their services in a number of places, instead of being confined to one. It would be better to have a dozen men of science and fifty caretakers than sixty curators, all receiving a very inadequate salary.

A vote of thanks to Professor Petrie for his paper having been passed, the Chairman invited remarks from any representatives of the various sections of the British Association who wished for the co-operation of the Corresponding Societies in any work.

SECTION C.

Mr. W. W. Watts said that, though the labours of some of the Committees nominated by Section C had come to an end, the Geological Photographs Committee was still in existence. Though much assistance had been received from Leicestershire and some other places, a very large area was still unphotographed. The eastern counties had sent very few photographs. The Erratic Blocks Committee still existed, and their work was being largely done by the committees of local societies. Some societies in Yorkshire were doing most admirable work. Those were the two chief committees of Section C which needed the co-operation of the local societies.

Mr. C. E. De Rance made some remarks on the labours of the Underground Waters Committee of the British Association. Though the Committee had ceased to exist, he hoped the delegates of the Corresponding Societies assembled there would urge on their members to record carefully in their districts everything bearing on that matter, not only as regards the geological nature of the strata, but also as to the temperature of water obtained from considerable depths. As to the Erratic

Blocks Committee, he wished to point out how much work had been done in that department by members of the Glacialists' Association.

Section H.

Mr. Sidney Hartland wished to ask for the co-operation of the local societies in the work of the Ethnographical Survey Committee. Considerable progress had been made in the work of the Committee since he had asked their aid at Ipswich last year. Many measurements of the natives of Galloway had been taken by Dr. Macgregor. During the present century the movements of our population had been immensely greater than in previous centuries. Still there were places where there had been little change in that respect. As it was the object of the Committee to acquire a knowledge of the distinguishing characteristics of the various races of British Isles, it was important that the measurements, &c., of individuals in any district should be those of persons whose families had lived there during a considerable period. Dr. Macgregor had accordingly been careful to select persons whose pedigrees could be traced back a century or more. He had also collected much of the folklore of the district. There was no department in which it was more desirable to have speedy information than that of folklore. Much had been done with regard to the dialects of the different counties of England by the publication of the English Dialect Dictionary, but in Scotland and Ireland there was still much work to be done both in dialect and in folklore. Education, facilities for railway travelling, and industrial migrations were rapidly destroying local customs, dialects, and traditions, so that it was more important that speedy information about them should be obtained than that there should be an immediate supply of physical measurements. The historic and prehistoric monuments of a locality should also be noted. Mr. Hartland concluded by remarking that he would be glad to furnish any delegates interested in the subject with copies of the Ethnographical Committee's Schedules, or with any help in his power.

Mr. John Gray, Buchan Field Club, said that in his district they had begun to note the physical characteristics of the inhabitants by placing themselves at the entrance to a field where some sports were being held, and observing the colour of the eyes and hair, the contour of the nose, and other characteristics of people entering the field. They also measured about 200 persons in the grounds, and obtained some very interesting results. In addition they had obtained measurements, &c., of almost all the school children of the district.

The Chairman remarked that Mr. Gray's Society was obtaining excellent results, and giving an example of the work required. As the information asked for by the Ethnographic Survey Committee was of so many different kinds, it appeared to him that the formation of sub-committees by the local societies would greatly expedite the work. One sub-committee might confine itself to physical measurements, another to dialect and folklore, a third to ancient monuments, and so on. Then photographers were needed for illustrations of people and monuments. And persons with a turn for history might consider the historical evidence of continuity of race. Investigations of this kind would at once enrich the Transactions of a local society, and help the work of the British Association.

The meeting then adjourned.

The Corresponding Societies of the British Association for 1896–97.

[An asterisk (*) indicates that the Society was not represented at the Conference of Delegates at Liverpool.]

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
*Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C.	Rev. W. W. Martin, Royal Literary and Scientific Institution, Bath	100	5s.	10s.	Proceedings, annually.
Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, B.A.	267	None	1l. 1s.	Report and Proceedings, annually.
*Belfast Naturalists' Field Club, 1863	Belfast Nat. F. C.	Museum, College Square. F. J. Bigger, M.R.I.A.	500	5s.	5s.	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Berwicksh. Nat. Club	Dr. J. Hardy, Oldcambus, Cockburnspath, N.B.	400	10s. 6d.	7s. 6d.	History of the Berwickshire Naturalists' Club, annually
Birmingham Natural History and Philosophical Society, 1858	Birm. N. H. Phil. Soc.	Mason College, Birmingham. W. P. Marshall and W. Boulton	273	None	1l. 1s.	Journal, bi-monthly; Proceedings, annually.
Bristol Naturalists' Society, 1862	Bristol Nat. Soc.	C. K. Rudge, Literary and Philosophic Club, 20 Berkeley Square, Bristol.	156	5s.	10s.	Proceedings, annually.
Buchan Field Club, 1887	Buchan F. C.	J. F. Tocher, 5 Chapel Street, Peterhead	147	5s.	5s.	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc.	Thomas Gibbs, 30 High Street, Burton-on-Trent	200	None	5s.	Annual Report. Transactions occasionally.
Caradoc and Severn Valley Field Club, 1893	Car. & Sev. Vall. F. C.	H. E. Forrest, 37 Castle Street, Shrewsbury.	180	5s.	5s.	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	Cardiff Nat. Soc.	Walter Cook, 98 St. Mary Street, Cardiff	450	None	10s. 6d.	Transactions, half-yearly.
Chester Society of Natural Science and Literature, 1871	Chester Soc. Nat. Sci.	Grosvenor Museum, Chester. G. R. Griffith and G. P. Miln	600	None	5s.	Annual Report. Proceedings, occasionally.
Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	Stephenson Memorial Hall. W. F. Howard, 15 Cavendish Street, Chesterfield	360	1l. 1s. None	Members 31s. 6d.; Associates and Students 20s.	Transactions of Federated Institution of Mining Engineers, about every two months.
*Cornwall, Mining Association and Institute of, 1859	Cornw. Min. Assoc. Inst.	William Thomas, C.E., F.G.S., Penelvan, Camborne	275	10s. 6d.	Minimum, 10s. 6d.	Transactions, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc.	G. B. Millett, Penzance	90 Membs. 13 Associates	None	1l. 1s.	Report and Transactions, annually.
*Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C.	Public Hall, Croydon. R. F. Grundy	226	None	10s.	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C.	N. M. Richardson, Montevideo, Chickerel, Weymouth	340	None	10s.	Proceedings, annually.
Dublin Naturalists' Field Club, 1885	Dublin N. F. C.	R. Lloyd Praeger, National Library of Ireland, Dublin	210	5s.	5s.	'Irish Naturalist,' monthly; Report, annually.
*Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	Dr. E. J. Chinnock, Grey Friars', Dumfries	210	2s. 6d.	5s.	Transactions and Journal of Proceedings, annually.
East Kent Natural History Society, 1857	E. Kent N. H. Soc.	19 Watling Street, Canterbury. Stephen Horsley	89	None	10s. 6d.	'South Eastern Naturalist,' occasionally.
East of Scotland Union of Natural-[illegible]	E. Scot. Union	William D. Sang, 28 Whyte's Causeway, Kirkcaldy, N.B.	10 Societies, 900 Membs.	None	Assessment of 4d. per member	Proceedings, occasionally.

Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	J. Barclay Murdoch, Capelrig, Mearns, Glasgow	250	None	10*s.*	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	S. M. Wellwood, 207 Bath Street, Glasgow	238 Memb. 25 Assoc.	7*s.* 6*d.* None	Members 7*s.* 6*d.* Associates 2*s.* 6*d.*	Proceedings and Transactions, annually.
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc.	John Mayer, 207 Bath Street, Glasgow	640	1*l.* 1*s.*	1*l.* 1*s.*	Proceedings, annually; occasional papers.
Hampshire Field Club, 1885	Hants F. C.	Hartley Institution, Southampton. W. Dale, F.G.S.	250	None	7*s.* 6*d.*	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	Herts N. H. Soc.	John Hopkinson, F.L.S., The Grange, St. Albans	250	10*s.*	10*s.*	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C.	A. J. Crosfield, Carr End, Reigate	89	10*s.*	10*s.*	Proceedings, every two or three years.
*Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc.	F. A. Black, 16 Union Street, Inverness	164	None	5*s.* and 2*s.*	Transactions, occasionally.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland	W. Lawson, 35 Molesworth Street, Dublin	100	None	1*l.*	Journal, annually.
Leeds Geological Association, 1874	Leeds Geol. Assoc.	Dr. D. Forsyth, Higher Grade School, Leeds	75	None	5*s.*	Transactions, annually.
Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. C. Sci. Assoc.	H. B. Wilson, Westfield, Armley, Leeds	203	None	6*s.*	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	J. M. Gimson, 100 New Walk, Leicester	327 Membs. & Associates	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Transactions, quarterly.
*Liverpool Engineering Society, 1875	Liv'pool E. Soc.	R. C. F. Annett, Royal Institution, Liverpool	322	None	Resident 1*l.* 1*s.* Non-Res. and Students 10*s.* 6*d.*	Transactions, annually.
Liverpool Geographical Society, 1891	Liv'pool. Geog. Soc.	Capt. E. C. Dubois Phillips, R.N., 14 Hargreave's Buildings, Chapel Street, Liverpool	500	None	1*l.* 1*s.*	Report, annually; Papers, occasionally.
Liverpool Geological Society, 1858	Liv'pool Geol. Soc.	Royal Institution. H. C. Beasley	50	None	21*s.* and 10*s.* 6*d.*	Proceedings, annually.
*Liverpool, Literary and Philosophical Society of, 1812	Liv'pool Lit. Phil. Soc.	Royal Institution. J. M. McMaster	272 Membs. 11 Assoc.	None	1*l.* 1*s.*; Ladies 10*s.* 6*d.*	Proceedings, annually.
Malton Field Naturalists' and Scientific Society, 1879	Malton F. N. Sci. Soc.	Museum, Yorkersgate, Malton, Yorkshire. Rev. S. Jenkinson	100	None	5*s.* and 2*s.* 6*d.*	Science Notes, monthly.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	P. M. C. Kermode, Hillside, Ramsey, Isle of Man	133	2*s.* 6*d.*	Gentlemen 6*s.*; Ladies 3*s.*	Yn Lioar Manninagh, quarterly
Manchester Geographical Society, 1884	Manch. Geog. Soc.	Eli Sowerbutts, F.R.G.S., 16 St. Mary's Parsonage, Manchester	800	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Journal, quarterly; 'Geography,' monthly.
Manchester Geological Society, 1838	Manch. Geol. Soc.	5 John Dalton Street, Manchester. James Tonge and Joseph Crankshaw	230	None	1*l.*	Transactions, eight or nine parts per annum.
Manchester Microscopical Society, 1880	Manch. Mic. Soc.	E. C. Stump, 16 Herbert Street, Moss Side, Manchester	214	5*s.*	6*s.*	Transactions and Report annually.
*Manchester Statistical Society, 1833	Manch. Stat. Soc.	63 Brown Street, Manchester. F. E. M. Beardsall and T. Gregory	227	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	339	1*s.* 6*d.*	3*s.* and 5*s.*	Report, annually.
*Midland Institute of Mining, Civil, and Mechanical Engineers, 1869	Midland Inst. Eng.	T. W. H. Mitchell, Regent Street, Barnsley	252	None	1*l.* 10*s.*	Transactions of Federated Institution of Mining Engineers, about every two months.
Norfolk and Norwich Naturalists' Society, 1869	Norf. Norw. Nat. Soc.	W. A. Nicholson, 3 Oxford Street, Norwich	264	None	5*s.*	Transactions, annually.

CORRESPONDING 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
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,100	None	21*s.* and 42*s.*	Transactions of Federated Institution of Mining Engineers, 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.	424	5*s.*	5*s.*	Report and Transactions, annually.
*Northamptonshire Natural History Society and Field Club, 1876	N'ton. N. H. Soc.	H. N. Dixon, M.A., East Park Parade, Northampton	150	None	10*s.*	Journal, quarterly.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	Henry Wilkins, 352 Alfreton Road, Nottingham	173	2*s.* 6*d.*	5*s.*	Transactions and Report, annually.
*Paisley Philosophical Institution, 1808	Paisley Phil. Inst.	J. Gardner, 3 County Place, Paisley	350	5*s.*	7*s.* 6*d.*	Report, annually; Meteorological Observations, occasionally.
*Penzance Natural History and Antiquarian Society, 1839	Penz. N. H. A. Soc.	Museum, Public Buildings, Penzance. Dr. H. Montgomerie	80	None	10*s.* 6*d.*	Report, annually.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci.	Tay Street, Perth. S. T. Ellison	320	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, B.Sc., 105 Freehold Street, Rochdale	243	None	6*s.*	Transactions, biennially.
*Rochester Naturalists' Club, 1878	Rochester N. C.	John Hepworth, Linden House, Rochester	140	None	5*s.*	'Rochester Naturalist,' quarterly.
Scotland, Mining Institute of	Mining Inst. Scot.	James Barrowman, Stanacre, Hamilton, N.B.	490	None	31*s.* 6*d.* and 21*s.*	Transactions of Federated Institution of Mining Engineers, about every two months.
Somersetshire Archæological and Natural History Society, 1848	Som'setsh. A. N. H. Soc.	The Castle, Taunton. F. T. Elworthy	557	10*s.* 6*d.*	10*s.* 6*d.*	Proceedings, annually.
*South African Philosophical Society, 1877	S. African Phil. Soc.	L. Péringuey, South African Museum, Cape Town	88	None	2*l.*	Transactions, annually.
*South Staffordshire and East Worcestershire Institute of Mining Engineers, 1867	S. Staff. Inst. Eng.	Alexander Smith, 3 Newhall Street, Birmingham	145	1*l.* 1*s.*	31*s.* 6*d.*	Transactions of Federated Institution of Mining Engineers, about every two months.
Tyneside Geographical Society, 1887	Tyneside Geog. Soc.	Geographical Institute, Barras Bridge, Newcastle-on-Tyne. G. E. T. Smithson	1,054	None	10*s.* and 5*s.*	Journal, half-yearly.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C.	Museum, Warwick. W. G. Fretton, F.S.A., and S. S. Stanlay	88	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	215	10*s.*	10*s.*	Transactions, biennially.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	Rev. Wm. Lower Carter, F.G.S., Hopton, Mirfield	156	None	13*s.*	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union	W. Denison Roebuck, F.L.S., Sunny Bank, Leeds	449 and 2,567 Associates.	None	Members 10*s.* 6*d.*; Associates 1*d.*	Transactions, annually; 'The Naturalist,' monthly.
*Yorkshire Philosophical Society	Yorks. Phil. Soc.	Museum, York. T. S. Noble, F.G.S.	400	None	2*l.*	Report, annually.

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, 1896.

*** 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	Published
Andson, Rev. W.	Meteorology of Dumfries, 1894	Dum. Gal. N. H. A. Soc.	*Trans.*	11	84–89	1896
Ashworth, J. R.	The Rainfall in Rochdale and the Neighbourhood	Rochdale Lit. Sci. Soc.	,,	IV.	55–60	1895
Bayard, F. C.	Report of the Meteorological Sub-Committee for 1894	Croydon M. N. H. C.	,,	1894–95	164–172	,,
Bird, Charles	Rochester Rainfall, No. II.	Rochester N. C.	*Roch. Naturalist*	II.	357–361	1896
Boys, Rev. H. A.	The Drought of 1895	N'ton. N. H. Soc.	*Journal*	VIII.	219, 220	1895
Boys, Rev. H. A., & C. A. Markham	Meteorological Observations	,, ,,	,,	,,	173–177 221–227 246–253 274–280	1896
Brown, John	Electrolytic Crystallisation of Metals	Belfast N. H. Phil. Soc.	*Report & Proc.*	1894–95	28–33	1895
Clark, J. E.	The Nine Weeks' Frost, 1894–95	Yorks. Phil. Soc.	*Report*	,,	30–35	1896
Club, The	The Meteorology of the District	Car. and Sev. Vall. F. C.	*Rec. of Bare Facts*	No. 5	23–28	,,
Collingwood, F. J. W.	Rainfall at Glanton Pyke, Northumberland, in 1894	Berwicksh. Nat. Club	*History*	XV.	197	,,
Craw, H. Hewat	Note of Rainfall and Temperature at West Foulden during 1894	,, ,,	,,	,,	195	,,
,, ,,	Note of Rainfall and Temperature at Rawburn during 1894	,, ,,	,,	,,	,,	,,
Cresswell, A.	Records of Meteorological Observations taken at the Observatory of the Birmingham and Midland Institute	Birm. N. H. Phil. Soc.	*Proc.*	XI.	201–240	1895
Crossman, Sir W.	Meteorological Observations at Cheswick, 1894	Berwicksh. Nat. Club	*History*	XV.	196	1896
Eaton, H. S.	Dorset Annual Rainfall, 1848–92	Dorset N. H. A. F. C.	*Proc.*	XVI.	17–43	1895
,, ,,	Report on Returns of Rainfall in 1894	,, ,,	,,	,,	195–208	,,
Elwen, T. L.	The Resistance of Air Currents in Mines	N. Eng. Inst.	*Trans. Fed. Inst.*	X.	62–66	,,

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
Ellacombe, Rev. Canon	The Great Frost of 1895	Bath N. H. A. F. C.	*Proc.*	VIII.	222–232	1896
Evans, F. G.	The Meteorology and Kindred Phenomena of 1894	Cardiff Nat. Soc.	*Trans.*	XXVII.	13–41	1895
Gill, Dr. David	Presidential Address	S. African Phil. Soc.	”	VIII.	xlix–lx	1896
Gray, P. L.	A Platinum Strip Radiator	Birm. N. H. Phil. Soc.	*Proc.*	XI.	73–76	1895
” ”	Some Methods of Measuring the Temperature of the Sun	” ”	”	”	103–115	”
Hopkinson, John	The Relative Advantages of Hard and Soft Water, with Special Reference to the Supply of Watford	Herts N. H. Soc.	*Trans.*	VIII.	101–115	”
” ”	Climatological Observations taken in Hertfordshire in the year 1894	” ”	”	”	125–128	”
” ”	Report on the Rainfall in Hertfordshire in the year 1894	” ”	”	”	131–140	”
” ”	The Floods of November 1894, in Hertfordshire	” ”	”	”	141–146	”
” ”	Meteorological Observations taken at The Grange, St. Albans, during the year 1894	” ”	”	”	161–168	”
” ”	The Gale of March 24, 1895, in Hertfordshire	” ”	”	”	199–202	1896
” ”	Supplementary Note on Rainfall and Temperature at Hitchin	” ”	”	”	204	”
Kelly, W. Redfern	The Great Mystery of Stellar and Planetary Evolution	Belfast N. H. Phil. Soc.	*Report & Proc.*	1894–95	68–73	1895
Kelvin, Lord	On the Electrification of Air	Glasgow Phil. Soc.	*Proc.*	XXVI.	233–243	”
Kelvin, Lord, and J. R. E. Murray	On the Temperature Variation of the Thermal Conductivity of Rocks	” ”	”	”	227–232	”
King, Dr. A.	On the Advantage of a Supply of Soft Water for the Town of Watford	Herts N. H. Soc.	*Trans.*	VIII.	116–124	”
Lodge, Prof. O. J.	Modern Views of Light	Liv'pool Lit. Phil. Soc.	*Proc.*	L.	85	1896
Lucas, William	Temperature and Rainfall at Hitchin, 1840–94	Herts N. H. Soc.	*Trans.*	VIII.	203	”
Moore, H. C.	The Tidal Wave in the Wye and Severn	Manch. Geog. Soc.	*Journal*	X.	227–241	1895
Paul, Rev. Dr. D.	On the Injuries done to Gardens by Frost, May 1894	Berwicksh. Nat. Club	*History*	XV.	41, 42	1896
Plowright, Dr. C. B.	Solar Halo, May 25, 1894	Norf. Norw. Nat. Soc.	*Trans.*	VI.	113	1895
Poynting, Prof. J. H.	On the New Radiation	Birm. N. H. Phil. Soc.	*Journal*	II.	13–14	1896

,, ,,	Notes on the Great Frost of 1894–95	,, ,,	,,	,,	95–99	,,
,, ,,	Notes on the Great Gale of March 24, 1895	,, ,,	,,	,,	99–101	,,
Ravenstein, E. G.	Meteorological Observations in British East Africa for 1893	Manch. Geog. Soc.	*Journal*	X.	317–320	,,
Rigden, Brian	Meteorological Observations in Canterbury, 1894	E. Kent N. H. Soc.	*S.E. Naturalist*	V.	165	1896
Roberts, A. W.	Variation of L. 6,187 (*R. Aræ*)	S. African Phil. Soc.	*Trans.*	VIII.	79–83	,,
,, ,,	Central Path of Solar Eclipses visible in South Africa as Total or Annual Eclipses during the Twentieth Century	,, ,,	,,	,,	93–109	,,
Rücker, Prof. A. W.	The Magnetic Survey of Great Britain	Fed. Inst. Min. Eng.	*Trans.*	IX.	417–420	1895
Ryves, Rev. G. T.	Sectional Report—Meteorology	N. Staff. N. F. C. A. Soc.	*Report & Trans.*	XXIX.	139–144	,,
Slater, M. B.	Notes on the Weather of 1895	Malton F. N. Sci. Soc.	*Science Notes*	2	69–71	1896
Smithson, T. S.	The Recent Cold Weather at Facit during the Winter of 1894–5	Rochdale Lit. Sci. Soc.	*Trans.*	IV.	81–85	1895
Steavenson, A. L.	The Mode of Obtaining a True North Line	N. Eng. Inst.	*Trans. Fed. Inst.*	X.	53–57	,,
Strickland, W. W.	Squares and Figures: An Arithmetical Query	Malton F. N. Sci. Soc.	*Science Notes*	2	107	1896
Turner, E. H.	Photo-micrography	Manch. Mic. Soc.	*Trans.*	For 1895	80–122	,,
Tyndall W. H.	Meteorological Notes, Redhill, 1892 and 1893	Holmesdale N. H. Soc.	*Proc.*	1893–95	16–21	,,
,, ,,	Meteorological Table, Redhill, 1894	,, ,,	,,	,,	37	,,

Section B.—Chemistry.

Atkinson, R. W.	Presidential Address	Cardiff Nat. Soc.	*Trans.*	XXVII.	1–12	1895
Charleton, A. G.	The Gold-milling Process at Pestarena, Italy	Fed. Inst. Min. Eng.	,,	IX.	344–352	,,
Clarkson, T.	Sampling	,, ,,	,,	,,	312–314	,,
Clowes, Prof. F.	The Limiting Explosive Mixtures of various Combustible Gases with Air	,, ,,	,,	,,	373–375	,,
,, ,,	The Change of Composition produced in Air by Flames and by Respiration	,, ,,	,,	,,	376–378	,,
Ferguson, Prof. J.	Presidential Address: Recent Contributions to the Literature of Gold-making	Glasgow Phil. Soc.	*Proc.*	XXVI.	1–13	,,
,, ,,	On the First Edition of the Chemical Writings of Democritus and Synesius: Postscript to Part IV.	,, ,,	,,	,,	54–56	,,
Hoskins, A. Percy	On a Sample of Glauconite	Belfast N. F. C.	*Report and Proc.*	IV.	195–202	,,
Jameson, John	The Recovery of By-products in the Manufacture of Hard Coke	N. Eng. Inst.	*Trans. Fed. Inst.*	X.	330–334	,,

Section B.—CHEMISTRY (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Keegan, Dr. P. Q.	Further Notes on the Chemistry of the Rosaceæ	Yorks. Nat. Union	*The Naturalist*	For 1896	91–93	1896
Lewes, Prof. V. B.	Mining Explosives	Fed. Inst. Min. Eng.	*Trans.*	IX.	320–332	1895
Lohmann, B. H.	Shot-firing in Fiery and Dusty Mines	N. Eng. Inst.	*Trans. Fed. Inst.*	X.	351–353	"
McConnell, J.	The MacArthur-Forrest Process	Fed. Inst. Min. Eng.	*Trans.*	IX.	410–416	"
Marloth, Dr. R.	The Origin of the Nitrates in Griqualand West	S. African Phil. Soc.	"	VIII.	113–118	1896
Martin, Robert	The Treatment of Timber for Use in Mines	Mining Inst. Scot.	*Trans. Fed. Inst.*	X.	531–533	"
Mathews, Paul	Presidential Address: Argon, &c.	Rochester N. C.	*Roch. Naturalist*	II.	305–318	1895
Meachem, F. G.	Poisoning of Horses by *Lathyrus sativus*	S. Staff. Inst. Eng.	*Trans. Fed. Inst.*	X.	183–186	"
Murton, C. J., and Saville Shaw	A Deposit found at Delaval Colliery, Benwell, Northumberland	N. Eng. Inst.	" "	"	67–71	"
Pennington, W. H.	On Recent Discoveries in the Manufacture of Artificial Indigo	Rochdale Lit. Sci. Soc.	*Trans.*	IV.	86–89	"
Sexton, Prof. A. H.	Aluminium: Is it to be the Metal of the Future?	Glasgow Phil. Soc.	*Proc.*	XXVI.	88–96	"
Siersch, Alfred	Photography in the Technology of Explosives	Fed. Inst. Min. Eng.	*Trans.*	XI.	2–6	1896
Steel, Thomas	Sugar Manufacture in Australia	Glasgow Phil. Soc.	*Proc.*	XXVI.	206–211	1895
Stokes, A. H.	Photometric Value of, and Notes upon, various Illuminants used in Mines	Chesterf. Mid. Count. Inst.	*Trans. Fed. Inst.*	X.	135–159	"
Winkhaus, Berg-assessor	Experiments with Explosives	N. Eng. Inst.	" "	IX.	250–274	"
" "	Safety-explosives	" "	" "	X.	337–350	"
" "	The Blasting Efficiency of Explosives	Fed. Inst. Min. Eng.	*Trans.*	"	264–271	"

Section C.—GEOLOGY.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Andrews, Miss M. K.	Notes on Moel Tryfaen	Belfast N. F. C.	*Report and Proc.*	IV.	205–210	1895
Andrews, Wm.	New Water Supply at Kenilworth	Warw. N. A. F. C.	*Proc.*	40	54	"
Barke, F.	Sectional Report—Geology	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXIX.	100–104	"
Bell, Dugald	On the Orientation of Boulders	Edinb. Geol. Soc.	*Trans.*	VII.	108–110	"
" "	On the Origin of certain Granite Boulders in the Clyde Valley	Glasgow Geol. Soc.	"	X.	16–22	"

" "	On the alleged Proofs of Submergence in Scotland during the Glacial Epoch: II. Clava and other Northern Localities	" "	"	"	105–120	"
Bennie, James	On the Occurrence of Peat with Arctic Plants in Boulder Clay at Faskine, near Airdrie, Lanarkshire	" "	"	"	148–152	"
Bolton, Herbert	On the Geology of North-east Lancashire in its relation to the Physical Geography	Manch. Geol. Soc.	"	XXIV.	56–67	"
Brodie, Rev. P. B.	The Reign of Dinosaurs	Warw. N. A. F. C.	*Proc.*	40	20	"
" "	Sections of Upper Keuper, near Rowington and Henley, Warwickshire	" "	"	"	58	"
Brown, Nicol	The Profit and Loss of Gold-mining: Ancient and Modern	Glasgow Phil. Soc.	"	XXVI.	14–35	"
Burton, F. M.	The Story of the Lincoln Gap	Yorks. Nat. Union	*The Naturalist*	For 1895	273–280	"
Cadell, H. M.	Notes on the Section in the new Haymarket Tunnel	Edinb. Geol. Soc.	*Trans.*	VII.	119–120	"
" "	Gold Mining in the Hauraki District, New Zealand	Mining Inst. Scot.	*Trans. Fed. Inst.*	X.	389–416	"
Callaway, Dr. C.	Lecture on the Igneous Rocks of Shropshire	Car. & Sev. Vall. F. C.	*Trans.*	I.	135–137	1896
Cantrill, T. C.	On a new Keuper Outlier near Kidderminster	Birm. N. H. Phil. Soc.	*Journal*	I.	162–166	1895
Coke, G. E.	Boring below the Blackshale Coal-seam at Apperknowle, near Sheffield	Chesterf.Mid.Count.Inst.	*Trans. Fed. Inst.*	X.	483–488	"
Cole, Prof. G. A. J.	Hullite	Belfast N. F. C.	*Report and Proc.*	IV.	221–225	"
Colenutt, G. W.	Plateau and Valley Gravels of the Isle of Wight	Hants F. C.	*Proc.*	III.	143–153	1896
Collins, J. H.	Notes on Cornish Fossils	Cornw. R. Geol. Soc.	*Trans.*	XII.	73–86	"
Currie, Jas., jun.	On an Iona Erratic containing Withamite	Edinburgh Geol. Soc.	"	VII.	115–118	1895
Davies, Rev. J. S.	Dolomites	E. Kent N. H. Soc.	*S.E. Naturalist*	V.	153–158	1896
Davies, T. W., and T. Mellard Reade	Description of the Strata exposed during the Construction of the Seacombe Branch of the Wirral Railway	Liv'pool Geol. Soc.	*Proc.*	VII.	327–348	1895
Dawkins, Prof. W. Boyd	Recent Additions to the Museum of Owens College	Manch. Geol. Soc.	*Trans.*	XXIV.	101–106	1896
De Rance, C. E.	The Depth to Productive Coal Measures between the Warwickshire and Lancashire Coalfields	Fed. Inst. Min. Eng.	"	X.	244–256	1895
" "	Glacial Theories, Past and Present, and the application to Staffordshire	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXIX.	107–128	"
Dickinson, Jos.	On River Valleys	Manch. Geol. Soc.	*Trans.*	XXIV.	137–163	1896
Dickson, E.	Chemistry as an Aid to Geology	Liv'pool Geol. Soc.	*Proc.*	VII.	243–270	1895

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Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Dickson, E.	The Geology of the Country between Preston and Blackburn	Liv'pool Geol. Soc.	*Proc.*	VII.	276–288	1895
" "	Further Notes on the Section at Skillaw Clough, near Parbold	" "	"	"	314–320	"
Dron, Robert W.	The Southern Ayrshire Coalfields	Mining Inst. Scot.	*Trans. Fed. Inst.*	X.	378–388	"
Durham, James	The Post-Glacial Geology of the Dundee District	E. Scot. Union	*Proc.*	1891–95	66–74	"
Fisher, Robert	Notes on Mining in Portugal	Mining Inst. Scot.	*Trans. Fed. Inst.*	X.	121–126	"
Forster-Heddle, Prof. M.	On the Occurrence of Tachylyte at Loch Screden, Mull	Glasgow Geol. Soc.	*Trans.*	X.	80–95	"
Fox, Howard	The Radiolarian Cherts of Cornwall	Cornw. R. Geol. Soc.	"	XII.	39–70	1896
" "	Supplementary Notes on the Cherts and Associated Rocks of Roundhole Point, Cataclews Point, and Dinas Head	" "	"	"	71–72	"
Fox-Strangways, C.	Glacial Phenomena near York	Yorks. Geol. Poly. Soc.	*Proc.*	XIII.	15–20	"
Gardner, J. Starkie	The Bournemouth Leaf-beds	Dorset N. H. A. F. C.	"	XVI.	178–184	1895
Greenly, Edward	Notes on the Sutherland Goldfield	Edinb. Geol. Soc.	*Trans.*	VII.	100–107	"
Halse, Edward	The Quicksilver Mines and Reduction Works at Huitzuco, Guerrers, Mexico	N. Eng. Inst.	*Trans. Fed. Inst.*	X.	72–351	"
Harrison, Rev. S.N.	Geological Report	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	21	"
" "	The Glacial Geology of the Isle of Man (Retiring Address)	" "	" "	"	27–32	"
Harrison, W. J.	A Bibliography of Midland Glaciology	Birm. N. H. Phil. Soc.	*Proc.*	IX.	116–199	"
Hick, Thomas	On some Recent Advances in Palæobotany	Yorks. Geol. Poly. Soc.	"	XIII.	43–57	1896
Hicks, Dr. H.	On the Pre-Cambrian and Cambrian Rocks of South Wales	Cardiff Nat. Soc.	*Trans.*	XXVII.	90–95	1895
Hind, Dr. W.	The Romance of a Flint (Presidential Address)	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXIX.	17–39	"
Hobson, Bernard	Notes on a Specimen of Permian Limestone from Skillaw Clough	Liv'pool Geol. Soc.	*Proc.*	VII.	320–322	"
Holmes, T. V.	The Geology of the Lea Valley	Essex F. C.	*Essex Naturalist*	VIII.	198–201	"
" "	Notes on the Geological Section at Chelmsford, in which Mammoth and other Remains were discovered, November 1891	" "	" "	IX.	10–16	"
" "	Notes on a Map including the greater part of S.E. England, recently issued by the Geological Survey	" "	" "	"	112–115	1896

J. C. Gould	the Railway Station at Harlow	” ”	” ”	”		”
Holmes, T. V., and E. T. Newton	Discovery of Mammalian Remains at Great Yeldham, Essex	” ”	” ”	”	115–118	”
Holroyd, W. F., and J. Barnes	On the Rocks and Fossils of the Yoredale Series of the Marsden and Saddleworth Valleys	Manch. Geol. Soc.	*Trans.*	XXIV.	70–99	”
” ”	On the Stratified Clay of Strathearn, and on the Imatra or 'Fairy Stones' found therein	” ”	”	”	110–112	”
Horne, John	Note on the Occurrence of *Alethopteris lonchitica* in the Carboniferous Beds of Loch Ryan	Edinb. Geol. Soc.	”	VII.	111–112	1895
” ”	Note on a Band of Fossiliferous Ironstone in the Cambrian Rocks of West Ross-shire	” ”	”	”	113–114	”
Howard, F. T.	The Geology of Barry Island	Cardiff. Nat. Soc.	”	XXVII.	42–55	”
Hull, Prof. E.	The Eastern Limits of the Eastern Coalfield	Fed. Inst. Min. Eng.	”	XI.	9–17	1896
Hutton, Alex.	Arbroath: its History, Geology, Botany, and Zoology	E. Scot. Union.	*Proc.*	1891–95	1–7	1895
Jenkinson, Rev. S.	Along the Cliffs from Hayburn Wyke to Robin Hood's Bay	Malton F. N. Sci. Soc.	*Science Notes*	2	37–38	”
Jukes - Browne, A. J.	The Origin of the Valleys in the Chalk Downs of North Dorset	Dorset N. H. A. F. C.	*Proc.*	XVI.	5–13	”
Jukes - Browne, A. J., and Rev. E. A. Woodruffe-Peacock	Coloured Map of the Surface Soils and Natural History Divisions of Lincolnshire	Yorks. Nat. Union	*The Naturalist*	For 1895	288	”
Kendall, J. D.	The Whitehaven Sandstone Series	N. Eng. Inst.	*Trans. Fed. Inst.*	X.	202–224	”
Kinahan, J. H.	On possible Land Connections, in recent Geological Times, between Ireland and Great Britain	Manch. Geol. Soc.	*Trans.*	XXIV.	113–130	1896
La Touche, Rev. J. D.	The Parallel Roads of Glen Roy	Car. & Sev. Vall. F. C.	”	I.	85–89	”
Lamplugh, G. W.	Notes on the White Chalk of Yorkshire. Parts I. and II.	Yorks. Geol. Poly. Soc.	*Proc.*	XIII.	65–87	”
Lapworth, Prof. C.	Discovery of the Lower Cambrian Fauna in the Midlands	Birm. N. H. Phil. Soc.	*Journal*	II.	1–2	”
Local Sub-Committee	Report on Coast Erosion	E. Kent N. H. Soc.	*S.E. Naturalist*	V.	147–148	”
Lomas, Joseph	Notes on some Fossil Plants from Doulton's Delph, St. Helens	Liv'pool Geol. Soc.	*Proc.*	VII.	288–292	1895
” ”	The Geology of the Faröe Islands	” ”	”	,	292–314	”

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Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Lomas, Joseph	A Theory to account for the Hexagonal Form of Basalt Columns and other Structures	Liv'pool Geol. Soc.	*Proc.*	VII.	323–325	1895
McDakin, Capt. J. G.	The Dover Coalfield	E. Kent N. H. Soc.	*S.E. Naturalist*	V.	149–151	1896
McLennan, Jas. S.	A Ramble up the Maich Water	Glasgow Geol. Soc.	*Trans.*	X.	121–128	1895
Maidwell, F. T.	Drift Deposits at Coventry	Warw. N. A. F. C.	*Proc.*	40	47	"
Mansel - Pleydell, J. C.	Plateau and Valley Gravels, Sarsen Stones at Little Bredy and elsewhere in the County	Dorset N. H. A. F. C.	"	XVI.	75–80	"
Mason, F. H.	Gold-mining in Nova Scotia	Fed. Inst. Min. Eng.	*Trans.*	X.	281–287	"
Merritt, W. H.	Economic Minerals of the Province of Ontario, Canada	" "	"	"	288–316	"
Monckton, H. W.	On the Geological Nature of the Land that has fallen out of Cultivation in Essex	Essex F. C.	*Essex Naturalist*	IX.	70–71	1896
Neilson, James	On the Calderwood Limestone and Cement-stone, with their associated Shales	Glasgow Geol. Soc.	*Trans.*	X.	61–79	1895
Newton, E. T.	Notes on the Remains of Pleistocene Mammals found in the neighbourhood of Chelmsford	Essex F. C.	*Essex Naturalist*	IX.	16–19	"
Oates, Robert	The Copper and Tin Deposits of Chotà-Nagpore, Bengal, India	Fed. Inst. Min. Eng.	*Trans.*	IX.	427–451	"
Oldfield, G.	Record of Borings	Malton F. N. Sci. Soc.	*Science Notes*	2	50,64,72	'95,96
Paul, J. D.	Cutting at the Swithland Reservoir	Leicester Lit. Phil. Soc.	*Trans.*	IV.	10–13	1895
Platt, S. Sydney	Large Fossil Trees found at Sparth Bottoms, Rochdale	Rochdale Lit. Sci. Soc.	"	"	90–92	"
Polwhele, T. R.	Anniversary Address: The Relation of other Sciences to Geology	Cornw. R. Geol. Soc.	"	XII.	9–17	1896
Reade, T. Mellard	The Moraine of Llyn Cwm Llwch on the Beacons of Brecon	Liv'pool Geol. Soc.	*Proc.*	VII.	270–276	1895
" "	Note of Further Glacial Striæ at the Quarry, Little Crosby	" "	"	"	326	"
Reid, Clement	On Charred Pine-wood from Dorset Peat Mosses	Dorset N. H. A. F. C.	"	XVI.	14–16	"
Reid, James	On the Landslip at Sandgate	E. Kent N. H. Soc.	*S.E. Naturalist*	V.	158–163	1896
" "	The Vegetable Origin of *Parka decipiens*	Perths. Soc. N. Sci.	*Trans. and Proc.*	II.	123–127	1895
Renwick, John	Notes on an Excursion to Glen Fruin, with a Description of the Moraine on its South Side	Glasgow Geol. Soc.	*Trans.*	X.	96–104	"
Richardson, Ralph	Old Edinburgh Geologists	Edinb. Geol. Soc.	"	VII.	81–99	"

,, ,,	... Berwickshire and East Lothian Coast, June 27, 1894					
Sawyer, A. R.	Remarks on the Banket Formation at Johannesburg, Transvaal	Fed. Inst. Min. Eng.	*Trans.*	IX.	360–369	1895
Seeley, Prof. H. G.	On a Pyritious Concretion from the Lias of Whitby	Yorks. Phil. Soc.	*Report*	For 1895	20–29	1896
Shaw, F. G.	The Goldfields of Matabeleland	Fed. Inst. Min. Eng.	*Trans.*	XI.	29–37	,,
Sheppard, Thos.	On another Section in the so-called Interglacial Gravels of Holderness	Yorks. Geol. Poly. Soc.	*Proc.*	XIII.	1–14	,,
Smallman, R.	The Geology of Warwickshire	Chesterf. Mid. Count. Inst,	*Trans. Fed. Inst.*	X.	160–161	1895
Smith, John	From the Doon to the Giryan Water, along the Carrick Shore	Glasgow Geol. Soc.	*Trans.*	X.	1–12	,,
,, ,,	On a Section of Carboniferous Strata near Giffen Station, Ayrshire	,, ,,	,,	,,	25–28	,,
,, ,,	The Geological Position of the Irvine Whale Bed	,, ,,	,,	,,	29–50	,,
,, ,,	On an alleged Bed of Shells at High Melmont, near Galston, between 400 and 500 feet above sea-level	,, ,,	,,	,,	58–60	,,
,, ,,	On a Bed of Fossil Plants, and one of Limestone with Magnesia, in the Calciferous Sandstone Series at Meikle Busbie, near Ardrossan	,, ,,	,,	,,	129–132	,,
,, ,,	On a Bed of Ironstone occurring in Trap Tuff, in the Parishes of Stevenston, Dalry, and Kilwinning	,, ,,	,,	,,	133–136	,,
,, ,,	On a Mineral in a Fumerole, at Auchenharvie Castle	,, ,,	,,	,,	137–138	,,
Sollas, Prof. W. J., & R. Ll. Praeger	Notes on Glacial Deposits in Ireland: II. Kill o' the Grange	Dublin N. F. C.	*Irish Naturalist*	IV.	321–329	,,
Stainier, Dr. X.	On the Pebbles found in the Belgian Coal Seams	Manch. Geol. Soc.	*Trans.*	XXIV.	163–184	1896
Steel, Thomas	On Australian Coals	Glasgow Geol. Soc.	,,	X.	51–57	1895
Stephens, F. J.	Some Geological Notes (on Radiolarian Chert Graptolites) for 1895	Cornw. R. Geol. Soc.	,,	XII.	87–88	1896
Stirrup, Mark	On the Work of Subterranean Waters: Recent Explorations of Swallow-holes, Caverns, and Watercourses of the Limestone Districts of France	Manch. Geol. Soc.	,,	XXIV.	53	1895
Sutcliffe, R.	Notes on the Leinster Coalfield	,, ,,	,,	XXIII.	238–251	,,

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Sykes, E. R.	List of a small Collection of Mollusca from a Raised Beach on Portland	Dorset N. H. A. F. C.	*Proc.*	XVI.	171–174	1895
Tate, Thomas	The Malham Dry River Bed	Yorks. Geol. Poly. Soc.	"	XIII.	58–63	1896
" "	The Yorkshire Boulder Committee and its Ninth Year's Work	Yorks. Nat. Union	*The Naturalist*	For 1895	339–345	1895
Thompson, Beeby	Geological Notes	N'ton. N. H. Soc.	*Journal*	VIII.	{ 139–144 214–218 }	"
Thompson, Miss S. M.	A Bit of Foreshore	Belfast N. F. C.	*Report & Proc.*	IV.	210–214	"
" "	The Galway Conference, 1895: Geology	Dublin N. F. C.	*Irish Naturalist*	"	235–237	"
Todd, John	On the Borings for Coal, and the Experimental Salt Works in the North of the Isle of Man	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	65–72	"
Ward, John	Summary of Literature relating to the Geology, Mineralogy, and Palæontology of North Staffordshire	N. Staff. N. F. C. A. Soc.	*Report & Trans.*	XXIX.	105–106	"
" "	On the Occurrence of Marine Fossils in the Coal Measures of North Staffordshire	" "	" "	"	129–138	"
Watts, W. W.	The Geology of the Shropshire Rocks (Microscopic Structure of the Rocks)	Car. & Sev. Vall. F. C.	*Rec. of Bare Facts*	No. 5	16–19	1896
Webb, W. M.	Notes on the Shells from the Brick-earth at Chelmsford	Essex F. C.	*Essex Naturalist*	IX.	19–20	1895
Werveke, Dr. L. van	The Occurrence, Mode of Working, and Origin of Petroleum in Lower Alsace	Fed. Inst. Min. Eng.	*Trans.*	"	390–401	"
Whitaker, W.	Some Surrey Wells	Croydon M. N. H. C.	"	1894–95	132–150	"
Winstanley, R.	Presidential Address: A Few Thoughts on Geology	Manch. Geol. Soc.	"	XXIV.	38–52	"
Woodward, A. S.	Presidential Address	Malton F. N. Sci. Soc.	*Science Notes*	2	54–56	"
" "	Notes on the Collection of Fossil Fishes from the Upper Lias of Ilminster in the Bath Museum	Bath N. H. A. F. C.	*Proc.*	VIII.	233–242	1896
" "	On the Fossil Fishes of the Upper Lias of Whitby. Part I.	Yorks. Geol. Poly. Soc.	*Proc.*	XIII.	25–42	"
Wright, Joseph	The Occurrence of Boulder Clay on Divis	Belfast N. F. C.	*Report & Proc.*	IV.	215	1895
Young, Dr. John	On the Occurrence of Pyroxene or Augite, in Large Crystals, in Two Localities in Western Scotland	Glasgow Geol. Soc.	*Trans.*	X.	13–15	"

,, ,,	On the Protoconch of *Orthoceras*, and on the Evidence of its Remains in certain Scottish Carboniferous Species, with illustrative Specimens	,, ,,	,,	,,	[illegible]	,,
,, ,,	Notes on the Occurrence of Ctenostomatous Polyzoa in the Carboniferous Limestone of Western Scotland	,, ,,	,,	,,	142–147	,,

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Adams, Lionel E.	The Mollusca of Northamptonshire	N'ton. N. H. Soc.	*Journal*	VIII.	255–267	1896
Angus, W. Craibe	The Little Auk (*Mergulus alle*, L.)	Glasgow N. H. Soc.	,,	IV.	241–243	,,
Ash, Rev. C. D.	Three Weeks in the Isle of Man	Yorks. Nat. Union	*The Naturalist*	For 1896	1–3	,,
,, ,,	The Season of 1895 at Skipwith: Notes on Lepidoptera	,, ,,	,, ,,	,,	85–89	,,
Bennett, Rev. D. D.	Fungi	Car. & Sev. Vall. F. C.	*Trans.*	I.	142	,,
Bird, Rev. M. C. H.	Notes on *Rallus aquaticus*	Norf. Norw. Nat. Soc.	,,	VI.	117–118	1895
Bolton, Herbert	Animal Life of the Lancashire Coal Measures	Manch. Mic. Soc.	,,	For 1895	123–135	1896
Boulenger, G. A.	On an Adder (*Vipera berus*) taken in Epping Forest	Essex F. C.	*Essex Naturalist*	IX.	81	,,
Bridgman, J. B.	*Pezomachus corruptor* bred from *Cionus scrophulariæ*	Norf. Norw. Nat. Soc.	*Trans.*	VI.	114	1895
Bruce, David	Notices of the Fulmar Petrel (*Fulmarus glacialis*, L.)	Berwicksh. Nat. Club	*History*	XV.	191	1896
,, ,,	Great Northern Diver (*Colymbus glacialis*, L.) at Dunbar	,, ,,	,,	,,	192	,,
,, ,,	Notice of the Dotterel (*Eudromius morinellus*, L.) near Dirleton, East Lothian	,, ,,	,,	,,	193	,,
Bruce, W. S.	Animal Life observed during a Voyage to Antarctic Seas	Manch. Geog. Soc.	*Journal*	X.	310–313	1895
Burton, F. M.	Lincolnshire Naturalists' Union at Lincoln	Yorks. Nat. Union	*The Naturalist*	For 1896	94–96	1896
Cambridge, Rev. O. P.	On New and Rare British Spiders	Dorset N. H. A. F. C.	*Proc.*	XVI.	92–128	1895
Campbell, Lieut.-Col.	The Distribution of Birds included in the Avi-Fauna of Perthshire	Perth Soc. N. Sci.	*Trans. and Proc.*	II.	101–119	,,
Campbell, James	A Word about Wasps	Glasgow N. H. Soc.	*Journal*	IV.	265–267	1896
Carpenter, G. H.	The Galway Conference, 1895: Arachnida and Myriopoda	Dublin N. F. C.	*Irish Naturalist*	IV.	254–256	1895

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Carpenter, G. H.	The Galway Conference, 1895: Insecta	Dublin N. F. C.	*Irish Naturalist*	IV.	257, 263	1895
" "	The Mingling of the North and the South	" "	" "	V.	57–68	1896
Cash, William	In Memoriam: Wm. Crawford Williamson, LL.D., F.R.S.	Yorks. Nat. Union	*The Naturalist*	For 1896	25–32	"
Chopin, A.	Notes on a recent Visit to Cumbræ	Manch. Mic. Soc.	*Trans.*	For 1895	56–60	"
Clarke, H. S.	Entomological Report	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	24	1895
Club, The	The Ornithology of the District	Car. & Sev. Vall. F. C.	*Rec. of Bare Facts*	No. 5	20–22	1896
Coates, Henry	Opening Address	Perths. Soc. N. Sci.	*Trans. & Proc.*	II.	xli.-xliv	1895
" "	Annual Address	" "	" "	"	liii.-lxvi	"
Cole, William	The Protection of Wild Birds in Essex	Essex F. C.	*Essex Naturalist*	XXXIX.	42–51	"
Collinge, W. E.	Some Researches upon the Sensory Canal System of Ganoids	Birm. N. H. Phil. Soc.	*Proc.*	IX.	77–83	"
Cordeaux, John	Northern Bullfinch in Yorkshire: An Addition to the British Avi-Fauna	Yorks. Nat. Union	*The Naturalist*	For 1896	4	1896
" "	Bird Notes from the Humber District in the Autumn of 1895	" "	" "	"	5–10	"
Crellin, John C.	Zoological Report	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	22–24	1895
Cruttwell, Rev. C. T.	Some Notes on Collecting Insects in the Rannoch District	Leicester Lit. Phil. Soc.	*Trans.*	IV.	14–21	"
Daltry, Rev. T. W.	Sectional Report—Entomology	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXIX.	91–94	"
Douglas, Dr. C.	Carrion Crow *versus* Rooks	Berwicksh. Nat. Club	*History*	XV.	193	1896
Dowker, George	Notes on the Fresh-water Polyzoa of the District	E. Kent N. H. Soc.	*S.E. Naturalist*	V.	151–152	"
Drane, R.	The Hare in Captivity	Cardiff Nat. Soc.	*Trans.*	XXVII.	101–109	1895
Duthie, Lieut.-Col. W. H. M.	The Home of the Dipper	Perths. Soc. N. Sci.	*Trans. and Proc.*	II.	120–123	"
Elliot, S. D.	On a Double Nest of the Corn Bunting (*Emberiza miliaria*, L.) found at Coltcrooks, near Gordon	Berwicksh. Nat. Club.	*History*	XV.	190	1896
Elliott, J. Steele	The Vertebrate Fauna of Sutton Coldfield Park	Birm. N. H. Phil. Soc.	*Journal*	II.	5–17	"
Evans, William	List of Spiders (*Araneidea*) and Harvestmen (*Phalangidea*) collected around Eyemouth, Berwickshire, in September 1895	Berwicksh. Nat. Club.	*History*	XV.	117–121	"

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Ferguson, John	List of Birds seen on Visit to Dunglass, June 27, 1894, and Notice of *Dendrocopus major* in Duns Castle Woods	" "	"	"	51	"
Forrest, H. E.	Lecture on Corals and Coral Reefs	Car. & Sev. Vall. F. C.	*Trans.*	I.	91–100	"
" "	The Natural History and Development of the Infusoria	" "	"	"	140–142	"
Fox, G. W.	British Birds	" "	"	"	89–91	"
Friend, Rev. Hilderic	Notes on Essex Worms: Description of a Species new to Britain (*Henlea ventriculosa*, D'Udekem), and of a Genus and Species new to Science (*Dichæta curvisetosa*, Friend), both from Essex	Essex F. C.	*Essex Naturalist*	IX.	110–111	"
" "	New and Little-known Oligochaets	Yorks. Nat. Union	*The Naturalist*	For 1896	141–147	"
Gamble, F. W.	Notes on a Zoological Expedition to Valentia Island, Co. Kerry	Manch. Mic. Soc.	*Trans.*	For 1895	60–66	"
Gibbs, A. E.	Notes on Lepidoptera observed in Hertfordshire during the year 1894	Herts N. H. Soc.	"	VIII.	188–192	"
Gilchrist, Dr. J. D. F.	*Lima hians*, Gmel., and its Mode of Life	Glasgow N. H. Soc.	*Journal*	IV.	218–225	"
Gillanders, A. T.	Some Insect Pests	Manch. Mic. Soc.	*Trans.*	For 1895	29–41	"
Glaisyer, Joseph	Entomological Report	Malton F. N. Sci. Soc.	*Science Notes*	2	80	"
" "	Migrant Table	"	"	"	91	"
Grabham, Oxley	Notes on a few of the lesser-known Fish observed in the Scarborough District during the last two years	Yorks. Nat. Union	*The Naturalist*	For 1895	177–179	1895
" "	Rough Notes on Marine Zoology in the Scarborough District during the last two years	"	" "	For 1896	81–84	1896
Green, Rev. W. S.	Sea Fish and Fishing off the West of Ireland	Belfast N. H. Phil. Soc.	*Report and Proc.*	1894-95	25–26	1895
Gurney, J. H.	On the Recent Abundance of the Little Auk (*Mergulus alle*, L.), in Norfolk	Norf. Norw. Nat. Soc.	*Trans.*	VI.	67–70	"
" "	Supposed Occurrence of the Spotted Sandpiper in Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1895	311–312	"
Halbert, J. N.	Insects collected at the Seagull Bog, Tullamore	Dublin N. F. C.	*Irish Naturalist*	IV.	172–174	1895
" "	The Galway Conference, 1895: Hemiptera	" "	" "	"	258	"
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Hardy, Dr. Jas.	*Fulmarus glacialis*	Berwicksh. Nat. Club	*History*	XV.	191	1896
Harries, H. F.	British Birds	Car. & Sev. Vall. F. C.	*Trans.*	I.	82–84, 110–113, 138–140	1896

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Harting, J. E.	Notes on the former Existence of Salmon in the River Lea	Essex F. C.	*Essex Naturalist*	VIII.	186–198	1895
Harvie-Brown, J. A.	The Marsh Tit in Scotland	Perths. Soc. N. Sci.	*Trans. and Proc.*	II.	97–100	"
Hey, Rev. W. C.	Moor Beetles	Yorks. Nat. Union	*The Naturalist*	For 1895	181, 182	"
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Hill, Daniel	Tree-wasp's Nest at Herga, Watford	Herts N. H. Soc.	*Trans.*	VIII.	203	1896
Hotblack, J. T.	Some Questions about Herrings	Norf. Norw. Nat. Soc.	"	VI.	15–22	1895
Hughes, W. R.	The Doctrine of Evolution as originated by Herbert Spencer	Rochester N. C.	*Roch. Naturalist*	II.	362–366	1896
Jameson, H. Lyster, and E. A. Martel	On the Exploration of the Caves of Enniskillen and Mitchelstown	Dublin N. F. C.	*Irish Naturalist*	V.	93–105	"
Jebb, A. G.	Coleoptera of Marlborough District	Marlb. Coll. N. H. Soc.	*Report*	44	55–74	"
Kane, W. F. de V.	The Galway Conference, 1895: Lepidoptera	Dublin N. F. C.	*Irish Naturalist*	IV.	263–264	1895
Kannemeyer, Dr.	Note on Locusts as propagators of Foot and Mouth Disease	S. African Phil. Soc.	*Trans.*	VIII.	84–85	1896
Kaye, W. J.	A Comparison between the Lepidoptera of Japan and Great Britain	Leicester Lit. Phil. Soc.	"	IV.	116–129	"
Kelsall, Rev. J. E.	The Protection of Birds' Eggs	Hants F. C.	*Proc.*	III.	229–232	"
Knight, Rev. G. F. A.	A Day with the Dredge at Machrie Bay, Arran	Glasgow N. H. Soc.	*Journal*	IV.	169–171	"
Lewis, Henry	Notes on Birds observed in Hertfordshire during the year 1894	Herts N. H. Soc.	*Trans.*	VIII.	147–154	1895
Lilford, Lord	Notes on the Ornithology of Northamptonshire and the Neighbourhood	N'ton. N. H. Soc.	*Journal*	VIII.	145–154	"
" "	The Black-throated Diver (*Colymbus arcticus*) in Northamptonshire	" "	"	"	273	1896
Linnell, John	Records of Diptera	Holmesdale N. H. Soc.	*Proc.*	1893–95	13, 29, 32	"
McAldowie, Dr. A.	Notes on Bird Life during the severe Weather of January and February 1895	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXIX.	84–90	1895
McAldowie, R.	An Ornithological Excursion to Aqualate	" "	" "	"	79–83	"
McGregor, T. M.	On the Formation of an Entomological Section of the East of Scotland Union	E. Scot. Union	*Proc.*	1891–95	77–79	"

Mansel-Pleydell, J. C.	On the *Castoridæ*, with special reference to *Castor fiber*, whose sub-fossilised Remains were found in the Valley of the Stour, near Keynston Mill	Dorset N. H. A. F. C.	,,	XVI.	163–170	,,
Masefield, J. R. B.	Sectional Report: Zoology	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXIX.	44–52	,,
Mason, J. E.	Further Additions to the List of some Hemiptera-Heteroptera of Lincolnshire	Yorks. Nat. Union	*The Naturalist*	For 1895	213–218	,,
,, ,,	Orthoptera, Neuroptera, and Trichoptera of the Alford District of North Lincolnshire	,, ,,	,, ,,	For 1896	129–132	1896
Mathews, Paul	The Evolution of Modern Zoological Thought	Rochester N. C.	*Roch. Naturalist*	II.	321–339	1895
Mawley, Edward	Report on Phenological Phenomena observed in Hertfordshire during the year 1894	Herts N. H. Soc.	*Trans.*	VIII.	193–198	1896
Meade, R. H.	Occurrence of Two early and rare Diptera at Grange	Yorks. Nat. Union	*The Naturalist*	For 1895	220	1895
Meyrick, E.	List of Birds of Marlborough District	Marlb. Coll. N. H. Soc.	*Report*	44	37–54	1896
,, ,,	Entomological Notes	,, ,,	,,	,,	109–119	,,
Mill, Dr. H. R., and James Coates	The Natural History of the Banks of the Tay	Perths. Soc. N. Sci.	*Trans. and Proc.*	II.	33–96	1895
Newman, Edward (the late)	The Bats of Epping Forest	Essex F. C.	*Essex Naturalist*	IX.	134–136	1896
Nicholson, W. A.	Proposal for a Fresh-water Biological Station in Norfolk	Norf. Norw. Nat. Soc.	*Trans.*	VI.	108–109	1895
North-Szigetváry, L.	The Japanese and Chinese Oak-silk Spinner: their Life and Cultivation	Manch. Geog. Soc.	*Journal*	X.	183–193	,,
Oldham, Charles	Palmated Newt in Cheshire	Yorks. Nat. Union	*The Naturalist*	For 1895	219	,,
,, ,,	The Land and Fresh-water Mollusca of Cheshire	,, ,,	,, ,,	For 1896	109–128	1896
Painter, Rev. W. H.	Palæozoic Cephalopoda and their present Representatives	Car. & Sev. Vall. F. C.	*Trans.*	I.	143–144	,,
Palmer, F. Danby	Old-time Yarmouth Naturalists	Norf. Norw. Nat. Soc.	,,	VI.	71–83	1895
Paterson, John	Notes on the Irruption of Little Auks (*Mergulus alle*, L.) in the Winter of 1894–95 on the West of Scotland—Oban to Ayr	Glasgow N. H. Soc.	*Journal*	IV.	195–198	1896
Patterson, A.	Some Marine Notes from Yarmouth	Norf. Norw. Nat. Soc.	*Trans.*	VI.	114–117	1895
Paulden, Frank	The Organs and Function of Reproduction in the Insecta	Manch. Mic. Soc.	,,	For 1895	43–56	1896
Peake, Edward	The Avi-Fauna of Settle and Upper Ribblesdale	Yorks. Nat. Union	*The Naturalist*	For 1896	35–48	,,
Petch, T.	The Land and Fresh-water Mollusca of West Norfolk	Norf. Norw. Nat. Soc.	*Trans.*	VI.	61–67	1895

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Plowright, C. T. M.	On the Occurrence of the Black Variety of the Water Vole	Norf. Norw. Nat. Soc.	*Trans.*	VI.	114	1895
Pye, Miss C. E.	A Butterfly Day	Rochester N. C.	*Roch. Naturalist*	II.	350–353	1896
Read, R. H.	The Nature, Distribution, and Uses of the Colours of Birds	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXIX.	53–78	1895
Richardson, N. M.	*Tinea vinculella*, H.-S., a Species of Lepidoptera new to the British Fauna, with other Entomological Notes on the Season of 1894	Dorset N. H. A. F. C.	*Proc.*	XVI.	81–91	"
" "	Report on Observations of the First Appearances of Birds, Insects, &c., and the First Flowering of Plants in Dorset during 1894	" "	"	"	185–193	"
Robertson, Dr. D.	The Gulls and their Neighbours	Glasgow N. H. Soc.	*Journal*	IV.	244–245	1896
Roebuck, W. D.	Bibliography: Marine Mollusca, 1889 to 1892	Yorks. Nat. Union	*The Naturalist*	For 1895	189–200	1895
" "	" Marine Fishes, 1889 to 1892	" "	" "	For 1896	17–23	1896
" "	" Birds, 1892	" "	" "	"	147–160	"
" "	The Yorkshire Naturalists' Union at the Hole of Horcum	" "	" "	For 1895	203–212	1895
Rowley, F. R.	Note on a Dermoid Tumour from a Frog (*Rana temporaria*, Linn.)	Leicester Lit. Phil. Soc.	*Trans.*	IV.	111–115	1896
Russell, J. B.	The Blastopore of the Frog's Egg in relation to the Hypoblast	Herts N. H. Soc.	"	VIII.	129–130	1895
Serle, Rev. W.	The Avi-Fauna of Buchan	Buchan F. C.	"	III.	195–212	"
Slater, M. B.	The Effect of the last Severe Winter on Birds	Malton F. N. Sci. Soc.	*Science Notes*	2	29	"
Smith, Joseph	Some Notes on Hydrozoa and Polyzoa	Manch. Mic. Soc.	*Trans.*	For 1895	66–79	1896
Southwell, Thos.	Occurrence of Young Grampuses on the Norfolk Coast	Norf. Norw. Nat. Soc.	"	VI.	58–60	1895
" "	Some Additions to the Norwich Castle Museum in 1894	" "	"	"	84–88	"
Stacy-Watson, C.	The Herring Fishery of 1894	" "	"	"	53–58	"
Standen, R.	The Galway Conference, 1895: Mollusca	Dublin N. F. C.	*Irish Naturalist*	IV.	264–270	"
Strickland, W. W.	On the Specimens of *Apus productus* in the Malton Museum	Malton F. N. Sci. Soc.	*Science Notes*	2	67, 74	'95, 96
Tuck, J. G.	Brünnich's Guillemot in Cambridgeshire	Norf. Norw. Nat. Soc.	*Trans.*	VI.	109–111	1895
Tuck, W. H.	A List of the Aculeate-Hymenoptera of a Suffolk Village	" "	"	"	36–46	"

	... the Neighbourhood of Heronsgate, Herts	Herts N. H. Soc.	,,	VIII.	155–160	,,
Watts, W.	On the Birds in Piethorn Valley	Rochdale Lit. Sci. Soc.	,,	IV.	36–54	,,
Whitlock, F. B.	The Otter in the Mid-Trent Valley and its Tributaries	Yorks. Nat. Union	*The Naturalist*	For 1895	329–332	,,
Wilson, William	The Ring-Ouzel in Aberdeenshire	E. Scot. Union	*Proc.*	1891–95	8–9	,,
Wood, Rev. F. H.	The Abundance of Spiders in 1895	N'ton. N. H. Soc.	*Journal*	VIII.	273	1896
Wright, Joseph	The Galway Conference, 1895: Foraminifera	Dublin N. F. C.	*Irish Naturalist*	IV.	252–263	1895
Wroot, Herbert E.	Natural History Notes from the Bradford Churchwardens' Accounts	Yorks. Nat. Union	*The Naturalist*	For 1895	183–187	,,

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Bellamy, C. H.	A Journey across the Rocky Mountains	Manch. Geog. Soc.	*Journal*	X.	199–203	1895
Bruce, Wm. S.	Antarctic Exploration	Tyneside Geog. Soc.	,,	III.	228–241	1896
Chapman, Gen. E. F.	The Mapping of Africa	Manch. Geog. Soc.	,,	XI.	192–202	,,
Cleaver, A. S.	Across the North Island of New Zealand through the Hot Lake District	Belfast N. H. Phil. Soc.	*Report and Proc.*	1894–95	34–40	1895
Clerke, Miss E. M.	M. E. A. Martel's Study of Subterranean France	Manch. Geog. Soc.	*Journal*	X.	286–289	,,
Colquhoun, A. R.	Nicaragua and its Canal	Tyneside Geog. Soc.	,,	III.	151–160	,,
Crook, H. T.	The proposed Nile Dam	Manch. Geog. Soc.	,,	XI.	186–191	1896
Crouch, Walter	Notes on the River Lea: Bromley, Bow, Old Ford	Essex F. C.	*Essex Naturalist*	IX.	89–98	,,
Derby, The Earl of	Canada	Manch. Geog. Soc.	*Journal*	X.	253–270	1895
Gleave, J. J.	A Journey through Italy	,, ,,	,,	XI.	164–167	1896
Goldsmid, Sir F. J.	Persia and her Neighbours	Tyneside Geog. Soc.	,,	III.	220–227	,,
Hanlon, Bishop	Two Notes on Ladak	Manch. Geog. Soc.	,,	XI.	38	,,
Hobhouse, Bishop	On a Map of Mendip	Som'setsh. A. N. H. Soc.	*Proc.*	XLI. Pt. II.	65–72	1895
Kingsley, Miss E. M.	The Ascent of Cameroons Peak and Travels in French Congo	Liv'pool Geog. Soc.	*Pamphlet*	—	1–20	1896
Littledale, St. G. R.	A Journey across Tibet, from North to South, and West to Ladak	Tyneside Geog. Soc.	*Journal*	III.	242–257	,,
MacGregor, Sir W.	British New Guinea	Manch. Geog. Soc.	,,	X.	271–285	1895
Markham, C. R.	Notes on an Antarctic Expedition	,, ,,	,,	XI.	81	1896
Mellor, E. W.	Southern Sweden, 1894	,, ,,	,,	,,	105–138	,,
Morgan, E. Delmar	The International Geographical Congress in London in 1895	Liv'pool Geog. Soc.	*Report*	IV.	29–47	,,
,, ,,	Notes on Polar Research	Manch. Geog. Soc.	*Journal*	XI.	159–163	,,

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Nevins, Dr. J. B.	Colonisation	Liv'pool Lit. Phil. Soc.	*Proc.*	L.	1	1896
Philip, Geo., jun.	The Enlargement of the Geographical Horizon	,, ,,	,,	,,	285	,,
Reed, J. Howard	The Uganda Experiences of Mr. F. C. Smith ('Simisi')	Manch. Geog. Soc.	*Journal*	X.	222–226	1895
,, ,,	The Malayan Trans-peninsular Railway	,, ,,	,,	,,	295–298	,,
,, ,,	Notes on Tenby	,, ,,	,,	,,	314–317	,,
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,, ,,	British Central Africa	,, ,,	,,	,,	168–182	,,
Roeder, C.	On Laurent's Map of Manchester of 1793	,, ,,	,,	,,	183–185	,,
Tayler, A. H.	Notes on the Isles of Scilly	Malton F. N. Sci. Soc.	*Science Notes*	2	104–105	,,
Unsworth, Mrs.	An English Lady in Siam	Manch. Geog. Soc.	*Journal*	XI.	141–158	,,
Wilde, J. D.	South Devon and Cornwall	,, ,,	,,	X.	217–221	1895

Section F.—ECONOMIC SCIENCE AND STATISTICS.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Atkinson, W. N.	Presidential Address	Fed. Inst. Min. Eng.	*Trans.*	IX.	299–309	1895
Barbour, Sir D.	Bimetallism	Stat. Soc. Ireland	*Journal*	XI.	100–122	,,
Dodd, Serjeant	The Doctrine of *Laisser faire* (Opening Address)	Stat. Soc. Ireland	,,	,,	47–63	,,
Dreydel, Thomas	On a Fifteen Years' Record of the Stock Exchange, 1880–1895	Manch. Stat. Soc.	*Trans.*	1895–96	57–90	1896
Hendrick, James	Education and Agriculture: A Discussion of the Bearings of the Technical Education Movement on our Greatest Industry	Glasgow Phil. Soc.	*Proc.*	XXVI.	124–147	1895
Hope, Dr. E. W.	Evolution of Sanitation in Liverpool, 1845–1895	Liv'pool Lit. Phil. Soc.	,,	L.	345	1896
Horsfall, T. C.	The Government of Manchester	Manch. Stat. Soc.	*Trans.*	1895-96	1–28	,,
Kirkup, Austin	The Prevention of Accidents in Mines	Fed. Inst. Min. Eng.	,,	X.	2–18	1895
Maguire, Joseph	Land Transfer and Local Registration of Title	Stat. Soc. Ireland	*Journal*	XI.	63–84	,,
Motion, James R.	Notes on the Scottish Poor Law, the Unemployed, and Labour Colonies	Glasgow Phil. Soc.	*Proc.*	XXVI.	73–87	,,
Osborne, Rev. H.	Prevention and Elimination of Disease, Insanity, Drunkenness, and Crime: a Sugges-	Stat. Soc. Ireland	*Journal*	XI.	85–99	,,

Rooke, George	On the Report of the Royal Commission on the Aged Poor	" "	"	"	29–55	"
Smart, Dr. Wm.	The Municipal Industries of Glasgow	Glasgow Phil. Soc.	*Proc.*	XXVI.	36–53	1895
Snape, Thomas	County Councils and Education	Manch. Stat. Soc.	*Trans.*	1895–96	175–189	1896
Tupper, Sir Charles	Canada and her Relations with the Mother Country	Tyneside Geog. Soc.	*Journal*	III.	163–187	1895
Whyatt, C. H.	Evening Continuation Schools	Manch. Stat. Soc.	*Trans.*	1895–96	151–174	1896
Wright, Prof. R. P.	The Labour Colony System, and its Adaptation to our Social Needs	Glasgow Phil. Soc.	*Proc.*	XXVI.	57–72	1895

Section G.—MECHANICAL SCIENCE.

Atherton, J.	New Method of Re-lighting Miners' Safety Lamps	Manch. Geol. Soc.	*Trans.*	XXIII.	234–238	1895
Bainbridge, E.	Presidential Address	Chesterf. Mid. Count. Inst.	*Trans. Fed. Inst.*	X.	419–430	1896
Baird, Dugald	The Duty of Pumping Engines	Mining Inst. Soc.	" "	XI.	94–102	"
Bennett, A. W.	Telephonic Communication in and about Coal Mines	Midland Inst. Eng.	" "	X.	372–375	"
Cooksey, J. H.	Presidental Address	S. Staff. Inst. Eng.	" "	"	172–176	1895
Durnford, H. St. J.	Notes on the Sinking of the No. 1 Pit at the Ackton Hall Colliery, with special reference to the Thinning out of the Silkstone and Beeston Coal Seam	Midland Inst. Eng.	" "	"	444–451	1896
Hall, Henry	Self-igniting Safety Lamps	Manch. Geol. Soc.	*Trans.*	XXIV.	131–137	"
Hay, William	Fencing-gates for Winding Shafts	Chesterf. Mid. Count. Inst.	*Trans. Fed. Inst.*	X.	480	"
Kell, G. J.	Obituary of Joseph Mitchell	Midland Inst. Eng.	" "	"	107–108	1895
Kennedy, R.	Electrical Machinery for Mines	" "	" "	"	98–105	"
Meachem, J., jun.	Electric Power Plant at Haden Hill Colliery	S. Staff. Inst. Eng.	" "	"	178–182	"
Platt, James	Coal-washing Plant at the Wirral Colliery, Neston, Cheshire	Fed. Inst. Min. Eng.	" "	XI.	55–59	1896
Reid, A.	Methods of closing the Tops of Upcast Winding Shafts	Midland Inst. Eng.	" "	X.	367–370	"
Saint, William	Improvements in Water-spraying Apparatus for Coal Mines	Manch. Geol. Soc.	*Trans.*	XXIII.	252–256	"
Scott-Anderson, T.	Electric Welding	Fed. Inst. Min. Eng.	"	XI.	40–52	"
Thompson, E.	The Use of Steel Girders in Mines	" "	"	X.	272–276	"

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

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Thomson, G. Carruthers	Smoke Abatement with reference to Steam Boiler Furnaces	Glasgow Phil. Soc.	*Proc.*	XXVI.	148–173	1895
Turner, George	Coal Mining in Assam, India	S. Staff. Inst. Eng.	*Trans. Fed. Inst.*	X.	356–364	1896
Walker, G. B.	The Roth Method of Firing Shots	Midland Inst. Eng.	,, ,,	,,	95–96	,,
Walters, H.	Lead and Lap of Winding and other Engines	Fed. Inst. Min. Eng.	,, ,,	XI.	64–68	1895
Winstanley, R.	On West's Safety Detaching Hook	Manch. Geol. Soc.	*Trans.*	XXIV.	108–110	,,

Section H.—ANTHROPOLOGY.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Arnott, Samuel	Some Kirkbean Folklore	Dum. Gal. N. H. A. Soc.	*Trans.*	11	11–17	1896
Black, Geo. F.	Descriptive Catalogue of Loan Collections of Prehistoric and other Antiquities from the Shires of Berwick, Roxburgh, and Selkirk	Berwicksh. Nat. Club	*History*	XV.	144–169	,,
Christy, Miller	On the Field-name of 'Puttock's Lees'	Essex F. C.	*Essex Naturalist*	IX.	108, 109	,,
Clarke, W. G.	Neolithic Man in Thetford District	Norf. Norw. Nat. Soc.	*Trans.*	VI.	23–36	1895
Coles, F. R.	The Standing Stones of the Stewartry	Dum. Gal. N. H. A. Soc.	,,	11	78–83	1896
Crellin, Miss A. M.	Anthropological Report	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	19	1895
Cunnington, E.	Poundbury: The Pastoral Camp and the Old Dunium of Ptolemy	Dorset N. H. A. F. C.	*Proc.*	XVI.	48–54	,,
,, ,,	Hambledon Hill, Dorset	,, ,,	,,	,,	156–158	,,
,, ,,	Helstone	,, ,,	,,	,,	175–177	,,
Evans, Sir John	The Stone Age in Hertfordshire (Anniversary Address)	Herts N. H. Soc.	*Trans.*	VIII.	169–187	1896
Galpin, Rev. A. J.	Wayland Smith's Cave	Marlb. Coll. N. H. Soc.	*Report*	44	88–91	,,
Gould, I. C.	Notes upon the Romano-British Settlement at Chigwell, Essex	Essex F. C.	*Pamphlet*	—	1–16	1895
Gray John	The Ethnographical Survey of Buchan	Buchan F. C.	*Trans.*	III.	216–225	,,
Gray, John, and J. F. Tocher	Report on Preliminary Ethnographical Observations at the Buchan Gathering, Mintlaw	,, ,,	,,	,,	226–240	,,
Gunn, Rev. George	On the British Camps above Lauder	Berwicksh. Nat. Club	*History*	XV.	31	1896
Hamilton-Starke,	Troqueer in the Olden Time	Dum. Gal. N. H. A. Soc.	*Trans.*	11	107–117	,,

[illegible]	Navestock in Olden Days: Stray Notes Prehistoric, Saxon, and Norman	Essex F. C.	*Essex Naturalist*	VIII.	220	1895
Hunt, Dr. Thomas	A Note on some Heywood Surnames	Rochdale Lit. Sci. Soc.	*Trans.*	IV.	64–69	„
Laver, Henry	Potash-making in Essex: A Lost Rural Industry	Essex F. C.	*Essex Naturalist.*	IX.	119–133	1896
Macdonald, Dr. J.	Roman Earthworks at Birrens and Birrenswark	Dum. Gal. N. H. A. Soc.	*Trans.*	11	55–67	„
M'Kie, John	A Superstitious Custom about young Calves in Galloway	„ „	„	„	98	„
Meldola, Prof. R.	Notes on an Ancient Entrenchment on Navestock Common, Essex	Essex F. C.	*Essex Naturalist*	VIII.	213–215	1895
„ „	The Eastern Boundary Stones of the Forest of Waltham	„ „	„ „	IX.	1–10	„
Meyrick, E.	Anthropometrical Statistics	Marlb. Coll. N. H. Soc.	*Report*	44	156–181	1896
Milligan, S. F.	Antiquarian Collections in Ulster	Belfast N. H. Phil. Soc.	*Report and Proc.*	1894-95	63–67	1895
Milne, Rev. P.	Ecclesiastical Punishments in the 17th Century	Buchan F. C.	*Trans.*	III.	167–176	„
Moore, A. W.	Foreign Elements in the Manx Language	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	59–64	„
Plowright, Dr. C. B.	May-day Customs at Lynn	Norf. Norw. Nat. Soc.	*Trans.*	VI.	106–107	„
Riley, William	Intrenchments and Camps on Mynydd Baidan and Mynydd Margam	Cardiff Nat. Soc.	„	XXVII.	71–89	„
Russell, Miss	Some Scottish Place-names	Berwicksh. Nat. Club	*History*	XV.	185–189	1896
Schönland, Dr. S.	On some Human Skulls in the Collection of the Albany Museum	S. African Phil. Soc.	*Trans.*	VIII.	110–112	„
Sephton, Rev. J.	Runic Remains	Liv'pool Lit. Phil. Soc.	*Proc.*	L.	183	„
Shaw, James	Notes of Thirty Years' Residence in Tynron	Dum. Gal. N. H. A. Soc.	*Trans.*	11	99–107	„
Shore, T. W.	Prehistoric Races and their Remains in the Old Clere Country of Hampshire	Hants F. C.	*Proc.*	III.	171–182	„
Simpson, Rev. R.	Notes on the Antiquities of Dunscore	Dum. Gal. N. H. A. Soc.	*Trans.*	11	27–38	„
Spence, James	Report on Antiquarian Remains at Schivas	Buchan F. C.	„	III.	241–246	1895
Spink, J.	Lake Dwellings in the Vale of Pickering	Yorks. Geol. Poly. Soc.	*Proc.*	XIII.	21	1896
Windle, Prof. C. A., & T. Manners-Smith	On the Physical Characters of a Group of Birmingham Pupil Teachers (Female)	Birm. N. H. Phil. Soc.	„	IX.	97–102	1895
Young, R. M.	Description of Three Irish Sepulchral Urns	Belfast N. H. Phil. Soc.	*Report and Proc.*	1894-95	44–46	„

Section I.—PHYSIOLOGY.

Crichton-Browne, Sir J.	Emotional Expression	Dum. Gal. N. H. A. Soc.	*Trans.*	11	76–77	1896
Fergus, Dr. Freeland	The New Rules of the Board of Trade as to Colour-testing for Mariners and Railway Servants	Glasgow Phil. Soc.	*Proc.*	XXVI.	212–226	1895

Section I.—PHYSIOLOGY (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Given, Dr. J. N.	Modern Aspects of Heredity	Liv'pool Lit. Phil. Soc.	*Proc.*	L.	101	1896
Glaister, Prof. J.	The Anti-Toxin Treatment of Diphtheria	Glasgow Phil. Soc.	"	XXVI.	174–199	1895
Hobson, Dr. J. M.	Some Points in the Life History of Bacteria	Croydon M. N. H. C.	*Trans.*	1894-95	123–132	"
MacCormac, Dr. J.	Education and Innervation	Belfast N. H. Phil. Soc.	*Report and Proc.*	"	52–63	"
Newton, John	The Mystery of Life	Liv'pool Lit. Phil. Soc.	*Proc.*	L.	315	1896

Section K.— BOTANY.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Amyot, T. C.	Winfarthing Oak	Norf. Norw. Nat. Soc.	*Trans.*	VI.	113	1895
Audley, J. A.	Sectional Report—Botany	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXIX.	95–99	"
Ballantyne, James	Occurrence of *Cladium germanicum*, Schrad., in Bute	Glasgow N. H. Soc.	*Trans.*	IV.	167–168	1896
Bennett, Arthur	*Carex cæspitosa* L.Fr. in Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1895	271–272	1895
Blackstock, W. S.	Plants of Kirkcaldy	E. Scot. Union	*Proc.*	1891–95	61–65	"
Blunt, T. P.	The Relation of certain Bacteria to Agriculture	Car. & Sev. Vall. F. C.	*Trans.*	I.	100–108	1896
Bowles, A. T.	List of Trees, Shrubs, &c., grown at Bothal Haugh	Berwicksh. Nat. Club	*History*	XV.	74–76	"
Christy, Miller	On an Ancient Oak at Chignal St. James, Essex	Essex F. C.	*Essex Naturalist*	IX.	108–109	"
Club, The	The Botany of the District (List of Plants)	Car. & Sev. Vall. F. C.	*Rec. of Bare Facts*	No. 5	5–15	"
Cooke, Dr. M. C.	Additions to the List of Epping Forest Fungi	Essex F. C.	*Essex Naturalist*	VIII.	244–245	1895
Cordeaux, John	Lincolnshire Agriculture One Hundred Years Ago	Yorks. Nat. Union	*The Naturalist*	For 1895	317–326	"
Dixon, G. B.	Reciprocity between Insects and Flowers	Leicester Lit. Phil. Soc.	*Trans.*	IV.	73–79	1896
Dixon, H. N.	Phenological Observations, 1894	N'ton. N. H. Soc.	*Journal*	VIII.	271	"
Dowker, George	*Silene dichotoma*—a Plant new to Britain	E. Kent N. H. Soc.	*S.E. Naturalist*	V.	152	"
Dunn, S. T.	Distribution of Plants in S.W. Surrey	Holmesdale N. H. Soc.	*Proc.*	1893–95	13–15	"
Ewing, Peter	Contribution to the Topographical Botany of the West of Scotland	Glasgow N. H. Soc.	*Trans.*	IV.	199–214	"
Eyre, Rev. W. L. W.,	List of Hampshire Fungi	Hants F. C.	*Proc.*	III.	225–227	"
Feilden, Col. H. W., and H. D. Geldart	Notes on a Small Collection of Spitzbergen Plants	Norf. Norw. Nat. Soc.	*Trans.*	VI.	47–53	1895
Fergusson, James	Gardens at Morpeth and Morpeth rare Wild Plants	Berwicksh. Nat. Club	*History*	XV.	59, 67	1896

Fulton, James	Mosses of the Sidlaw Hills	E. Scot. Union	*Proc.*	1891–95	12–19	1895
Glaisyer, Joseph	Floral Calendar	Malton F. N. Sci. Soc.	*Science Notes*	2	89–91	1896
Gray, Peter	Food Plants—The Cereals	Dum. Gal. N. H. A. Soc.	*Trans.*	11	146–151	"
Gunn, Rev. George	Plants found or exhibited on Visit to Coast of Berwickshire and East Lothian	Berwicksh. Nat. Club.	*History*	XV.	43, 50	"
" "	Plants found at Morpeth	" "	"	"	76	"
" "	Plants observed at Mellerstain; also Dimensions of the largest Trees	" "	"	"	82, 89	"
Hamson, J.	Fungus Flora of Bedfordshire	Birm. N. H. Phil. Soc.	*Journal*	I.	166–174	1895
Hardy, Dr. James	Localities for *Pimpinella magna*, L.	Berwicksh. Nat. Club.	*History*	XV.	77	1896
Hensman, Miss R.	Some Causes of the Disintegration of Shells	Dublin N. F. C.	*Irish Naturalist*	IV.	137–141	1895
Hepworth, J.	Flora of Our Ten-mile Radius	Rochester N. C.	*Roch. Naturalist*	II.	353–356, 366–370	1896
Hick, Thomas	Lessons in Plant Life	Malton F. N. Sci. Soc.	*Science Notes*	2	99	"
Holmes, W. Murton	The Nutrition of Plants	Croydon M. N. H. C.	*Trans.*	1894–95	157–164	1895
Hottinger, Miss	Notes on the Flora of Australia	Leicester Lit. Phil. Soc.	"	IV.	37–42	"
Johnson, Prof. T., & Miss Hensman	The Galway Conference, 1895: Algæ	Dublin N. F. C.	*Irish Naturalist*	IV.	241–242	"
Kermode, Rev. S. A. P.	Botanical Report	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	III.	22	"
L., F. A.	In Memoriam: Lord Tabley and Prof. Cardale Babington	Yorks. Nat. Union	*The Naturalist*	For 1896	49, 50	1896
Ledger, Charles	Local Fresh-water Algæ	Manch. Mic. Soc.	*Trans.*	For 1895	42, 43	"
Lees, F. Arnold	A Lowland Land-loving Gentian (*Gentiana baltica*, Murb.)	Yorks. Nat. Union	*The Naturalist*	For 1895	225–228	1895
McAndrew, James	Botanical Notes for 1894	Dum. Gal. N. H. A. Soc.	*Trans.*	11	10–11	1896
" "	New Galloway Fresh-water Algæ	" "	"	"	97	"
M'Ardle, D.	The Galway Conference, 1895: Mosses and Liverworts	Dublin N. F. C.	*Irish Naturalist*	IV.	243–245	1895
M'Kay, R., and John Renwick	Records of Measurements of Trees made in 1893 and 1894	Glasgow N. H. Soc.	*Journal*	IV.	246–264	1896
M'Weeney, Dr. E. J.	The Galway Conference, 1895: Fungi	Dublin N. F. C.	*Irish Naturalist*	IV.	238–240	1895
" "	A New Irish Fungus	" "	" "	"	273–277	"
" "	Fungi from Brackenstown, Co. Dublin	" "	" "	V.	6–11	1896
Marloth, Dr. R.	Means of Distribution of Seeds in the South African Flora	S. African Phil. Soc.	*Trans.*	VIII.	lxxiv.–lxxxviii	"
" "	Progress of Natural Science in relation to South Africa during the last Ten Years	" "	"	"	civ.–cxxi.	"
" "	Some Scientific Results of an Excursion to the Hex River Mountains	" "	"	"	86–92	"

Section K.—BOTANY (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Marshall, J. J.	Notes from the East Riding	Malton F. N. Sci. Soc.	*Science Notes*	2	32	1895
" "	Mosses	" "	" "	"	97	1896
Meyrick, E.	Botanical Notes	Marlb. Coll. N. H. Soc.	*Report*	44	99–108	"
Miller, late Rev. J. K., and Rev. E. A. Woodruffe-Peacock	The Rarer Plants of the Walkeringham Neighbourhood in Nottinghamshire, Lincolnshire, and Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1895	161–171	1895
Mott, F. T.	The Leicestershire Brooks	Leicester Lit. Phil. Soc.	*Trans.*	IV.	5–9	"
Murray, Rev. R. P.	The Flora of Somerset: Part III.	Som'setsh. A. N. H. Soc.	*Proc.*	XLI. Pt. II.	241–437	"
Norman, F. M.	Coniferous Timber of Commerce, locally imported	Berwicksh. Nat. Club	*History*	XV.	99–103	1896
Nuttall, Mrs. C. D.	Symbiosis in Plant Life	Leicester Lit. Phil. Soc.	*Trans.*	IV.	43–49	1895
Palmer, F. Danby	A Transplanted Mulberry Tree	Norf. Norw. Nat. Soc.	"	VI.	112	"
Parsons, Dr. H. F.	Habits and Habitats of Plants: Some Remarks on Superficial Resemblances between Plants of Different Affinities	Croydon M. N. H. C.	"	1894–95	150–157	"
Pettigrew, W. W.	The Botanical Garden, Roath Park, Cardiff	Cardiff Nat. Soc.	"	XXVII.	56–62	"
Petty, Lister	The Constituents of the North Lancashire Flora, 1597 (?)–1893	Yorks. Nat. Union	*The Naturalist*	For 1895 For 1896	261–268 101–103	" 1896
Plowright, Dr. C. B.	Presidential Address	Norf. Norw. Nat. Soc.	*Trans.*	VI.	1–14	1895
Praeger, R. Ll., & Prof. J. W. Carr	The Galway Conference, 1895: Phanerogams, Ferns, &c.	Dublin N. F. C.	*Irish Naturalist*	IV.	246–252	"
Robertson, Dr. D.	*Bonnemaisonia asparagoides*, C. Ag., that gave a blue stain to paper	Glasgow N. H. Soc.	*Trans.*	IV.	172–173	1896
" "	*Halicystis ovalis* (Areschoug), an Alga from Lamlash	" "	"	"	174	"
Roebuck, W. D.	Bibliography: Marine Algæ, 1888 to 1892	Yorks. Nat. Union	*The Naturalist*	For 1895	173–176	1895
" "	" Lichens, 1888 to 1893	" "	" "	"	221–224	"
" "	" Fungi, 1888 to 1893	" "	" "	"	243–254	"
" "	" Mosses & Hepatics, 1884 to 1894	" "	" "	"	281–288	"
" "	" Phanerogamic Botany, 1890	" "	" "	For 1896	61–64	1896
Rotheray, Lister	Further Discoveries of *Arenaria gothica*	" "	" "	For 1895 For 1896	303–307 97–100	1895 1896
Roy, Dr. John	The Desmidieæ of the Stormont District	E. Scot. Union	*Proc.*	1891–95	19–25	1895
Salmon, E. S., & C. E.	Localities for Plants	Holmesdale N. H. C.	"	1893–95	6, 23	1896
[illegible]	[illegible]	Dum. Gal. N. H. A. Soc.	*Trans.*	11	143–146	"

Sibley, Miss S. J.	The Effects of Environment on Plants	Rochester N. C.	*Roch. Naturalist*	II.	341–350	1896
Slater, M. B.	On Orchids that grow in the District	Malton F. N. Sci. Soc.	*Science Notes*	2	7, 101	'95'96
" "	On some of the rarer Wild Plants seen in Flower during this season	" "	"	"	8	1895
" "	On some Native Maritime Plants observed near Felixstowe	" "	"	"	45–46	"
" "	*Fortula brevirostris*, Hook and Grev.	" "	"	"	61–62	"
" "	Botanical Report	" "	"	"	78–80	1896
" "	On some of the Earliest Spring Hardy Flowers	" "	"	"	88	"
" "	Plant Notes of April	" "	"	"	92	"
" "	The Wavy-leaved Fork-toothed Moss	" "	"	"	98	"
Smith, John	*Plantago maritima*, L., its Distribution in Ayrshire	Glasgow N. H. Soc.	*Journal*	IV.	226–228	"
Somerville, A.	*Cystopteris montana*, Bernhardi, in Stirlingshire	" "	"	"	215–217	"
Stabler, George	On the Hepaticæ and Musci of Westmorland	Yorks. Nat. Union	*The Naturalist*	For 1896	133–140	"
Stewart, S. A., and R. Ll. Praeger	A Supplement to the Flora of the North-east of Ireland of Stewart and Corry	Belfast N. F. C.	*Report and Proc.*	IV.	App. 133–236	'95
Strickland, W. W.	The Law of the Symmetry of Composite Flowers and its relation to Decorative Art	Malton F. N. Sci. Soc.	*Science Notes*	2	41, 5, 21, 33, 58	"
Trail, Prof. J. W. H.	Botanical Notes from Murthly	Perths. Soc. N. Sci.	*Trans. and Proc.*	II.	127–131	"
Turner, G. C.	Notes on the Swiss Flora	Leicester Lit. Phil. Soc.	*Trans.*	IV.	107–112	1896
Various	The Management of Epping Forest: Reports, &c.	Essex F. C.	*Essex Naturalist*	IX.	74–80	"
Weiss, Prof. F. E.	The Influence of External Conditions on Reproductive Processes in Plants	Manch. Mic. Soc.	*Trans.*	For 1895	21–28	"
West, H., jun.	Some Additional West Riding Plant Localities	Yorks. Nat. Union	*The Naturalist*	For 1895	333–335	1895
White, Dr. F. B.	The Beatitudes of Breadalbane	E. Scot. Union	*Proc.*	1891–95	57–61	"
Whitton, James	Meteorological Notes and Remarks upon the Weather during the Year 1894, with its General Effects upon Vegetation	Glasgow N. H. Soc.	*Journal*	IV.	229–240	1896
Whitwell, Wm.	More about *Arenaria gothica*	Yorks. Nat. Union.	*The Naturalist*	For 1895	257–260	1895
Wilkinson, H. J.	List of Plants in the Herbarium of the Yorkshire Philosophical Society	Yorks. Phil. Soc.	*Report*	For 1895	1–19	1896
Wilson, William	The Acclimatisation of *Valeriana aurea*	E. Scot. Union	*Proc.*	1891–95	25	1895
Woodruffe-Peacock, Rev. E. A.	The Yorkshire and Lincolnshire Naturalists' Unions at Broughton Wood and Twigmoor Gallery	Yorks. Nat. Union	*The Naturalist*	For 1895	229–237	"
" "	The Natural History Divisions of Lincolnshire	" "	" "	"	289–301	"
" "	Lincolnshire Naturalists at Sleaford	" "	" "	"	313–315	"
" "	Lincolnshire Naturalists at Market Rasen	" "	" "	For 1896	11–16	1896
" "	A Critical Catalogue of Lincolnshire Plants	" "	" "	"	53–60	"

Calculation of the G (r, ν)-Integrals.—Preliminary Report of the Committee, consisting of Rev. ROBERT HARLEY (*Chairman*), Professor A. R. FORSYTH (*Secretary*), Mr. J. W. L. GLAISHER, Professor A. LODGE, *and* Professor KARL PEARSON. (*Drawn up by* Professor KARL PEARSON.)

Preliminary Report on the Integral $G(r, \nu) = \int_0^\pi \sin^r\theta\, e^{\nu\theta}\, d\theta$.

1. THE integral G (r, ν) occurs in the determination of frequency curves and of the probable errors of their constants under the form $e^{-\frac{1}{2}\pi\nu}$ G (r, ν), or, what is the same thing, the integral

$$\int_{-\pi/2}^{\pi/2} \cos^r\theta\, e^{-\nu\theta}\, d\theta$$

occurs. The calculation of this integral for the values of r, which most frequently arise in practice, is for special cases somewhat laborious, and this much impedes the use of the generalised frequency curves by statisticians and biologists.[1] It seems desirable, accordingly, to form tables of the values of the integral for the most usual values of r and ν. If $\tan\phi = \nu/r$, then $r=2$ to $r=50$, and $\phi=0°$ to $\phi=90°$ are the ranges of values which experience has shown to be most useful for statistical purposes. For the same purposes it is not necessary to calculate to a greater degree of exactitude than 1 in 1,000. Hence, if a table of double entry be formed proceeding by units from $r=1$ to $r=50$, and by degrees from $\phi=0°$ to $\phi=90°$, intermediate values of r and ϕ will be given with sufficient accuracy by interpolation; such a table will contain 4,500 entries, and involves a large amount of labour in its calculation.

The integral G (r, ν) is, however, of considerable interest from the standpoint of pure mathematics,[2] and is not unlikely to be required for a variety of investigations, as it is closely related to the Eulerian integrals. Hence the formulæ of this report and the scheme of the proposed tables are adapted to expansion, should it be found ultimately of service to form as complete a table for G (r, ν) as exists for $\Gamma(x)$.

2. The value of the integral may be expressed in terms of Eulerian integrals with complex arguments (see Forsyth, *Quarterly Journal of Mathematics*, 1895). Thus:

$$G(r, \nu) = \frac{2^{-r}\pi\, e^{\frac{1}{2}\pi\nu}\,\Gamma(r+1)}{\Gamma(\frac{1}{2}r+1-\frac{1}{2}\nu i)\,\Gamma(\frac{1}{2}r+1+\frac{1}{2}\nu i)} \quad . \quad . \quad . \quad (i.)$$

$$= \frac{2^{-r}\pi\, e^{\frac{1}{2}\pi\nu}}{r+1}\;\frac{1}{B(\frac{1}{2}r+1-\frac{1}{2}\nu i,\ \frac{1}{2}r+1+\frac{1}{2}\nu i)} \quad . \quad . \quad (ii.)$$

Since $e^{\frac{1}{2}\pi\nu}$ is the mid-value of $\sin^r\theta\, e^{\nu\theta}$, it is very roughly proportional to the value of G (r, ν), and accordingly $e^{-\frac{1}{2}\pi\nu}$ G (r, ν) = F (r, ν) will be found to change more uniformly and gradually than G (r, ν), and as this

[1] See a paper on 'Skew Variation in Homogeneous Material,' *Phil. Trans.*, vol. 186 A, pp. 377–380. A further memoir on the probable errors of frequency constants also largely involves the values of G (r, ν).

[2] Professor Klein, I am told, has drawn the attention of his students to G (r, ν) in unpublished lectures, and has suggested to them its fuller consideration.

is the quantity actually required in statistical problems, it is $F(r, \nu)$, which will be tabulated. Interpolation between two values of $F(r, \nu)$ gives better results for $G(r, \nu)$ than direct interpolation between two values of $G(r, \nu)$.

It has been shown by Lipschitz (*Crelle* : Bd. 56, S. 20) that the well-known expansion in terms of Bernoulli's numbers for $\log \Gamma(n+1)$ still holds when n is a complex quantity ; the remainder after B_{2m-1} is

$$+(-1)^m \frac{B_{2m+1}}{(2m+1)(2m+2)} \frac{1}{n^{2m+1}} (\epsilon + \epsilon' i),$$

where ϵ and ϵ' are both less than unity.

We can accordingly use this expansion to obtain a semi-convergent series for $F(r, \nu)$.

$$\log F(r, \nu) = \log 2\pi - \overline{r+1} \log 2 + \log \Gamma(r+1) - \log \Gamma(\tfrac{1}{2}r + 1 - \tfrac{1}{2}\nu i) - \log \Gamma(\tfrac{1}{2}r + 1 + \tfrac{1}{2}\nu i).$$

Let $r = 2\beta \cos\phi$, $\nu = 2\beta \sin\phi$, and let the Γ-function terms be calculated separately.

$$\log \Gamma(r+1) = \log \sqrt{2\pi} + (r + \tfrac{1}{2}) \log r - r + S(-1)^m \frac{B_{2m+1}}{(2m+1)(2m+2)} \frac{1}{r^{2m+1}},$$

$$\log \Gamma(\tfrac{1}{2}r + 1 - \tfrac{1}{2}\nu i) = \log \Gamma(\beta e^{-i\phi} + 1)$$
$$= \log \sqrt{2\pi} + (\beta e^{-i\phi} + \tfrac{1}{2})(\log \beta - i\phi) - \beta e^{-i\phi} + S(-1)^m \frac{B_{2m+1}}{(2m+1)(2m+2)} \frac{1}{\beta^{2m+1}} e^{(2m+1)i\phi},$$

and

$$\log \Gamma(\tfrac{1}{2}r + 1 + \tfrac{1}{2}\nu i) = \log \Gamma(\beta e^{i\phi} + 1)$$
$$= \log \sqrt{2\pi} + (\beta e^{i\phi} + \tfrac{1}{2})(\log \beta + i\phi) - \beta e^{i\phi} + S(-1)^m \frac{B_{2m+1}}{(2m+1)(2m+2)} \frac{1}{\beta^{2m+1}} e^{-(2m+1)i\phi}.$$

Hence :

$$\log \frac{F(r+1)}{\Gamma(\tfrac{1}{2}r + 1 - \tfrac{1}{2}\nu i)\,\Gamma(\tfrac{1}{2}r + 1 + \tfrac{1}{2}\nu i)} = -\log \sqrt{2\pi} - \log \sqrt{r} + \log(\cos\phi)^{r+1} + r\phi \tan\phi + (1+r)\log 2 + S(-1)^m \frac{B_{2m+1}}{(2m+1)(2m+2)} \frac{1}{r^{2m+1}} (1 - 2^{2m+2} \cos^{2m+1}\phi \cos \overline{2m+1}\phi).$$

Let $\chi(r, \phi) = \frac{1}{2}$ (the Bernoulli number series in this expansion), then :

$$\log F(r, \nu) = \log \sqrt{\frac{2\pi}{r}} + \log(\cos\phi)^{r+1} + r\phi \tan\phi + 2\chi(r, \phi),$$

or,

$$F(r, \nu) = e^{-\frac{1}{2}\pi\nu}\, G(r, \nu)$$
$$= \sqrt{\frac{2\pi}{r}} (\cos\phi)^{r+1} e^{\nu\phi + 2\chi(r,\phi)} \quad . \quad . \quad . \quad . \quad . \quad \text{(iii.)}$$

Here :

$$\chi(r, \phi) = \frac{\chi_1(\phi)}{(\frac{1}{2}r)} - \frac{\chi_3(\phi)}{(\frac{1}{2}r)^3} + \frac{\chi_5(\phi)}{(\frac{1}{2}r)^5} + (-1)^m \frac{\chi_{2m+1}(\phi)}{(\frac{1}{2}r)^{2m+1}} + \quad . \quad \text{(iv.)}$$

where $\chi_{2m+1}(\phi)=\dfrac{B_{2m+1}}{(2m+1)(2m+2)}\{(\tfrac{1}{2})^{2m+2}-\cos^{2m+1}\phi\cos(2m+1)\phi\}$,

and the series will be semi-convergent, if $r>2$, as it always is in statistical problems. Throughout m is to be summed for all integer values from 0 to ∞, and the logarithms are to Napier's base.

The results (iii.) and (iv.) allow us to calculate F (r, ν) and G (r, ν) to any degree of accuracy that may be required. If we stop at the m^{th} term in $\chi(r, \phi)$ then the error in the value of $\chi(r, \phi)$ will be less than

$$(-1)^m\frac{\chi_{2m+1}(\phi)}{(\frac{1}{2}r)^{2m+1}}.$$

Now, it is easy to show that although $\chi_{2m+1}(\phi)$ has several maxima given by

$$\phi=\frac{s\pi}{2(m+1)},$$

where s is an integer, still its absolutely greatest numerical value is given by $\phi=0$, and it is then equal to

$$-\frac{B_{2m+1}}{(2m+1)(2m+2)}(1-(\tfrac{1}{2})^{2m+2}).$$

Thus, if we stop the calculation of $\chi(r, \nu)$ at the m^{th} term, we shall not make an error $+$ or $-$ in its value so great as

$$\frac{B_{2m+1}}{(2m+1)(2m+2)}\frac{\{1-(\frac{1}{2})^{2m+2}\}}{(\frac{1}{2}r)^{2m+1}}.$$

We accordingly obtain the following system of the maximum errors possible when we stop at successive terms in $\chi(r, \nu)$:

Term stopped at:	1st	2nd	3rd
Error less than:	$\pm\cdot0625000/(\frac{1}{2}r)$	$\pm\cdot0026042/(\frac{1}{2}r)^3$	$\pm\cdot0007812/(\frac{1}{2}r)^5$.
Term stopped at:	4th	5th	6th
Error less than:	$\pm\cdot0005929/(\frac{1}{2}r)^7$	$\pm\cdot0008409/(\frac{1}{2}r)^9$	$\pm\cdot0019171/(\frac{1}{2}r)^{11}$.
Term stopped at:	7th	8th	9th
Error less than:	$\pm\cdot0064099/(\frac{1}{2}r)^{13}$	$\pm\cdot0295499/(\frac{1}{2}r)^{15}$	$\pm\cdot1796437/(\frac{1}{2}r)^{17}$.
Term stopped at:	10th		
Error less than:	$\pm1\cdot3933926/(\frac{1}{2}r)^{19}$.		

Now, if $r=2$, we ought to stop at χ_7 to get the closest result from our semi-convergent series. We shall then make an error of less than 6 in the 10,000. Such a result is generally close enough for statistical practice, but is hardly sufficient for the purposes of pure mathematics. However, if we start with $r=4$, and proceed only to the fourth term, χ_7, we should obtain results only showing error in the sixth place of decimals. If we calculate $\chi(r, \nu)$ up to χ_9, we have an error less than $\cdot000002$ for $r=4$, and less errors for larger values of r. Finally, if we limit ourselves to values of $r=$ or <6, we shall find that by proceeding to χ_7 only we have errors of less than $\cdot0000003$ in our results. As the tables of logarithms and trigonometrical functions in general use do not go beyond seven figures, it does not seem necessary for practical purposes to go beyond χ_7 in the calculation of the χ-functions. If we, then, start our tables with $r=6$, we shall obtain results for $\chi(r, \nu)$ certainly correct to the sixth figure. The earlier portion of the table may then be calculated from the formula of reduction :

$$G(r, \nu)=\frac{(r+2)^2+\nu^2}{(r+2)(r+1)}G(r+2, \nu) \quad . \quad . \quad . \quad \text{(v.)}$$

and the entire tables will then be correct to the sixth place.

3. It may be observed that the formula (iv.) is of considerable significance. It is quite independent of the nature of r, whether fractional or integer, and thus shows that there is no abrupt change in the value of G (r, ν) when we pass from integer to fractional values. It thus justifies interpolation between integer values of r, in order to find the value of the function for r fractional. It might be supposed, if for statistical purposes it is sufficiently accurate to interpolate between integer values of r, and as G (r, ν) is directly integrable in a terminable series [1] when r is integer, that to use this latter series would be the readiest means of calculating tables of G (r, ν). But this is far from being the case, and for the following reasons :

(i.) We have always as many terms to calculate as in finding $\chi(r, \phi)$, and often many more.

(ii.) These terms are not the same for all values of ϕ, and must be calculated afresh for each pair of values of ϕ and r; *i.e.*, they cannot be broken up into ϕ-factors and r-factors, and the former and latter calculated independently and once for all.

Hence, even when r is an integer the calculation of G (r, ν) proceeds best by aid of the χ-functions.

4. The process of calculation has accordingly been the following :—

(*a*) The calculation of a table of χ-functions from χ_1 to χ_7 for values of ϕ from 0° to 90°. This table will be found at the end of this paper, and, until the complete tables of F (r, ν) are ready, will enable the value of F (r, ν) for any value of r and ν to be found with a fairly small amount of labour.

(*b*) Very considerable progress has been made with the calculation of F (r, ν) from the χ-functions for selected values of r. It is proposed to fill in the gaps by means of the reduction formula (v.). A test of the accuracy of the calculations will thus be obtained by the agreement of the directly calculated values with those obtained by reduction from the last directly calculated value.

The arithmetic has proved much more laborious than was at all anticipated at the start. It was originally undertaken by Mr. H. J. Harris, assistant to Professor M. J. M. Hill at University College, London, but the whole of the calculations have been again and independently worked out by members of the Department of Applied Mathematics in that College.

5. It seems desirable to illustrate the method of calculation, and to show, in one case at any rate, the degree of accuracy obtainable by interpolating between integer values of r and values of ϕ proceeding by degrees.

Let it be required to calculate F (r, ν), when $r=9{\cdot}35$ and $\nu=3{\cdot}51133$.

It will be found that $\phi=20°\ 35'$, and hence, when the tables are completed, it will be necessary to interpolate between $r=9$ and 10 and $\phi=20°$

[1] By expressing $\sin^r\theta$ in cosines or sines of multiple angles.

and 21°. The values of χ might be taken at once from our table, but the method of calculation is illustrated by calculating them *ab initio.* The following are the logarithmic values of the χ's to base 10 :—

$$\log \chi_1 = \bar{2}\cdot9208188 + \log(\cdot250000 - \cos\phi\cos\phi)$$
$$\log \chi_3 = \bar{3}\cdot4436975 + \log(\cdot062500 - \cos^3\phi\cos 3\phi)$$
$$\log \chi_5 = \bar{4}\cdot8996294 + \log(\cdot015625 - \cos^5\phi\cos 5\phi)$$
$$\log \chi_7 = \bar{4}\cdot7746907 + \log(\cdot003906,(25) - \cos^7\phi\cos 7\phi).$$

These are obtained by inserting the values of the Bernoulli numbers.[1] In the case of the trigonometrical quantity in the argument of the last logarithm being greater than the numerical constant, care must be taken to make the corresponding χ negative.

We find

	$\phi=20°$	$\phi=21°$	$\phi=20°\ 35'$ By Interpolation	$\phi=20°\ 35'$ Direct Calculation
χ_1	$-\cdot052752$	$-\cdot051798$	$-\cdot052196$	$-\cdot052200$
χ_3	$-\cdot000979$	$-\cdot000852$	$-\cdot000905$	$-\cdot000905$
χ_5	$+\cdot000113$	$+\cdot000158$	$+\cdot000139$	$+\cdot000140$
χ_7	$+\cdot000297$	$+\cdot000311$	$+\cdot000305$	$+\cdot000306$

$\chi(9, 20°) = -\cdot0117119$ $\chi(9, 21°) = -\cdot0115013$ $\chi(9\cdot35, 20°\ 35') = -\cdot011157$

$\chi(10, 20°) = -\cdot0105425$ $\chi(10, 21°) = -\cdot0103527$

$F(9, 20°) = 1\cdot374821$ $F(9, 21°) = 1\cdot456858$

$F(10, 20°) = 1\cdot394909$ $F(10, 21°) = 1\cdot488643$ $F(9\cdot35, 20°\ 35') = 1\cdot429911$ by direct calculation.

$$F(9\cdot35, 20°\ 35'') = F(9, 20°) + \frac{35}{60}(\cdot082037) + \frac{35}{100}(\cdot020088)$$
$$= 1\cdot429707 \text{ by interpolation.}$$

Thus we see that if tables of $F(r, \phi)$, proceeding by units and degrees, are calculated, the value of $F(9\cdot35, 20°\ 35')$, as found by interpolation from the tables or direct calculation, would only differ by two units in the fifth place of figures. Such a degree of approximation is more than sufficient for practical purposes in statistics. Had we used values of the χ's correct to the seventh place of figures and used second differences, our results would have agreed to the sixth place of figures. Should this not suffice for the more exact purposes of pure mathematics, our table would still serve as a skeleton to be filled in at smaller intervals of the variables, when necessity arises.

So far as the value of $F(r, \phi)$ we have selected is concerned, χ_5 and χ_7 contribute no sensible portion up to the sixth place of decimals. They have been included above, however, to indicate how their values for

[1] Higher values of χ are given by

$$\log \chi_9 = \bar{4}\cdot9251836 + \log(\cdot000976(56) - \cos^9\phi\cos 9\phi)$$
$$\log \chi_{11} = \bar{3}\cdot2827414 + \log(\cdot000244(14) - \cos^{11}\phi\cos 11\phi)$$
$$\log \chi_{13} = \bar{3}\cdot8068754 + \log(\cdot000061(04) - \cos^{13}\phi\cos 13\phi)$$
$$\log \chi_{15} = \bar{2}\cdot4705670 + \log(\cdot000015(26) - \cos^{15}\phi\cos 15\phi)$$
$$\log \chi_{17} = \bar{1}\cdot2544136 + \log(\cdot000003(82) - \cos^{17}\phi\cos 17\phi)$$
$$\log \chi_{19} = \cdot1440741 + \log(\cdot000000(96) - \cos^{19}\phi\cos 19\phi).$$

Still higher values of χ may be found almost exactly from

$$\chi_{2n+1} = -\frac{2\lfloor 2n}{(2\pi)^{2n+2}}\cos^{2n+1}\phi\cos(2n+1)\phi.$$

$\phi=20^\circ\ 35'$ are sensibly identical with those obtained by interpolation from a table of χ's proceeding by degrees. The tables of the χ-functions will thus, till the $F(r, \phi)$ tables are completed, save a great deal of calculation in the finding of any series of χ-functions; the interpolated values must then be substituted in equation (iv.) to find $\chi(r, \phi)$, and this value substituted in (iii.) will give $F(r, \nu)$. It will be found that this needs only a moderate amount of arithmetic, but if it has to be done for a considerable number of frequency curves, the statistician may still reasonably demand the completion of the $F(r, \nu)$ tables themselves.

APPENDIX.

Tables of χ-functions (χ_1, χ_3, χ_5, and χ_7).

These tables have been calculated by Miss A. Lee, Mr. G. U. Yule, Dr. C. E. Cullis, and Mr. Karl Pearson, and the independent values thus obtained used for the verification and correction of the tables originally provided by Mr. H. F. Harris.

The figures in brackets will generally only be required to determine the accurate seventh figure in the value of the χ-function or its differences. The differences in the higher values of χ have been found by calculating χ to eleven figures and then dropping the last two. On this account it will be found that the tabulated differences do not in the bracketed figures always agree in the last place with the results obtained by subtracting the tabulated χ's.

Two differences will always suffice to calculate χ_3, χ_5, and χ_7 to seven places, and even with χ_1 two differences will very rarely give a unit error in the last place of figures, while the use of the third difference would amply suffice for all seven places.

TABLE OF VALUES OF χ_1.

ϕ	$\log(\pm\chi_1)$	χ_1	Δ_1	Δ_2
°				
0	$\bar{2}$·7958800	−·0625000(00)	—	—
1	$\bar{2}$·7957037	−·0624746(30)	+ 253(70)	—
2	$\bar{2}$·7951742	−·0623985(00)	+ 761(30)	+507(60)
3	$\bar{2}$·7942911	−·0622717(57)	+ 1267(43)	+506(13)
4	$\bar{2}$·7930532	−·0620945(14)	+ 1772(43)	+505(00)
5	$\bar{2}$·7914590	−·0618670(00)	+ 2275(14)	+502(71)
6	$\bar{2}$·7895066	−·0615894(84)	+ 2775(16)	+500(02)
7	$\bar{2}$·7871935	−·0612623(30)	+ 3271(54)	+496(38)
8	$\bar{2}$·7845168	−·0608859(00)	+ 3764(30)	+492(76)
9	$\bar{2}$·7814731	−·0604607(00)	+ 4252(00)	+487(70)
10	$\bar{2}$·7780586	−·0599872(00)	+ 4735(00)	+483(00)
11	$\bar{2}$·7742688	−·0594660(14)	+ 5211(86)	+476(86)
12	$\bar{2}$·7700986	−·0588977(27)	+ 5682(87)	+471(01)
13	$\bar{2}$·7655426	−·0582831(00)	+ 6146(27)	+463(40)
14	$\bar{2}$·7605945	−·0576228(13)	+ 6602(87)	+456(60)
15	$\bar{2}$·7552476	−·0569177(40)	+ 7050(73)	+447(86)
16	$\bar{2}$·7494942	−·0561686(64)	+ 7490(76)	+440(03)
17	$\bar{2}$·7433260	−·0553765(50)	+ 7921(14)	+430(38)
18	$\bar{2}$·7367341	−·0545423(75)	+ 8341(75)	+420(61)
19	$\bar{2}$·7297083	−·0536671(25)	+ 8752(50)	+410(75)
20	$\bar{2}$·7222378	−·0527518(61)	+ 9152(64)	+400(14)

TABLE OF VALUES OF χ_1—*continued.*

ϕ	$\log(\pm\chi_1)$	χ_1	Δ_1	Δ_2
°				
21	$\bar{2}$·7143105	−·0517977(00)	+ 9541(61)	+388(97)
22	$\bar{2}$·7059136	−·0508058(35)	+ 9918(65)	+377(04)
23	$\bar{2}$·6970325	−·0497774(35)	+10284(00)	+365(35)
24	$\bar{2}$·6876518	−·0487137(80)	+10636(55)	+352(55)
25	$\bar{2}$·6677543	−·0476161(54)	+10976(26)	+339(71)
26	$\bar{2}$·6673213	−·0464859(11)	+11302(43)	+326(17)
27	$\bar{2}$·6563320	−·0453244(00)	+11615(11)	+312(68)
28	$\bar{2}$·6447639	−·0441330(40)	+11913(60)	+298(49)
29	$\bar{2}$·6325919	−·0429133(00)	+12197(40)	+283(80)
30	$\bar{2}$·6197888	−·0416666(77)	+12466(23)	+268(83)
31	$\bar{2}$·6063238	−·0403946(47)	+12720(30)	+254(07)
32	$\bar{2}$·5921635	−·0390988(09)	+12958(38)	+238(08)
33	$\bar{2}$·5772700	−·0377806(95)	+13181(14)	+222(76)
34	$\bar{2}$·5616016	−·0364419(50)	+13387(45)	+206(31)
35	$\bar{2}$·5451113	−·0350841(81)	+13577(69)	+190(24)
36	$\bar{2}$·5277464	−·0337090(39)	+13751(42)	+173(73)
37	$\bar{2}$·5094475	−·0323182(22)	+13908(17)	+156(75)
38	$\bar{2}$·4901470	−·0309134(14)	+14048(08)	+139(91)
39	$\bar{2}$·4697679	−·0294963(27)	+14170(87)	+122(79)
40	$\bar{2}$·4482220	−·0280686(85)	+14276(42)	+105(55)
41	$\bar{2}$·4254073	−·0266322(12)	+14364(73)	+ 88(31)
42	$\bar{2}$·4012056	−·0251886(87)	+14435(25)	+ 70(52)
43	$\bar{2}$·3754780	−·0237398(54)	+14488(33)	+ 53(08)
44	$\bar{2}$·3480610	−·0222874(82)	+14523(72)	+ 35(39)
45	$\bar{2}$·3187588	−·0208333(40)	+14541(42)	+ 17(70)
46	$\bar{2}$·2873356	−·0193791(90)	+14541(50)	+ (08)
47	$\bar{2}$·2535031	−·0179268(12)	+14523(78)	− 17(72)
48	$\bar{2}$·2169040	−·0164779(84)	+14488(28)	− 35(50)
49	$\bar{2}$·1770877	−·0150344(60)	+14435(24)	− 53(04)
50	$\bar{2}$·1334748	−·0135979(94)	+14364(66)	− 70(58)
51	$\bar{2}$·0853029	−·0121703(45)	+14276(49)	− 88(17)
52	$\bar{2}$·0315400	−·0107532(57)	+14170(88)	−105(61)
53	$\bar{3}$·9707394	−·0093484(50)	+14048(07)	−122(81)
54	$\bar{3}$·9007836	−·0079576(27)	+13908(23)	−139(84)
55	$\bar{3}$·8183905	−·0065824(95)	+13751(32)	−156(91)
56	$\bar{3}$·7180635	−·0052247(25)	+13577(70)	−173(62)
57	$\bar{3}$·5894999	−·0038859(74)	+13387(51)	−190(19)
58	$\bar{3}$·4095729	−·0025678(69)	+13181(05)	−206(46)
59	$\bar{3}$·1044934	−·0012720(19)	+12958(50)	−222(55)
60	$-\infty$	0	+12720(19)	−238(31)
61	$\bar{3}$·0957397	+·0012466(36)	+12466(36)	−253(83)
62	$\bar{3}$·3920585	+·0024663(72)	+12197(36)	−269(00)
63	$\bar{3}$·5632104	+·0036577(19)	+11913(47)	−283(89)
64	$\bar{3}$·6829775	+·0048192(28)	+11615(09)	−298(38)
65	$\bar{3}$·7744793	+·0059494(84)	+11302(56)	−312(53)
66	$\bar{3}$·8480110	+·0070471(10)	+10976(26)	−326(30)
67	$\bar{3}$·9090619	+·0081107(67)	+10636(57)	−339(69)
68	$\bar{3}$·9609062	+·0091391(60)	+10283(93)	−352(64)
69	$\bar{2}$·0056538	+·0101310(38)	+ 9918(78)	−365(15)
70	$\bar{2}$·0447430	+·0110851(87)	+ 9541(49)	−377(29)
71	$\bar{2}$·0791975	+·0120004(50)	+ 9152(63)	−388(86)
72	$\bar{2}$·1097712	+·0128757(12)	+ 8752(62)	−400(01)
73	$\bar{2}$·1370343	+·0137099(00)	+ 8341(88)	−410(74)
74	$\bar{2}$·1614281	+·0145020(07)	+ 7921(07)	−420(81)
75	$\bar{2}$·1833000	+·0152510(60)	+ 7490(53)	−430(54)
76	$\bar{2}$·2029282	+·0159561(55)	+ 7050(95)	−439(58)
77	$\bar{2}$·2205374	+·0166164(19)	+ 6602(64)	−448(31)
78	$\bar{2}$·2363121	+·0172310(64)	+ 6146(45)	−456(19)

TABLE OF VALUES OF χ_1—*continued.*

ϕ	$\log(\pm\chi_1)$	χ_1	Δ_1	Δ_2
°				
79	$\bar{2}$·2504036	+·0177993(30)	+ 5682(66)	−463(79)
80	$\bar{2}$·2629380	+·0183205(25)	+ 5211(95)	−470(71)
81	$\bar{2}$·2740198	+·0187940(26)	+ 4735(01)	−476(94)
82	$\bar{2}$·2837362	+·0192192(40)	+ 4252(14)	−482(87)
83	$\bar{2}$·2921598	+·0195956(54)	+ 3764(14)	−488(00)
84	$\bar{2}$·2993508	+·0199228(23)	+ 3271(69)	−492(45)
85	$\bar{2}$·3053584	+·0202003(23)	+ 2775(00)	−496(69)
86	$\bar{2}$·3102225	+·0204278(42)	+ 2275(19)	−499(81)
87	$\bar{2}$·3139744	+·0206050(84)	+ 1772(42)	−502(77)
88	$\bar{2}$·3166378	+·0207318(33)	+ 1267(49)	−504(93)
89	$\bar{2}$·3182293	+·0208079(48)	+ 761(15)	−506(34)
90	$\bar{2}$·3187588	+·0208333(33)	+ 253(85)	−507(30)

TABLE OF VALUES OF χ_3.

ϕ	$\log(\pm\chi_3)$	χ_3	Δ_1	Δ_2
°				
0	$\bar{3}$·4156688	−·0026041(67)	—	—
1	$\bar{3}$·4148216	−·0025990(91)	+ 50(76)	—
2	$\bar{3}$·4122765	−·0025839(05)	+ 151(86)	+101(10)
3	$\bar{3}$·4080198	−·0025587(02)	+ 252(03)	+100(17)
4	$\bar{3}$·4020305	−·0025236(58)	+ 350(44)	+ 98(41)
5	$\bar{3}$·3942768	−·0024790(02)	+ 446(56)	+ 96(12)
6	$\bar{3}$·3847176	−·0024250(33)	+ 539(69)	+ 93(13)
7	$\bar{3}$·3732999	−·0023621(09)	+ 629(24)	+ 89(55)
8	$\bar{3}$·3599580	−·0022906(46)	+ 714(63)	+ 85(39)
9	$\bar{3}$·3446110	−·0022111(13)	+ 795(33)	+ 80(70)
10	$\bar{3}$·3271611	−·0021240(32)	+ 870(81)	+ 75(48)
11	$\bar{3}$·3074892	−·0020299(68)	+ 940(64)	+ 69(83)
12	$\bar{3}$·2854513	−·0019295(29)	+1004(39)	+ 63(75)
13	$\bar{3}$·2608723	−·0018233(60)	+1061(69)	+ 57(30)
14	$\bar{3}$·2335381	−·0017121(35)	+1112(25)	+ 50(56)
15	$\bar{3}$·2031839	−·0015965(55)	+1155(80)	+ 43(55)
16	$\bar{3}$·1694793	−·0014773(36)	+1192(19)	+ 36(39)
17	$\bar{3}$·1320082	−·0013552(15)	+1221(21)	+ 29(02)
18	$\bar{3}$·0902342	−·0012309(32)	+1242(83)	+ 21(62)
19	$\bar{3}$·0434528	−·0011052(30)	+1257(02)	+ 14(19)
20	$\bar{4}$·9907133	−·0009788(46)	+1263(84)	+ 6(82)
21	$\bar{4}$·9307004	−·0008525(12)	+1263(34)	− (50)
22	$\bar{4}$·8614987	−·0007269(40)	+1255(72)	− 7(62)
23	$\bar{4}$·7801902	−·0006028(23)	+1241(17)	− 14(55)
24	$\bar{4}$·6819914	−·0004808(30)	+1219(93)	− 21(23)
25	$\bar{4}$·5582220	−·0003615(95)	+1192(35)	− 27(58)
26	$\bar{4}$·3904405	−·0002457(20)	+1158(75)	− 33(60)
27	$\bar{4}$·1263481	−·0001337(67)	+1119(53)	− 39(22)
28	$\bar{5}$·4191943	−·0000262(54)	+1075(14)	− 44(39)
29	$\bar{5}$·8827886	+·0000763(46)	+1026(00)	− 49(14)
30	$\bar{4}$·2395775	+·0001736(11)	+ 972(65)	− 53(35)
31	$\bar{4}$·4235223	+·0002651(69)	+ 915(58)	− 57(07)
32	$\bar{4}$·5449369	+·0003507(01)	+ 855(32)	− 60(26)
33	$\bar{4}$·6334118	+·0004299(44)	+ 792(43)	− 62(89)
34	$\bar{4}$·7012995	+·0005026(89)	+ 727(45)	− 65(02)
35	$\bar{4}$·7549475	+·0005687(84)	+ 660(95)	− 66(50)
36	$\bar{4}$·7980501	+·0006281(31)	+ 593(47)	− 67(48)
37	$\bar{4}$·8329471	+·0006806(86)	+ 525(55)	− 67(91)

TABLE OF VALUES OF χ_3—*continued.*

ϕ	log $(\pm\chi_3)$	χ_3	Δ_1	Δ_2
°				
38	$\bar{4}$·8612122	+·0007264(61)	+ 457(74)	− 67(81)
39	$\bar{4}$·8839544	+·0007655(16)	+ 390(55)	− 67(19)
40	$\bar{4}$·9019828	+·0007979(63)	+ 324(47)	− 66(08)
41	$\bar{4}$·9159058	+·0008239(59)	+ 259(96)	− 64(51)
42	$\bar{4}$·9261915	+·0008437(07)	+ 197(48)	− 62(49)
43	$\bar{4}$·9332071	+·0008574(47)	+ 137(40)	− 60(08)
44	$\bar{4}$·9372466	+·0008654(59)	+ 80(13)	− 57(27)
45	$\bar{4}$·9385475	+·0008680(56)	+ 25(96)	− 54(16)
46	$\bar{4}$·9373057	+·0008655(77)	− 24(79)	− 50(75)
47	$\bar{4}$·9336844	+·0008583(89)	− 71(88)	− 47(09)
48	$\bar{4}$·9278214	+·0008468(79)	− 115(10)	− 43(23)
49	$\bar{4}$·9198345	+·0008314(47)	− 154(32)	− 39(22)
50	$\bar{4}$·9098275	+·0008125(08)	− 189(39)	− 35(07)
51	$\bar{4}$·8978917	+·0007904(81)	− 220(26)	− 30(87)
52	$\bar{4}$·8841103	+·0007657(91)	− 246(90)	− 26(64)
53	$\bar{4}$·8685611	+·0007388(58)	− 269(33)	− 22(42)
54	$\bar{4}$·8513188	+·0007100(99)	− 287(59)	− 18(26)
55	$\bar{4}$·8324575	+·0006799(20)	− 301(79)	− 14(20)
56	$\bar{4}$·8120529	+·0006487(13)	− 312(06)	− 10(27)
57	$\bar{4}$·7901839	+·0006168(56)	− 318(57)	− 6(51)
58	$\bar{4}$.7669366	+·0005847(05)	− 321(51)	− 2(94)
59	$\bar{4}$·7424064	+·0005525(94)	− 321(10)	+ (41)
60	$\bar{4}$·7166988	+·0005208(33)	− 317(61)	+ 3(50)
61	$\bar{4}$·6899344	+·0004897(05)	− 311(29)	+ 6(32)
62	$\bar{4}$·6622497	+·0004594(62)	− 302(43)	+ 8(87)
63	$\bar{4}$·6338018	+·0004303(30)	− 291(32)	+ 11(11)
64	$\bar{4}$·6047677	+·0004025(02)	− 278(29)	+ 13(03)
65	$\bar{4}$·5753491	+·0003761(40)	− 263(62)	+ 14(67)
66	$\bar{4}$·5457711	+·0003513(75)	− 247(64)	+ 15(98)
67	$\bar{4}$·5162823	+·0003283(09)	− 230(67)	+ 16(98)
68	$\bar{4}$·4871534	+·0003070(11)	− 212(98)	+ 17(69)
69	$\bar{4}$·4586715	+·0002875(22)	194(88)	+ 18(10)
70	$\bar{4}$·4311341	+·0002698(57)	− 176(65)	+ 18(23)
71	$\bar{4}$·4048397	+·0002540(03)	− 158(54)	+ 18(11)
72	$\bar{4}$·3800749	+·0002399(25)	− 140(79)	+ 17(75)
73	$\bar{4}$·3571014	+·0002275(63)	− 123(62)	+ 17(17)
74	$\bar{4}$·3361417	+·0002168(41)	− 107(22)	+ 16(40)
75	$\bar{4}$·3173648	+·0002076(65)	− 91(76)	+ 15(46)
76	$\bar{4}$·3008735	+·0001999(28)	− 77(37)	+ 14(38)
77	$\bar{4}$·2867038	+·0001935(10)	− 64(18)	+ 13(19)
78	$\bar{4}$·2748163	+·0001882(85)	− 52(25)	+ 11(93)
79	$\bar{4}$·2651037	+·0001841(21)	− 41(64)	+ 10(61)
80	$\bar{4}$·2573990	+·0001808(83)	− 32(38)	+ 9(26)
81	$\bar{4}$·2514896	+·0001784(39)	− 24(45)	+ 7(93)
82	$\bar{4}$ 2471302	+·0001766(57)	− 17(82)	+ 6(63)
83	$\bar{4}$·2440616	+·0001754(13)	− 12(43)	+ 5(38)
84	$\bar{4}$·2420230	+·0001745(91)	− 8(22)	+ 4(21)
85	$\bar{4}$·2407665	+·0001740(87)	− 5(04)	+ 3(17)
86	$\bar{4}$·2400676	+·0001738(07)	− 2(80)	+ 2(24)
87	$\bar{4}$·2397333	+·0001736(73)	− 1(34)	+ 1(46)
88	$\bar{4}$·2396084	+·0001736(23)	− (50)	+ (84)
89	$\bar{4}$·2395795	+·0001736(12)	− (12)	+ (38)
90	$\bar{4}$·2395775	+·0001736(11)	− (1)	+ (11)

TABLE OF VALUES OF χ_5.

(ϕ)	$\log (\pm\chi_5)$	χ_5	Δ_1	Δ_2
°				
0	$\bar{4}$ 8927900	−·0007812(50)	—	—
1	$\bar{4}$·8907716	−·0007776(28)	+ 36(22)	—
2	$\bar{4}$·8846906	−·0007668(15)	+108(13)	+71(90)
3	$\bar{4}$·8744634	−·0007489(68)	+178(47)	+70(34)
4	$\bar{4}$·8599470	−·0007243(47)	+246(21)	+67(74)
5	$\bar{4}$·8409266	−·0006933(09)	+310(39)	+64(18)
6	$\bar{4}$·8171020	−·0006562(99)	+370(09)	+59(70)
7	$\bar{4}$·7880613	−·0006138(49)	+424(51)	+54(42)
8	$\bar{4}$·7532440	−·0005665(57)	+472(91)	+58(40)
9	$\bar{4}$·7118821	−·0005150(89)	+514(69)	+41(78)
10	$\bar{4}$·6629054	−·0004601(56)	+549(32)	+34(64)
11	$\bar{4}$·6047756	−·0004025(09)	+576(47)	+27(15)
12	$\bar{4}$·5351936	−·0003429(21)	+395(88)	+19(41)
13	$\bar{4}$·4505186	−·0002821(75)	+607(46)	+11(57)
14	$\bar{4}$·3444970	−·0002210(53)	+611(22)	+ 3(76)
15	$\bar{4}$·2049877	−·0001603(20)	+607(33)	− 3(88)
16	$\bar{4}$·0030767	−·0001007(11)	+596(09)	−11(24)
17	$\bar{5}$·6326875	−·0000429(23)	+577(88)	−18(21)
18	$\bar{5}$·0934494	+·0000124(01)	+553(23)	−24(64)
19	$\bar{5}$·8107272	+·0000646(74)	+522(73)	−30(51)
20	$\bar{4}$·0545335	+·0001133(79)	+487(06)	−35(67)
21	$\bar{4}$·1988645	+·0001580(75)	+446(96)	−40(09)
22	$\bar{4}$·2975411	+·0001984(00)	+403(24)	−43(72)
23	$\bar{4}$·3693484	+·0002340(71)	+356(72)	−46(53)
24	$\bar{4}$·4230728	+·0002648(94)	+308(23)	−48(49)
25	$\bar{4}$·4635286	+·0002907(56)	+258(62)	−49(61)
26	$\bar{4}$·4936239	+·0003116(19)	+208(63)	−49(99)
27	$\bar{4}$·5152802	+·0003275(52)	+159(33)	−49(30)
28	$\bar{4}$·5297595	+·0003386(57)	+111(05)	−48(28)
29	$\bar{4}$·5379822	+·0003451(30)	+ 64(73)	−46(31)
30	$\bar{4}$·5405975	+·0003472(14)	+ 20(85)	−43(88)
31	$\bar{4}$·5381198	+·0003452(39)	− 19(75)	−40(60)
32	$\bar{4}$·5308763	+·0003395(29)	− 57(10)	−37(35)
33	$\bar{4}$·5191401	+·0003304(76)	− 90(53)	−33(42)
34	$\bar{4}$·5030997	+·0003184(93)	−119(83)	−29(30)
35	$\bar{4}$·4828826	+·0003040(06)	−144(87)	−25(04)
36	$\bar{4}$·4585690	+·0002874(54)	−165(52)	−20(65)
37	$\bar{4}$·4301924	+·0002692(73)	−181(82)	−16(30)
38	$\bar{4}$·3977466	+·0002498(89)	−193(84)	−12(02)
39	$\bar{4}$·3611876	+·0002297(14)	−201(75)	− 7(91)
40	$\bar{4}$·3204315	+·0002091(37)	−205(77)	− 4(02)
41	$\bar{4}$·2753479	+·0001885(16)	−206(21)	− (45)
42	$\bar{4}$·2257891	+·0001681(86)	−203(30)	+ 2(91)
43	$\bar{4}$·1715210	+·0001484(30)	−197(56)	+ 5(74)
44	$\bar{4}$·1122697	+·0001295(00)	−189(30)	+ 8(26)
45	$\bar{4}$·0476919	+·0001116(07)	−178(93)	+10(37)
46	$\bar{5}$·9773563	+·0000949(20)	−166(87)	+12(05)
47	$\bar{5}$·9007216	+·0000795(65)	−153(55)	+13(33)
48	$\bar{5}$·8171055	+·0000656(30)	−139(34)	+14(20)
49	$\bar{5}$·7256634	+ 0000531(70)	−124(61)	+14(74)
50	$\bar{5}$·6251809	+·0000421(87)	−109(82)	+14(78)
51	$\bar{5}$·5142314	+·0000326(76)	− 95(11)	+14(71)
52	$\bar{5}$·3907754	+·0000245(91)	− 80(85)	+14(26)
53	$\bar{5}$·2519153	+·0000178(61)	− 67(30)	+13(56)
54	$\bar{5}$·0934494	+·0000124(01)	− 54(61)	+12(69)
55	$\bar{6}$·9088385	+·0000081(07)	− 42(94)	+11(66)
56	$\bar{6}$·6871147	+·0000048(65)	− 32(41)	+10(53)
57	$\bar{6}$·4078385	+·0000025(58)	− 23(08)	+ 9(34)

TABLE OF VALUES OF χ_5—*continued.*

ϕ	$\log(\pm\chi_5)$	χ_5	Δ_1	Δ_2
°				
58	$\bar{6}$·0243944	+·0000010(58)	− 15(00)	+ 8(08)
59	$\bar{7}$·3896300	+·0000002(45)	− 8(13)	+ 6(87)
60	−∞	0	− 2(45)	+ 5(67)
61	$\bar{7}$·3196347	+·0000002(09)	+ 2(09)	+ 4(54)
62	$\bar{7}$·8844716	+·0000007(66)	+ 5(58)	+ 3(49)
63	$\bar{6}$·1980458	+·0000015(78)	+ 8(11)	+ 2(54)
64	$\bar{6}$·4079975	+·0000025(59)	+ 9(81)	+ 1(69)
65	$\bar{6}$·5606390	+·0000036(36)	+ 10(78)	+ (97)
66	$\bar{6}$·6766617	+·0000047(50)	+ 11(14)	+ (36)
67	$\bar{6}$·76715435	+·0000058(50)	+ 11(00)	− (13)
68	$\bar{6}$·8387661	+·0000068(99)	+ 10(49)	− (52)
69	$\bar{6}$·8959488	+·0000078(70)	+ 9(71)	− (78)
70	$\bar{6}$·9416395	+·0000087(43)	+ 8(73)	− (98)
71	$\bar{6}$·9781301	+·0000095(09)	+ 7(66)	− 1(07)
72	$\bar{5}$·0070832	+·0000101(64)	+ 6(56)	− 1(11)
73	$\bar{5}$·0298592	+·0000107(12)	+ 5(47)	− 1(08)
74	$\bar{5}$·0475559	+·0000111(57)	+ 4(46)	− 1(02)
75	$\bar{5}$·0610926	+·0000115(10)	+ 3(53)	− (92)
76	$\bar{5}$·0712481	+·0000117(83)	+ 2(72)	− (81)
77	$\bar{5}$·0786911	+·0000119(86)	+ 1(04)	− (69)
78	$\bar{5}$·0839956	+·0000121(34)	+ 2(47)	− (56)
79	$\bar{5}$·0876523	+·0000122(36)	+ 1(03)	− (44)
80	$\bar{5}$·0900732	+·0000123(05)	+ (68)	− (34)
81	$\bar{5}$·0916043	+·0000123(48)	+ (43)	− (25)
82	$\bar{5}$·0925156	+·0000123(74)	+ (26)	− (17)
83	$\bar{5}$·0930207	+·0000123(89)	+ (14)	− (12)
84	$\bar{5}$·0932759	+·0000123(96)	+ (07)	− (07)
85	$\bar{5}$·0933903	+·0000123(99)	+ (03)	− (04)
86	$\bar{5}$·0934338	+·0000124(00)	+ (01)	− (02)
87	$\bar{5}$·0934466	+·0000124(01)	+ (00)	− (01)
88	$\bar{5}$·0934492	+·0000124(01)	+ (00)	− (00)
89	$\bar{5}$·0934493	+·0000124(01)	+ (00)	− (00)
90	$\bar{5}$·0934494	+·0000124(01)	+ (00)	− (00)

TABLE OF VALUES OF χ_7.

ϕ	$\log(\pm\chi_7)$	χ_7	Δ_1	Δ_2
°				
0	$\bar{4}$·7729909	−·0005929(13)	—	—
1	$\bar{4}$·7692636	−·0005878(46)	+ 50(67)	—
2	$\bar{4}$·7579831	−·0005727(74)	+150(72)	+100(06)
3	$\bar{4}$·7388346	−·0005480(68)	+247(05)	+ 96(33)
4	$\bar{4}$·7112524	−·0005143(42)	+337(26)	+ 90(20)
5	$\bar{4}$·6743324	−·0004724(24)	+419(18)	+ 81(92)
6	$\bar{4}$·6266854	−·0004233(36)	+490(88)	+ 71(70)
7	$\bar{4}$·5661551	−·0003682(60)	+550(76)	+ 59(87)
8	$\bar{4}$·4892611	−·0003085(04)	+597(56)	+ 46(81)
9	$\bar{4}$·3899824	−·0002454(61)	+630(43)	+ 32(87)
10	$\bar{4}$·2566463	−·0001805(70)	+648(91)	+ 18(47)
11	$\bar{4}$·0617321	−·0001152(74)	+652(96)	+ 4(05)
12	$\bar{5}$·7073862	−·0000509(78)	+642(96)	− 10(00)
13	$\bar{5}$·0408812	+·0000109(87)	+619(65)	− 23(30)
14	$\bar{5}$·8413740	+·0000694(02)	+584(15)	− 35(50)
15	$\bar{4}$·0905690	+·0001231(88)	+537(86)	− 46(29)
16	$\bar{4}$·2340881	+·0001714(30)	+482(42)	− 55(44)

TABLE OF VALUES OF χ_7—*continued.*

ϕ	log $(\pm\chi_7)$	χ_7	Δ_1	Δ_2
°				
17	$\bar{4}$·3291940	+ ·0002134(00)	+ 419(69)	− 62(73)
18	$\bar{4}$·3954352	+ ·0002485(62)	+ 351(62)	− 68(07)
19	$\bar{4}$·4418311	+ ·0002765(87)	+ 280(24)	− 71(38)
20	$\bar{4}$·4732548	+ ·0002973(41)	+ 207(54)	− 72(70)
21	$\bar{4}$·4926043	+ ·0003108(88)	+ 135(47)	− 72(07)
22	$\bar{4}$·5017047	+ ·0003174(71)	+ 65(83)	− 69(64)
23	$\bar{4}$·5017357	+ ·0003174(94)	+ (23)	− 65(61)
24	$\bar{4}$·4934603	+ ·0003115(02)	− 59(92)	− 60(15)
25	$\bar{4}$·4773422	+ ·0003001(53)	− 113(49)	− 53(56)
26	$\bar{4}$·4536153	+ ·0002841(94)	− 159(58)	− 46(10)
27	$\bar{4}$·4223126	+ ·0002644(32)	− 197(62)	− 38(04)
28	$\bar{4}$·3832747	+ ·0002416(99)	− 227(33)	− 29(71)
29	$\bar{4}$·3361339	+ ·0002168(37)	− 248(62)	− 21(28)
30	$\bar{4}$·2802643	+ ·0001906(62)	− 261(75)	− 13(14)
31	$\bar{4}$·2147019	+ ·0001639(46)	− 267(16)	− 5(40)
32	$\bar{4}$·1379807	+ ·0001373(98)	− 265(48)	+ 1(67)
33	$\bar{4}$·0478425	+ ·0001116(46)	− 257(52)	+ 7(96)
34	$\bar{5}$·9406535	+ ·0000872(27)	− 244(18)	+ 13(34)
35	$\bar{5}$·8101146	+ ·0000645(82)	− 226(45)	+ 17(73)
36	$\bar{5}$·6439284	+ ·0000440(48)	− 205(34)	+ 21(11)
37	$\bar{5}$·4126451	+ ·0000258(61)	− 181(87)	+ 23(47)
38	$\bar{5}$·0068700	+ ·0000101(59)	− 157(02)	+ 24(86)
39	$\bar{6}$·4783225	− ·0000030(08)	− 131(68)	+ 25(34)
40	$\bar{5}$·1359447	− ·0000136(75)	− 106(67)	+ 25(00)
41	$\bar{5}$·3413499	− ·0000219(46)	− 82(70)	+ 23(97)
42	$\bar{5}$·4468500	− ·0000279(80)	− 60(34)	+ 22(36)
43	$\bar{5}$·5049463	− ·0000319(85)	− 39(95)	+ 20(40)
44	$\bar{5}$·5340041	− ·0000341(98)	− 22(13)	+ 17(81)
45	$\bar{5}$·5425420	− ·0000348(77)	− 6(79)	+ 15(34)
46	$\bar{5}$·5351259	− ·0000342(87)	+ 5(90)	+ 12(69)
47	$\bar{5}$·5143971	− ·0000326(89)	+ 15(98)	+ 10(07)
48	$\bar{5}$·4819215	− ·0000303(33)	+ 23(55)	+ 7(57)
49	$\bar{5}$·4385785	− ·0000274(52)	+ 28(81)	+ 5(26)
50	$\bar{5}$·3847545	− ·0000242(52)	+ 32(00)	+ 3(19)
51	$\bar{5}$·3204121	− ·0000209(13)	+ 33(40)	+ 1(40)
52	$\bar{5}$·2450869	− ·0000175(83)	+ 33(30)	− (10)
53	$\bar{5}$·1577914	− ·0000143(81)	+ 32(02)	− 1(28)
54	$\bar{5}$·0567973	− ·0000113(97)	+ 29(84)	− 2(18)
55	$\bar{6}$·9391658	− ·0000086(93)	+ 27(04)	− 2(80)
56	$\bar{6}$·7997191	− ·0000063(05)	+ 23(87)	− 3(17)
57	$\bar{6}$·6284650	− ·0000042(51)	+ 20(55)	− 3(33)
58	$\bar{6}$·4025971	− ·0000025(27)	+ 17(24)	− 3(31)
59	$\bar{6}$·0486660	− ·0000011(19)	+ 14(08)	− 3(15)
60	$-\infty$	0	+ 11(19)	− 2(90)
61	$\bar{7}$·9350331	+ ·0000008(61)	+ 8(61)	− 2(57)
62	$\bar{6}$·1762223	+ ·0000015(00)	+ 6(39)	− 2(22)
63	$\bar{6}$·2911520	+ ·0000019(55)	+ 4(54)	− 1(85)
64	$\bar{6}$·3542091	+ ·0000022(60)	+ 3(05)	− 1(49)
65	$\bar{6}$·3891777	+ ·0000024(50)	+ 1(90)	− 1(16)
66	$\bar{6}$·4070609	+ ·0000025(53)	+ 1(03)	− (87)
67	$\bar{6}$·4140706	+ ·0000025(95)	+ (41)	− (61)
68	$\bar{6}$·4141831	+ ·0000025(95)	+ (01)	− (41)
69	$\bar{6}$·4101432	+ ·0000025(71)	− (24)	− (25)
70	$\bar{6}$·4039127	+ ·0000025(35)	− (37)	− (12)
71	$\bar{6}$·3968830	+ ·0000024(94)	− (41)	− (04)
72	$\bar{6}$·3900030	+ ·0000024(55)	− (39)	+ (01)
73	$\bar{6}$·3838549	+ ·0000024(20)	− (34)	+ (05)
74	$\bar{6}$·3787363	+ ·0000023(92)	− (28)	+ (06)

TABLE OF VALUES OF χ_7—*continued.*

ϕ	log ($\pm\chi_7$)	χ_7	Δ_1	Δ_2
°				
75	$\bar{6}$·3747265	+·0000023(70)	− (22)	+ (06)
76	$\bar{6}$·3717581	+·0000023(54)	− (16)	+ (06)
77	$\bar{6}$·3696785	+·0000023(42)	− (11)	+ (05)
78	$\bar{6}$·3683035	+·0000023(35)	− (07)	+ (04)
79	$\bar{6}$·3674469	+·0000023(30)	− (05)	+ (03)
80	$\bar{6}$·3669474	+·0000023(28)	− (03)	+ (02)
81	$\bar{6}$·3666778	+·0000023(26)	− (01)	+ (01)
82	$\bar{6}$·3665439	+·0000023(26)	− (01)	+ (01)
83	$\bar{6}$·3664842	+·0000023(25)	− (00)	+ (00)
84	$\bar{6}$·3664609	+·0000023(25)	− (00)	+ (00)
85	$\bar{6}$·3664532	+·0000023(25)	− (00)	+ (00)
86	$\bar{6}$·3664512	+·0000023(25)	− (00)	+ (00)
87	$\bar{6}$·3664508	+·0000023(25)	− (00)	+ (00)
88	$\bar{6}$·3664508	+·0000023(25)	− (00)	+ (00)
89	$\bar{6}$·3664508	+·0000023(25)	− (00)	+ (00)
90	$\bar{6}$·3664508	+·0000023(25)	− (00)	+ (00)

On the Establishment of a National Physical Laboratory.—Report of the Committee, consisting of Sir DOUGLAS GALTON (*Chairman*), Lord RAYLEIGH, Lord KELVIN, Sir H. E. ROSCOE, Professors A. W. RÜCKER, R. B. CLIFTON, CAREY FOSTER, A. SCHUSTER, *and* W. E. AYRTON, Dr. W. ANDERSON, Dr. T. E. THORPE, Mr. FRANCIS GALTON, Mr. R. T. GLAZEBROOK, and Professor O. J. LODGE (*Secretary*).

AT the Ipswich Meeting of the British Association held in September 1895 the Committee were reappointed for the purpose of reporting on 'the establishment of a National Physical Laboratory for the more accurate determination of physical constants, and for other quantitative research, and to confer with the Council of the Association.'

It will be convenient in the first place briefly to enumerate the present facilities afforded by the Government, by educational establishments, and by private societies for aiding research in Great Britain, independently of that direct aid which Government Departments are continually furnishing for their own purposes.

The most direct sources of aid given to research are the 4,000*l.* a year given by the Government for research purposes and administered by the Government Grant Committee of the Royal Society; the Donation Fund of the Royal Society derived from its surplus income; the contributions made to research by the British Association; the investigations carried on at the Royal Institution which afford magnificent examples of private munificence in aiding science; the City and Guilds of London Institute; the Royal Commission of the Exhibition of 1851, which devotes 6,000*l.* a year to research scholarships; research committees of various scientific societies; the Clarendon Laboratory at the University of Oxford and the Cavendish Laboratory at Cambridge; the laboratories at Glasgow, Edinburgh, and Aberdeen; the Victoria University; and the larger Colleges not yet incorporated into universities.

The facilities which the laboratories of the Universities and of the

University Colleges afford for research are much reduced by the large demands usually made upon the time and energy of the Professor and the staff for elementary teaching. Nor is a thorough appreciation of the essential connection between research and all higher scientific education so widely diffused in England as it is in Germany, in the United States, and elsewhere.

It must be manifest that the cure for this latter evil is not to be found in the establishment of a National Laboratory, but in such a change of public opinion as will make it possible to reproduce in England the conditions which have long obtained elsewhere. It is to be hoped that the research work now conducted at educational establishments in this country will largely increase in the future. We should earnestly deprecate any divorce between higher teaching and investigation, and should regard anything tending in that direction as a retrograde step.

There are, however, investigations of particular types which have been recognised both in this country and abroad as lying outside the range of effort possible either to an individual or to a great teaching institution.

These may be divided into three principal classes, viz.—

(1) The observations of natural phenomena, the study of which must be prolonged through periods of time longer than the average duration of life ;

(2) The testing and verification of instruments for physical investigation, and the preservation of standards for reference ; and

(3) The systematic accurate determination of physical constants and of numerical data which may be useful either for scientific or industrial purposes.

A laboratory for such purposes would aid and would not compete with laboratories maintained by individuals or institutions for more general physical research, and the reasons for establishing it as a National Institution are much of the same kind as those for maintaining a National Astronomical Observatory.

If England is to keep pace with other countries in scientific progress, it is essential that such an institution should be provided ; and this can scarcely be maintained continuously on an adequate scale, except as a national laboratory supported mainly by Government.

In a paper read at Ipswich on the Reichsanstalt, it was suggested that the Kew Observatory might be extended so as to afford a satisfactory nucleus for a national physical laboratory.

The Kew Observatory, endowed by the late Mr. Gassiot with an income that is now somewhat less than 500*l.* a year, is under the control and management of an unpaid committee appointed by the Council of the Royal Society. It is the central observatory of the Meteorological Office, from which it receives 400*l.* a year ; and it has gradually become an important standardising institution, as well as a recognised base station for observations in meteorology and terrestrial magnetism. Its gross income from these various sources is now somewhat less than 3,000*l.* a year ; but the greater part of this is derived from testing fees, and is almost entirely absorbed in working expenses. The Observatory is, however, at the present time in a thoroughly sound financial position.

The building of the Observatory [1] stands in the Old Deer Park at

[1] See the 'History of Kew Observatory,' by Mr. R. H. Scott, in *Proceedings of the Royal Society*, 1885, vol. xxxix. pp 37 86

Richmond, and is the property of the Government, from whom the Committee hold it at a small rent. They have latterly been permitted to add about five acres to their holding.

The work of the Observatory is very varied, but may be roughly divided into

(1) Routine observation—magnetic, meteorological, and solar.

(2) Experimental work connected with the routine observations and research work generally.

(3) Standardising of between thirty and forty different kinds of instruments, whose number in the gross amounted to 23,000 last year.

The general heads under which most of these instruments fall are

(*a*) Thermometers of all kinds.
(*b*) Barometers, anemometers, and all sorts of meteorological apparatus.
(*c*) Theodolites, sextants, artificial horizons, compasses, and telescopes.
(*d*) Watches and chronometers.
(*e*) Photographic lenses.

Particulars will be found in the annual reports, printed in the 'Proceedings of the Royal Society.'.

The present work of the Observatory is therefore of a character which is strictly consistent with a large portion of the work which would find a place in a national physical laboratory.

Having thus briefly shown what the Kew Observatory now performs, it will be convenient to consider what would be—

(*a*) The function which a national laboratory should fulfil.
(*b*) The system which should be adopted for its control and management.

(*a*) *Functions.*—In addition to the special research work, the scope of which we have already partially indicated, the work of the proposed institution would include an extension of certain branches of work now performed by the Kew Observatory. This work has now for its object the verification of standards for instruments of utility in scientific investigation, but it hardly attempts investigation into the properties of the materials of which they are, or should be, composed. An enlargement of this work to its proper extent would in the case of many delicate standards relieve British investigators from their present dependence upon foreign laboratories. Indeed, in the prosecution of research the necessity for accurate standards is being daily more and more felt. This class of work, as recognised in the Reichsanstalt, comprises, not only comparisons of length, weight, capacity, gravity, sound, light, &c., but variations of conditions due to temperature, vibrations, or other causes, as well as quality of materials in regard to their uses. It is a class of work which is not touched by the Standards Department of the Board of Trade, for this department is restricted by Act of Parliament to the work of making standards of length, weight, and capacity, and of such electrical quantities as may be of use for trade.

(*b*) *Management.*—The present form of government of the Kew Observatory affords a basis upon which the management of the extended laboratories might be safely founded. The present government is by a paid superintendent, who is controlled by an unpaid committee appointed under the Council of the Royal Society. The Committee consists of the leading authorities on the special subjects which form the present work of the laboratory, and they lay down the general lines on which investigations are to go on. It would appear to be desirable that the government of the enlarged Institution should be in the hands of a Committee appointed either as now by the Royal Society alone or in conjunction with one or more of the chief scientific bodies in the country. But it is to be hoped that in addition to this Council of Advice the immediate executive and initiative power would vest in a paid chief or Director of the utmost eminence attainable. Unless such an appointment were made, either an altogether unfair amount of work would be thrown upon some members of the governing committee, or the institution would fail to rise to the highest usefulness.

The present accommodation at Kew Observatory is quite insufficient for the proposed extension of its work; and to carry out the idea suggested will require increased space, increased buildings, and increased staff.

There would probably be no difficulty in obtaining from the Government an extension of space out of the park at Richmond; but the proposal would entail an expenditure of money for new buildings. It would be unfortunate if such expenditure had to be taken from the small fund which Parliament allots to scientific research under the Royal Society, but there can be little doubt that when a satisfactory scheme has been elaborated it will not be unreasonable to ask the Government to assist in providing the necessary buildings.

Additions to buildings require much consideration, and, therefore, as a preliminary to any action a small committee might be asked to draw up a detailed scheme, with the aid of an architect, for an extension of Kew Observatory, having regard to the site and to utilising the present erections upon it.

Since it is difficult to foresee the direction in which a rapidly growing subject like Physics may develop, it is probably wisest to begin with buildings of an adaptable and not too elaborate character, and to stock them with but a moderate supply of the best available apparatus. In such a subject as Physics a large annual maintenance grant is more useful than an extravagant initial equipment which might speedily become antiquated. We would suggest to those whose business it may be hereafter to approach the Government that some such sum as 20,000*l.* or 25,000*l.* would serve to erect a building sufficient for all immediate necessities, and that posterity may be left to increase it as need arises. A sum of 5,000*l.* would provide a fair amount of initial instrumental equipment of a permanent kind, and the rest should be met out of an annual grant.

The commercial testing department may be considered self-supporting, but for secular research and the determination of constants considerable expense would be entailed. This would fall under the heads of salaries, new apparatus, maintenance, warming, lighting, and taxes.

We propose that the head of this National Laboratory should receive 1,200*l.* a year, and we estimate that an annual grant, in addition to the sum at present expended, of 5,000*l.* per annum, and an initial expenditure of 30,000*l.* for buildings and equipment, would do all that is essential to carry out the scheme in a wise and worthy manner.

APPENDIX.

Physikalisch-technische Reichsanstalt.

I. Department (Physical).

			Marks.
1. Value of land (originally presented by W. S. Siemens)			500,000
2. Buildings, &c.:	(*a*) Laboratory building	387,000	
	(*b*) Engine house	50,000	
	(*c*) Administrat building	100,000	
	(*d*) President's house	99,254	
	(*e*) Gardens, drainage, &c.	10,472	
	(*f*) Paving adjacent streets	30,274	
	(*g*) Accumulator house	8,500	
			685,000
3. Furniture, &c., for (*a*), (*b*), and (*c*)			58,000
4. Machines, engines, apparatus of all sorts			82,310

II. Department (Technical).

			Marks.
1. Value of land			373,106
2. Buildings:	(*a*) Principal laboratory building	922,000	
	(*b*) Smaller ditto	218,000	
	(*c*) Engine house	180,000	
	(*d*) House for officials	140,000	
	(*e*) Additional structures, &c.	348,000	
		1,808,000	
In budget 1895–96 reduced by		47,500	
			1,760,500
3. Furniture, &c., for these buildings			81,000
4. Engines, machines, instruments, &c.			363,690
			3,904,106

In round numbers—£200,000 sterling capital expenditure.

Yearly Expenses.

1°. Personal: Salaries, remunerations, &c.	172,357
2°. Repairs to buildings, cost of administration, experimental work	115,000
	287,000

In round numbers—£15,000 sterling a year.

Uniformity of Size of Pages of Scientific Societies' Publications.—Report of the Committee, consisting of Professor SILVANUS P. THOMPSON (*Chairman*), Dr. G. H. BRYAN, Dr. C. V. BURTON, Mr. R. T. GLAZEBROOK, Professor A. W. RÜCKER, Dr. G. JOHNSTONE STONEY, Mr. JAMES SWINBURNE (*Secretary*).

YOUR Committee has prepared a circular for distribution to the various learned societies and academies, pointing out the desirability of all proceedings and transactions being issued in one or other of the standard sizes recommended in the British Association report of last year.

Upon the printing and postage of this circular, which will be distributed early in the winter session, the balance of the Association's grant will be expended.

A proposal having been made by the Council of the Royal Society last year to change the sizes of its 'Proceedings' and 'Transactions' to royal 8vo, thus not only spoiling the historic continuity of its publications, but departing from the already existing uniformity of the majority of British publications, the Chairman of your Committee addressed a remonstrance against the taking of such a step. Happily any further action was rendered needless by the resolve of the Council not to persist in the suggested change.

Of the publications which at the present time depart from the standard sizes proposed in the report of last year, the most important are the 'Sitzungsberichte der Berliner Akademie der Wissenschaften' and the 'Atti della Reale Accademia dei Lincei,' which cannot be bound with either quarto or octavo publications of the ordinary size.

Your Committee desires reappointment without further grant.

Comparison of Magnetic Instruments.—Report of the Committee, consisting of Professor A. W. RÜCKER (*Chairman*), Mr. W. WATSON (*Secretary*), Professor A. SCHUSTER, and Professor H. H. TURNER, *appointed to confer with the Astronomer Royal and the Superintendents of other Observatories with reference to the Comparison of Magnetic Standards with a view of carrying out such Comparison.*

THE work of comparing the magnetic instruments in the different magnetic observatories of the United Kingdom was carried out by Professor Rücker and Mr. Watson during the summer of 1895.

Unfortunately, however, nothing could be done at Greenwich. The peculiar form of the declination needle in use there makes it impossible to place another instrument on the same site. A good deal of iron and a dynamo (carefully shielded by a triple iron case) have recently been introduced into the Observatory, and it is doubtful whether, if another position were chosen in the Observatory grounds, the differences measured might not include some errors due to the presence of these causes of magnetic disturbance.

The authorities of the Observatory hope that it may be possible to arrange for the establishment of a new magnetic Observatory in the Park, and it is most desirable that when this is done the instruments in use at Greenwich and at Kew should be compared.

The work of the Committee has therefore been limited to the comparison of the Kew standards with the instruments in use at Falmouth, Stonyhurst, and Valentia. The Committee have learned with much regret that the magnetic observations at Valentia have now been discontinued. The extreme westerly position of that station makes it one of the most important in Europe for determining the relation between the rate of secular change and geographical position. It is much to be desired that funds may be forthcoming by means of which the work may be resumed and placed on a more permanent footing.

The work of the Falmouth Observatory is also hampered by want of funds. Other buildings are now being erected near to it, and the purchase of a small plot of land, to maintain the isolation which is desirable, is an urgent need. The vertical force-recording instrument has never worked properly, and appears to want expensive alterations.

The observations made by the superintendent, Mr. E. Kitto, are of a very high order of excellence, and it is to be hoped that the Royal Cornwall Polytechnic Society, by which the Observatory was founded, will be able to ensure the maintenance of the magnetic observations under the best conditions.

The instruments used in the comparisons which have been carried out are magnetometer No. 70, by Messrs. Elliott Brothers, and dip circle No. 94, by Dover. They had been used in the recent magnetic survey of the United Kingdom, and are indicated hereafter, as in the published account of that survey, by the letter S.

They were in the first place compared again with the Kew standards at Kew by Professor Rücker. Some changes had been made in No. 70, so that the differences with Kew are not strictly comparable with those which have previously been published. In the case of the dip circle the results were in satisfactory accord with earlier measurements.

The method of comparison of the instruments was altered, so as to diminish the risk of error from variation in the zeros of the self-recording instruments. To this end alternate sets of observations were made with the instruments to be compared at short intervals on the same day, so that the zero lines of the self-recording instruments, by which these observations were reduced to the same time, could not have appreciably altered (see 'Phil. Trans.,' 1896, 188, p. 11).

After the instruments had been compared with those used in the other observatories they were brought back to Kew, and a similar set of comparisons to that above described were made, chiefly by Mr. Watson.

The results of the two sets of experiments are entered in the following tables.

As it was desirable to show that the Kew standard instruments gave normal results when used by Professor Rücker and Mr. Watson, observations were made with them by the Observatory officials on days near those on which the comparisons were carried out, and the readings for the zero lines of the self-registering instruments were determined so as to serve as a check on the corresponding values obtained when the survey instruments were compared with the standards. These observations are indicated by an asterisk.

The most convenient way of making the comparison is as follows:—

Let C_0 and C be the readings of the self-registering instruments at the time when the value of the element was determined by the Kew standard (K) and No. 70 (S′) respectively. Then $K-C_0=Z_0$ and $S'-C=Z$ are the values of the zero line of the self-registering instrument according to the two observations. But if the observation with No. 70 had been made at the same instant as that with the Kew standard, and if the zero line remained unaltered in the interval which actually occurred between the two experiments, the simultaneous values of the element given by the two instruments would have been K and $S=S'+C_0-C$.
$\therefore K-S=K-C_0-(S'-C)=Z_0-Z$.

On October 12 the self-registering instruments at Kew were disturbed, owing to some work which was being done in the room in which they are placed.

The Astronomer Royal was therefore good enough to supply us with the values of the elements given by the Greenwich instruments at the time of our observations at Kew, and by using these instead of C_0 and C the proper allowance for diurnal variation and disturbance could be made.

In the following tables the number of whole degrees in the values of Z_0 and Z is omitted:—

Comparison of Magnetometer No. 70 *with the Kew Standard Instrument. Declination. Observer :* Professor RÜCKER.

Date	Time	Instrument	Declination	Curve (C)	$K-C_0 = Z_0$	$S'-C=Z$	$Z_0-Z= K-S=\beta$
	H. M.		° ′	′	′	′	′
July 6*	12 25	K	17 25·1	54·4	(30·7)	—	—
„ 16	12 10	K	21·3	50·0	31·3	—	—
„ 16	13 12	S	21·3	49·2	—	32·1	−0·8
„ 16	14 45	K	20·3	50·1	30·2	—	—
„ 16	15 2	S	20·7	49·5	—	31·2	−1·0
„ 16	15 54	K	18·5	48·0	30·5	—	—
„ 16	16 36	S	19·0	47·5	—	31·5	−1·0
„ 17*	16 20	K	18·4	47·0	(31·4)	—	—
„ 20	11 42	K	22·2	51·5	30·7	—	—
„ 20	13 9	S	22·8	51·7	—	31·1	−0·4
„ 22	11 42	K	21·1	51·0	30·1	—	—
„ 22	12 55	S	24·0	52·3	—	31·7	−1·6
„ 22	14 24	S	22·4	52·0	—	30·4	—
„ 22	15 2	K	21·8	51·0	30·8	—	+0·4
„ 27*	12 30	K	25·0	53·1	(31·9)	—	—
Mean .	—	—	—	—	30·6	31·3	−0·7

Comparison of Magnetometer No. 70 *with the Kew Standard Instrument. Declination. Observers :* Professor RÜCKER *and* Mr. WATSON.

Date	Time	Instrument	Declination	Curve (C)	$K-C = Z_0$	$S'-C=Z$	$Z_0-Z= K-S=\beta$
	H. M.		° ′	′	′	′	′
Oct. 5*	12 32	K	17 20·1	50·2	(29·9)	—	—
„ 8*	16 9	K	18·9	47·0	(31·9)	—	—
„ 9	11 15	K	21·9	50·9	31·0	—	—
„ 9	11 40	S	21·8	51·0	—	30·8	+0·2
„ 10	10 41	K	15·6	43·7	31·9	—	—
„ 10	11 27	S	18·2	46·7	—	31·5	+0·4
„ 11	15 44	K	18·3	48·1	30·2	—	—
„ 11	16 0	S	18·6	48·0	—	30·6	−0·4
„ 12	10 54	S	18·6	1·3	—	17·3	—
„ 12	12 43	K	21·7	5·2	16·5	—	−0·8
„ 25*	12 29	K	18·7	49·0	(29·7)	—	—
Mean .	—	—	—	—	—	—	−0·1

In the case of the horizontal force the two necessary observations—the vibration and the deflection—are indicated by the letters V and D.

If H′ be the value of the horizontal force deduced from these observations, and if ϕ and ψ are the total increments of the horizontal force due to diurnal variation and disturbance at the time when the deflection and vibration experiments are made,

$$H=H'-(\phi+\psi)/2.$$

If C_1 and C_2 are the curve readings of the self-registering instrument at these times,

$$H+\phi=Z+C_1,\ H+\psi=Z+C_2\ ;$$

$$\therefore H+\frac{\phi+\psi}{2}=H'=Z+\frac{C_1+C_2}{2}.$$

Hence the difference between the uncorrected value of the force, taken without reference to diurnal variation, &c., and the mean of the curve readings at the times of the two observations gives the reading corresponding to the zero line of the instrument.

If, then, we write K and S′ for H′, and C_0 and C for the corresponding means of the curve readings, we have as before :

$$K=Z_0+C_0,\ S'=Z+C\ ;$$
$$\therefore Z_0-Z=K-C_0-(S'-C).$$

Comparison of Magnetometer No. 70 *with the Kew Standard Instrument. Horizontal Force. Observer :* Professor RÜCKER.

Date	Time	Instrument and Observation	H	Curve	Mean Curve	$K-C_0=Z_0$ $\times 10^5$	$S'-C=Z$ $\times 10^5$	$K-S=$ $Z_0-Z=\beta$
	H. M.							
July 18	12 4	K V	0·18280	0·18180	0·18196	+84		
"	14 8	K D		0·18213				−0 00010
"	12 37	S V	0·18290	0·18200	0·18196		+94	
"	15 0	S D		0·18193				
"	15 50	K D	0·18292	0·18206	0·18208	+84		
"	16 32	K V		0·18211				0·00000
"	17 7	S D	0·18295	0·18207	0·18211		+84	
"	17 38	S V		0·18216				
July 20	12 32	K V	0·18289	0·18200	0·18204	+85		
"	15 39	K D		0·18208				+0·00007
"	13 35	S V	0·18282	0·18209	0·18204		+78	
"	14 44	S D		0·18200				−0·00013
"	16 46	K D	0·18286	0·18220	0·18221	+65		
"	17 29	K V		0·18222				
July 22	16 0	K V	0·18301	0·18230	0·18228	+73		
"	16 36	K D		0·18227				
"	17 35	S D	0·18297	0·18221	0·18220		+77	−0·00004
"	18 7	S V		0·18219				
Mean .	—	—	—	—	—	—	—	−0·00004

Comparison of Magnetometer No. 70 *with the Kew Standard Instrument. Horizontal Force. Observers :* Professor RÜCKER *and* Mr. WATSON.

Date	Time	Instrument and Observation	H	Curve	Mean Curve	$K-C_0=Z_0$ $\times 10^5$	$S'-C=Z$ $\times 10^5$	$K-S=$ $Z_0-Z=\beta$
	H. M.							
Oct. 9	14 14	K V	0·18256	0·18190	0 18195	+61		
"	14 52	K D		0·18200				
Oct. 10	12 24	K D		0·18178				
"	15 30	K V	0·18263	0·18200	0·18189	+74		
"	15 56			0·18200				
"	14 18	S D	0·18286	0·18193	0·18196		+90	−0·00016
"	14 51	S V		0·18199				
"	16 18	S V	0·18283	0·18206	0·18200		+83	−0·00022
"	14 18	S D		0·18193				
Oct. 12	11 18	S V	0·18290	0·18200	0·18203		+87	−0·00018
"	11 51	S D		0·18206				
"	13 14	K V	0·18296	0·18223	0·18227	+69		
"	14 52	K D		0·18232				
"	14 10	K V	0·18288	0.18212	0·18222	+66		
"	14 52	K D		0·18232				
"	11 51	S D	0·18300	0·18206	0·18216		+84	−0·00018
"	15 46	S V		0·18227				
Mean .	—	—	—	—	—	—	—	—0·00018

As no observation was made with No. 70 on October 9, and as the earlier observations on October 10 were arranged so that the experiments with No. 70 were interpolated between those made with the Kew instrument, that with No. 70 on October 9 has been combined with the second result obtained on October 10 with the Kew instrument.

These observations indicate that a small change took place in magnetometer No. 70 during the journeys to the other observatories. The differences are not very great, and if we take the mean of the results obtained in July and October, viz. $-0'\cdot4$, for the difference in declination, and $-0\cdot00011$ for that in horizontal force, the final results will only be affected with an uncertainty of $\pm0'\cdot3$ and $\pm0\cdot00007$ respectively.

In the case of the dip observations, experiments were either made with each instrument alternately, or so that the mean time of two observations made with one instrument was nearly the same as the mean time of two corresponding observations made with the other. In this way the effects of diurnal variation, &c., were nearly eliminated. We also, however, determined the dip at the time of each observation from the self-registering records of the horizontal and vertical force.

Comparison of Dip Circle, Dover, No. 94 *with the Kew Standard.*
Observers : Professor Rücker *and* Mr. Watson.

Date	Time	Instrument and Needle	Dip	Curve (C)	$K-C=Z_0$ Needle 1	$K-C=Z_0$ Needle 2	$S'-C=Z$ 3	$S'-C=Z$ 4
	H. M.		° ′	° ′				
July 14 .	12 6	S 3	67 26·6	67 25·9	—	—	+0′·7	—
,, .	12 42	K 1	23·8	25·5	−1′·7	—	—	—
,, .	13 16	S 4	23·7	24·7	—	—	—	−1′·0
,, .	14 46	K 2	23·2	24·9	—	−1′·7	—	—
,, .	15 16	S 3	22·8	24·3	—	—	−1′·5	—
,, .	15 45	K 1	24·9	24·4	+0′·5	—	—	—
,, .	16 21	S 4	23·7	24·7	—	—	—	−1′·0
,, .	16 48	K 2	21·1	24·3	—	−3′·2	—	—
July 25 .	11 38	K 1	24·9	25·2	−0′·3	—	—	—
,, .	12 14	S 3	22·6	24·6	—	—	−2′·0	—
,, .	12 34	S 4	23·7	24·7	—	—	—	−1′·0
,, .	12 55	K 2	23·8	24·7	—	−0′·9	—	—
Mean				—	−0′·5	−1′·9	−0′·9	−1′·0
(K−S=−0′·3)				—	−1′·2		−0′·9	
	H. M.		° ′	° ′				
October 9	15 29	S 3	67 24·4	67 25·2	—	—	−0′·8	—
,,	15 55	K 1	22·3	24·7	−2′·4	—	—	—
October 11	10 39	K 2	23·2	25·4	—	−2′·2	—	—
,,	11 24	S 4	24·0	25·3	—	—	—	−1′·3
,,	11 51	S 3	23·7	25·0	—	—	−1′·3	—
,,	12 22	K 1	20·9	24·7	−3′·8	—	—	—
,,	14 2	K 1	22·3	23·8	−1′·5	—	—	—
,,	14 33	S 4	22·0	24·0	—	—	—	−2′·0
,,	14 51	S 3	21·7	23·5	—	—	−1′·8	—
,,	15 20	K 2	21·5	23·7	—	−2′·2	—	—
Mean				—	−2′·6	−2′·2	−1′·3	−1′·6
(K−S=−0′·9)				—	−2′·4		−1′·5	

The means of six experiments made in July by the first method with No. 94, and of a like number with the Kew instrument, were 67° 23′·8 and 67° 23′·6, so that the average result with No. 94 was 0′·2 higher.

The means of five experiments with each instrument in October were 67° 23′·2 with No. 94 and 67° 22′·0 with the Kew standard, so that the difference had apparently increased by a minute. It will be seen from the above table that these results do not differ much from those obtained when the comparison was made with the recording instruments, and that therefore the method by which they were obtained, which was perforce adopted at Falmouth, Stonyhurst, and Valentia, is sufficiently good for the purpose in view.

In the table each needle is treated separately. The mean of the two differences obtained in July and October, viz.: $\beta = -0'{\cdot}6$, is in close accord with the values obtained in February and October, 1892, when No. 94 was last compared with Kew. They were $-0'{\cdot}4$ and $-0'{\cdot}5$ respectively.

Summing up the results obtained at Kew we get the following table:—

—	$K-S=\beta$
Declination . . .	$-0'{\cdot}4$
Horizontal Force . .	$-0{\cdot}00011$ (C.G.S.)
Dip	$-0'{\cdot}6$

Falmouth Observatory.

The observations at Falmouth were made by Professor Rücker, using the survey instruments, and by the superintendent, Mr. E. Kitto, who used the Falmouth instruments.

On the first day Professor Rücker also used the Falmouth magnetometer to make sure that no personal equation of importance affected the results.

Comparison of Magnetometer No. 70 with the Instrument used in the Falmouth Observatory. . Declination.

Date	Time	Instrument and Observer	Declination	Curve (C)	$F-C=Z_0$	$S'-C=Z$	$F-S=Z_0-Z=\beta$
	H. M.		° ′	° ′	′	′	′
August 6	9 53	F K	18 53·7	18 49·9	3·8 } 4·5	—	
,,	10 33	F R	56·4	51·1	5·3	—	+0·4
,,	15 7	S R	57·8	53·7	—	4·1	
August 7	10 5	F K	53·0	48·5	4·5	—	+0·2
,,	12 14	S R	19 1·2	56·9	—	4·3	
August 8	9 52	F K	18 49·6	45·0	4·6	—	+0·2
,,	12 37	S R	58·0	53·6	—	4·4	
August 9	9 52	F K	52·5	48·0	4·5	—	−1·1
,,	12 0	S R	57·7	52·1	—	5·6	
August 10	9 58	F K	52·2	44·9	7·3	—	+1·9
,,	12 37	S R	59·4	54·0	—	5·4	
August 12	9 53	F K	50·7	44·7	6·0	—	+1·0
,,	12 43	S R	57·0	52·0	—	5·0	
Mean .	—	—	—	—	—	—	+0′·4

Comparison of Magnetometer No. 70 with the Instrument used in the Falmouth Observatory. Horizontal Force.

Date	Time	Instrument and Observation	H	Curve	Mean Curve	$F-C=Z_o$ $\times 10^5$	$S'-C=Z$ $\times 10^5$	$F-S=Z_o-Z$ $=\beta$
	H. M.							
Aug. 6	10 56	F V	—	0·18572	—	—	—	+0·00003
"	12 43	F D	0·18545	0·18569	0·18571	−26		
"	13 24	F D	0·18537	0·18560	0·18566	−29		
"	11 24	F V		0·18578				
"	12 0	F D	0·18534	0·18578	0·18578	[−44]		
"	15 22	S V		0·18594				
"	16 22	S D	0·18555	0·18578	0·18586	—	−31	
Aug. 7	10 44	F V	0·18519	0·18541	0·18542	−23		
"	11 32	F D		0·18543				6
"	12 27	S V	0·18520	0·18549	0·18549	—	−29	
"	13 15	S D		0·18549				
Aug. 8	11 7	F V	0·18521	0·18542	0·18545	−24		
"	11 49	F D		0·18548				13
"	12 50	S V	0·18523	0·18564	0·18565	—	−37	
"	13 34	S D		0·18566				
Aug. 9	10 45	F V	0·18536	0·18558	0·18553	−17		
"	11 11	F D		0·18548				9
"	11 44	S V	0·18529	0·18555	0·18557	—	−28	
"	12 50	S D		0·18559				
Aug. 10	10 55	F V	0·18468	0·18490	0·18492	−24		
"	11 43	F D		0·18494				6
"	12 50	S V	0·18487	0·18514	0·18517	—	−30	
"	13 31	S D		0·18521				
Aug. 12	10 53	F V	0·18500	0·18519	0·18525	−25		
"	11 37	F D		0·18530				5
"	12 50	S V	0·18520	0·18548	0·18550	—	−30	
"	13 31	S D		0·18552				
Mean .	—	—	—	—	—	—	—	+0·00007

Comparison of Dip Circle No. 94 with the Instrument in use in the Falmouth Observatory.

Date	Time	Instrument	Dip	$F-S=\beta$
	H. M.		° ′	′
August 6 . .	17 32	S	66 58·8	−0·8
" . .	18 46	F	66 58·0	
August 7 . .	16 14	S	66 57·1	+1·5
" . .	14 38	F	66 58·6	
August 9 . .	15 25	S	66 57·8	+1·7
" . .	15 28	F	66 59·5	
" . .	17 35	S	66 54·5	+1·9
" . .	17 35	F	66 56·4	
August 10 . .	15 27	S	67 0·6	+0·5
" . .	15 24	F	67 1·1	
August 12 . .	15 32	S	66 59·8	+0·3
" . .	15 28	F	67 0·1	
" . .	16 17	S	66 59·0	+1·6
" . .	16 42	F	67 0·6	
Mean				+1·0

The curves used were those obtained from the self-recording instruments in use in the Observatory; but as the vertical force instrument was not working well the dip circles were directly compared with each other, as in the first method used at Kew. Each of the dips given in the above table is the mean of the two observations, one of which was made with each of the two needles employed with the instruments. The individual observations were in close agreement, and it hardly seems necessary to record them, as the value of β is itself a test of the accuracy of the observations.

Stonyhurst Observatory.

Comparison of Magnetometer No. 70 with the Instrument in use in the Stonyhurst Observatory. Declination.

Date	Time	Instrument	Declination	Curve (C)	$\Sigma - C = Z_0$	$S' - C = Z$	$\Sigma - S = Z_0 - Z = \beta$
	H. M.		° ′	′	′	′	′
August 17	16 46	S	18 36·4	49·4	—	47·0	−2·2
,,	17 35	Σ	34·2	49·4	44·8		
August 18	9 30	Σ	31·1	46·8	44·3		−2·8
,,	9 53	S	35·1	48·0	—	47·1	
August 19	9 30	Σ	35·0	48·1	46·9		−0·4
,,	10 0	S	37·1	49·8	—	47·3	
,,	17 50	Σ	34·3	47·8	46·5		−0·1
,,	18 6	S	34·8	48·2	—	46·6	
August 20	10 0	Σ	31·2	46·9	44·3		−2·4
,,	10 29	S	34·7	48·0	—	46·7	
August 21	9 33	S	34·2	47·2	—	47·0	−1·0
,,	9 56	Σ	34·1	48·1	46·0		
,,	15 48	Σ	35·8	51·0	44·8		−1·8
,,	16 11	S	37·4	50·8	—	46·6	
August 22	9 51	S	33·9	47·1	—	46·8	−1·0
,,	10 8	Σ	34·2	48·4	45·8		
Mean	—	—	—	—	—	—	−1′·5

Comparison of Magnetometer No. 70 with the Instrument in use in the Stonyhurst Observatory. Horizontal Force.

Date	Time	Instrument and Observation	H	Curve	Mean Curve	$\Sigma' - C = Z_0$	$S' - C = Z$	$\Sigma - S = Z_0 - Z = \beta$
	H. M.							
Aug. 16	9 59	Σ V	0·17182	0·00276	0·00277	0·16905		
,,	10 57	Σ D		278				+0·00010
,,	12 6	S V		284				
,,	12 21	S V	0·17175	284	0·00280		0·16895	
,,	12 52	S D		278				
,,	1 22	S V		273				
Aug. 17	11 0	S V	0·17193	284	0·00287		0·16906	
,,	11 28	S D		291				−0·00001
,,	12 22	Σ V	0·17198	285	0·00293	0·16905		
,,	13 58	Σ D		302				
Aug. 19	10 20	S V	0·17162	270	0·00268		0·16894	
,,	10 47	S D		266				+0·00010
,,	12 22	Σ V	0·17190	279	0·00283	0·16904		
,,	14 0	Σ D		293				
Aug. 20	10 56	S V	0·17171	271	0·00271		0·16900	
,,	11 19	S D		272				+0·00003
,,	12 18	Σ V	0·17201	279	0·00298	0·16903		
,,	14 0	Σ D		318				
Aug. 21	10 53	Σ V	0·17186	259	0·00263	0·16923		
,,	11 44	Σ D		268				+0·00017
,,	12 14	S V	0·17177	277	0·00271		0·16906	
,,	12 42	S D		265				
,,	14 38	Σ V	0·17206	293	0·00300	0·16906		
,,	15 21	Σ D		308				−0·00009
,,	16 28	S V	0·17212	300	0·00297		0·16915	
,,	16 51	S D		294				
Mean	—	—	—	—	—	—	—	−0·00005

Comparison between Dip Circle Dover No. 94 and the Instrument in use at the Stonyhurst Observatory.

Date	Time	Instrument	Dip	Σ−S=β
	H. M.		′	′
August 18 . .	16 25	Σ	3·2	−2·9
„ . .	16 27	S	6·1	
August 19 . .	16 1	Σ	2·1	−2·2
„ . .	16 4	S	4·3	
August 20 . .	15 23	Σ	1·2	−2·8
„ . .	15 22	S	4·0	
August 22 . .	11 20	S	6·0	−3·2
„ . .	12 16	Σ	2·8	
Mean . . .	—	—	—	−2′·8

In the account of the observations at Stonyhurst the Observatory instruments are indicated by the letter Σ. The measurements with the survey instruments were made by Mr. Watson; those with the Observatory instruments by Mr. Ronchette, who usually makes the regular observations.

The dip observations were not very satisfactory. The needles used at the Observatory were not in good agreement, and after some trials it was determined to use the needles employed with No. 94 in the experiments with both instruments. Whereas, therefore, the dip observations elsewhere included any difference between the 'bias' of the needles ordinarily used at the Observatory and of dip circle 94, at Stonyhurst this element of error was eliminated, and the comparison was between the dip *circles* only.

In this as in other cases each dip recorded in the table is the mean of the results obtained with the two needles.

Valentia Observatory (Caherciveen).

The observations at Caherciveen were made by Mr. Watson, using the survey instruments, and by the superintendent, Mr. J. E. Cullum, who used the observatory instruments.

Since there are no self-recording instruments at Caherciveen, the observations were made in a slightly different manner from that adopted at the other observatories. A tripod was erected at a distance of about ten yards from the magnet house, and on the line joining the pillar and the fixed mark. Observations were then made simultaneously with one instrument in the magnet house and the other on the tripod outside. The instruments were then interchanged and the observations repeated. By this means it was possible to eliminate the effect of any change in the element and any difference between the value at the two positions. In the case of the dip observations only one set were performed in the above manner; the rest were taken as at the other observatories. The lens of the vibration magnet was found to be loose, as it had not been screwed 'home' after the lens and scale were interchanged when the observatory was moved from Valentia to Caherciveen. It was therefore screwed in as far as it would go, and the moment of inertia was again determined by Mr. Cullum.

Comparison of Magnetometer No. 70 with the Instrument used in the Valentia Observatory (Caherciveen). Declination.

Date	Time	Instrument	Position of Instrument	Declination	V−S (S outside)	V−S (V outside)
	H. M.			° ′	′	′
August 31	11 2	V	M. H.	21 55·7	−2·2	—
		S	outside	21 57·9	—	—
„	11 38	V	M. H.	21 58·5	−2·4	—
		S	outside	22 0·9	—	—
„	12 26	V	outside	22 2·6	—	±0·0
		S	M. H.	22 2·6	—	—
„	13 16	V	outside	22 3·9	—	—
		S	M. H.	22 3·8	—	+0·1
„	13 47	V	outside	22 6·1	—	—
		S	M. H.	22 5·3	—	+0·8
„	13 57	V	outside	22 6·3	—	—
		S	M. H.	22 5·6	—	+0·7
„	15 20	V	M. H.	22 1·4	—	—
		S	outside	22 2·0	−0·6	—
„	15 31	V	M. H.	22 0·3	—	—
		S	outside	22 1·2	−0·9	—
„	15 59	V	M. H.	21 59·2	—	—
		S	outside	21 59·9	−0·7	—
„	16 8	V	M. H.	21 58·3	−0·6	—
		S	outside	21 58·9	—	—
„	16 41	V	outside	21 56·6	—	+0·2
		S	M. H.	21 56·4	—	—
„	16 53	V	outside	21 56·0	—	+0·1
		S	M. H.	21 55·9	—	—
Mean .	—	—	—	—	−1·2	+0·3

$\beta = -0'{\cdot}4$.

Comparison of Magnetometer No. 70 with the Instrument used in the Valentia Observatory (Caherciveen). Horizontal Force.

Date	Time	Instrument	Position of Instrument	H.	V−S × 10⁵ (S outside)	V−S × 10⁵ (V outside)
	H. M. H. M.					
Aug. 30	17 39 to 18 53	V	outside	0·17603	—	−51
		S	M.H.	0·17654	—	—
Aug. 31	17 29 to 18 24	V	outside	0·17615	—	−35
		S	M.H.	0·17650	—	—
„	18 41 to 18 52	V	M.H.	0·17600	−70	—
		S	outside	0·17670	—	—
Sept. 1	15 38 to 16 21	V	M.H.	0·17611	−47	—
		S	outside	0·17658	—	—
„	17 14 to 18 29	V	outside	0·17619	—	−31
		S	M.H.	0·17650	—	—
„	13 21 to 13 31	V	M.H.	0·17602	−39	—
		S	outside	0·17641	—	—
Sept. 2	11 10 to 12 0	V	M.H.	0·17600	−23	—
		S	outside	0·17623	—	—
„	12 13 to 13 3	V	outside	0·17602	—	−28
		S	M.H.	0·17630	—	—
Mean .	.	.	.	.	−45	−36

$\beta = -0{\cdot}00010$.

Comparison of Dip Circle No. 94 with the Instrument in use in the Valentia Observatory (Caherciveen).

Date	Time	Instrument	Position of Instrument	Dip	V − S = β
	H. M.			° ′	′
Aug. 28	16 57	V	M.H.	68 39·7	+0·5
		S	outside	39·2	
"	18 53	V	outside	42·1	+3·5
		S	M.H.	38·6	
Aug. 29	11 43	V	"	41·9	+0·9
	11 37	S	"	41·0	
"	13 29	V	"	41·9	+1·2
	13 23	S	"	40·7	
Sept. 1	12 15	V	"	42·5	±0·0
	12 11	S	"	42·5	
Mean					+1′·2

Summary.

The following is a summary of the results obtained at the different observatories :—

—	K − S	F − S	Σ − S	V − S
Declination	−0′·4	+0′·4	−1′·5	−0′·4
Horizontal Force . .	−0·00011	+0·00007	−0·00005	−0·00040
Dip	−0′·6	+1′·0	−2′·8	+1′·2

By subtraction we eliminate the instruments used in the comparisons, and get the following relations among the instruments of the observatories :

The three figures refer to declination, horizontal force, and dip—in order—the differences of H being expressed in terms of 0·00001 C.G.S. units.

The table is to be read from left to right, thus :—

The declination given by the Kew standard=that given by the Falmouth instrument −0′·8.

—	Kew	Falmouth	Stonyhurst	Valentia
Kew	— — —	−0′·8 −18 −1′·6	+1′·1 −6 +2′·2	0′·0 +29 −1′·8
Falmouth . . .	+0′·8 +18 +1′·6	— — —	+1′·9 +12 +3′·8	+0′·8 +47 −0′·2
Stonyhurst . . .	−1′·1 +6 −2′·2	−1′·9 −12 −3′·8	— — —	−1′·1 +35 −4′·0
Valentia	0′·0 −29 +1′·8	−0′·8 −47 +0′·2	+1′·1 −35 +4′·0	— — —

Mathematical Functions.—Report of the Committee, consisting of Lord RAYLEIGH (*Chairman*), Lord KELVIN, Professor B. PRICE, Mr. J. W. L. GLAISHER, Professor A. G. GREENHILL, Professor W. M. HICKS, Professor P. A. MACMAHON, Lieut.-Colonel ALLAN CUNNINGHAM, *and* Professor A. LODGE (*Secretary*), *appointed for the purpose of calculating Tables of certain Mathematical Functions, and, if necessary, of taking steps to carry out the Calculations, and to publish the results in an accessible form.*

THE first report of the Committee was made in 1889, when they published tables of the Bessel Functions, $I_n(x)$, for integral values of n from 0 to 11, from $x=0$ to 6·0, at intervals of 0·2. The original intention had been to calculate tables of $J_n(x)$ for various values of n, but in 1889 extensive tables of $J_0(x)$ and $J_1(x)$ were published by Dr. Meissel of Kiel, and it was therefore considered advisable to work at tables of $I_n(x)$, which had not previously been calculated, the two classes of functions being connected by the equation—

$$I_n(x)=i^{-n}J_n(i\,x).$$

In 1893 the report of the Committee contained a detailed table of $I_1(x)$ from $x=0$ to 5·100, at intervals of ·001, to nine decimal places, of which the last figure was approximate. A short table of $J_0(x\sqrt{i})$ was also given, to nine decimal places, from $x=0$ to 6·0 at intervals of 0·2.

The present table of $I_0(x)$ is from $x=0$ to 5·100, at intervals of ·001, to nine decimal places, the last figure being approximate, being exactly on the lines of the 1893 table of $I_1(x)$.

The Committee desire to recommend that tables of the Bessel Functions be published by the Association to six decimal places, with a preface giving some of their chief properties.

The Committee have considered a proposition made at the Ipswich meeting last year by Colonel Cunningham, viz. that the British Association should be asked to undertake the publication of a 'New Canon Arithmeticus' which he had already nearly computed. Colonel Cunningham undertook to prepare one copy at his own expense, and asked that the British Association should pay the expense (about 25*l.*) of preparing a second copy and of having the two copies compared and checked; one copy to be Colonel Cunningham's property, one copy to be the property of the Association; the British Association to be asked also to pay the whole cost of printing and publication of the work in a separate 4to. volume (which would be of about same size as Jacobi's 'Canon Arithmeticus'). Colonel Cunningham would undertake to superintend the whole work to completion, and to provide a preface descriptive of the tables.

The Committee propose to recommend the Association ultimately to undertake the publication of Colonel Cunningham's 'New Canon Arithmeticus' as proposed by the author. They desire to be reappointed with a grant of 25*l.* for the purpose of preparing a second copy of Colonel Cunningham's table and of comparing and checking the two copies.

x	I_0x	Difference	x	I_0x	Difference
0·000	1·000 000 000	0,250	0·050	1·000 625 098	25,258
0·001	1·000 000 250	750	0·051	1·000 650 356	25,759
0·002	1·000 001 000	1,250	0·052	1·000 676 115	26,259
0·003	1·000 002 250	750	0·053	1·000 702 374	760
0·004	1·000 004 000	2,250	0·054	1·000 729 134	27,260
0 005	1·000 006 250	750	0·055	1·000 756 394	761
0·006	1·000 009 000	3,250	0·056	1·000 784 155	28,261
0·007	1·000 012 250	750	0·057	1·000 812 416	762
0·008	1·000 016 000	4,250	0·058	1·000 841 178	29,262
0·009	1·000 020 250	750	0 059	1·000 870 440	763
0·010	1·000 025 000	5,250	0·060	1·000 900 203	30,264
0·011	1·000 030 250	5,750	0·061	1·000 930 467	30,764
0·012	1·000 036 000	6,251	0·062	1·000 961 231	31,264
0·013	1·000 042 251	750	0·063	1·000 992 495	766
0·014	1·000 049 001	7,250	0·064	1·001 024 261	32,268
0·015	1·000 056 251	750	0·065	1·001 056 529	767
0·016	1·000 064 001	8,250	0·066	1·001 089 296	33,269
0·017	1·000 072 251	750	0·067	1·001 122 565	770
0·018	1·000 081 001	9,251	0·068	1·001 156 335	34,269
0·019	1·000 090 252	751	0·069	1·001 190 604	771
0·020	1·000 100 003	10,251	0·070	1·001 225 375	35,273
0·021	1·000 110 254	10,751	0·071	1·001 260 648	35,772
0·022	1·000 121 005	11,250	0·072	1·001 296 420	36,274
0·023	1·000 132 255	751	0·073	1·001 332 694	775
0·024	1·000 144 006	12,251	0·074	1·001 369 469	37,276
0·025	1·000 156 257	751	0·075	1·C01 406 745	777
0·026	1·000 169 008	13,251	0·076	1·001 444 522	38,277
0·027	1·000 182 259	751	0·077	1·001 482 799	779
0·028	1·000 196 010	14,251	0·078	1·001 521 578	39,281
0·029	1·000 210 261	752	0·079	1·001 560 859	781
0·030	1·000 225 013	15,252	0·080	1·001 600 640	40,283
0·031	1·000 240 265	15,752	0·081	1·001 640 923	40,784
0·032	1·000 256 017	16,252	0·082	1·001 681 707	41,285
0·033	1·000 272 269	752	0·083	1·001 722 992	786
0·034	1·000 289 021	17,253	0·084	1·001 764 778	42,288
0·035	1·000 306 274	753	0·085	1·001 807 066	789
0·036	1·000 324 027	18,253	0·086	1·001 849 855	43,291
0·037	1·000 342 280	753	0·087	1·001 893 146	791
0·038	1·000 361 033	19.253	0·088	1·001 936 937	44,294
0·039	1·000 380 286	754	0·089	1·001 981 231	794
0·040	1·000 400 040	20,254	0·090	1·002 026 025	45,297
0·041	1·000 420 294	20,754	0·091	1·002 071 322	45,798
0·042	1·000 441 048	21,255	0·092	1·002 117 120	46,299
0·043	1·000 462 303	755	0·093	1·002 163 419	801
0·044	1·000 484 058	22.256	0·094	1·002 210 220	47,303
0·045	1·000 506 314	756	0·095	1·002 257 523	805
0·046	1·000 529 070	23,256	0·096	1·002 305 328	48,306
0·047	1·000 552 326	757	0·097	1·002 353 634	808
0·048	1·000 576 083	24,257	0·098	1·002 402 442	49,309
0·049	1·000 600 340	758	0·099	1·002 451 751	812
0·050	1·000 625 098	25,258	0·100	1·002 501 563	50,313

x	I_0x	Difference	x	I_0x	Difference
0·100	1·002 501 563	50,313	0·150	1·005 632 915	75,463
0·101	1·002 551 876	50,816	0·151	1·005 708 378	75,969
0·102	1·002 602 692	51,317	0·152	1·005 784 347	76,471
0·103	1·002 654 009	820	0·153	1·005 860 818	976
0·104	1·002 705 829	52,321	0·154	1·005 937 794	77,481
0·105	1·002 758 150	823	0·155	1·006 015 275	984
0·106	1·002 810 973	53,325	0·156	1·006 093 259	78,491
0·107	1·002 864 298	828	0·157	1·006 171 750	995
0·108	1·002 918 126	54,330	0·158	1,006 250 745	79,498
0·109	1·002 972 456	832	0·159	1·006 330 243	80,004
0·110	1·003 027 288	55,335	0·160	1·006 410 247	80,510
0·111	1·003 082 623	55,836	0·161	1·006 490 757	81,013
0·112	1·003 138 459	56,340	0·162	1·006 571 770	518
0·113	1·003 194 799	842	0·163	1·006 653 288	82,024
0·114	1·003 251 641	57,343	0·164	1·006 735 312	528
0·115	1·003 308 984	847	0·165	1·006 817 840	83,034
0·116	1·003 366 831	58,349	0·166	1·006 900 874	538
0·117	1·003 425 180	851	0·167	1·006 984 412	84,045
0·118	1·003 484 031	59,354	0·168	1·007 068 457	549
0·119	1·003 543 385	856	0·169	1·007 153 006	85,055
0·120	1·003 603 241	60,360	0·170	1·007 238 061	85,560
0·121	1·003 663 601	60,862	0·171	1·007 323 621	86,065
0·122	1·003 724 463	61,365	0·172	1·007 409 686	572
0·123	1·003 785 828	868	0·173	1·007 496 258	87,076
0·124	1·003 847 696	62,370	0·174	1·007 583 334	583
0·125	1·003 910 066	874	0·175	1·007 670 917	88,089
0·126	1·003 972 940	63,377	0·176	1·007 759 006	593
0·127	1·004 036 317	880	0·177	1·007 847 599	89,100
0·128	1·004 100 197	64,382	0·178	1·007 936 699	607
0·129	1·004 164 579	886	0·179	1·008 026 306	90,111
0·130	1·004 229 465	65,389	0 180	1·008 116 417	90.618
0·131	1·004 294 854	65,893	0·181	1·008 207 035	91,125
0·132	1·004 360 747	66,394	0·182	1·008 298 160	630
0·133	1·004 427 141	899	0·183	1·008 389 790	92,138
0·134	1·004 494 040	67,402	0·184	1·008 481 928	642
0·135	1·004 561 442	906	0·185	1·008 574 570	93,150
0·136	1·004 629 348	68,409	0·186	1·008 667 720	655
0·137	1·004 697 757	914	0·187	1·008 761 375	94,163
0·138	1·004 766 671	69,415	0·188	1·008 855 538	669
0·139	1·004 836 086	920	0·189	1·008 950 207	95,176
0·140	1·004 906 006	70,424	0·190	1·009 045 383	95,683
0·141	1·004 976 430	70,927	0·191	1·009 141 066	96,190
0·142	1·005 047 357	71,431	0·192	1·009 237 256	697
0·143	1·005 118 788	934	0·193	1·009 333 953	97,203
0·144	1·005 190 722	72,439	0·194	1·009 431 156	710
0·145	1·005 263 161	942	0·195	1·009 528 866	98,218
0·146	1·005 336 103	73,448	0·196	1·009 627 084	724
0·147	1·005 409 551	950	0·197	1·009 725 808	99,233
0·148	1·005 483 501	74,455	0·198	1·009 825 041	739
0·149	1·005 557 956	959	0·199	1·009 924 780	100,248
0·150	1·005 632 915	5,463	0·200	1·010 025 028	100,755

x	I_0x	Difference	x	I_0x	Difference
0·200	1·010 025 028	100,755	0·250	1·015 686 141	126,235
0·201	1·010 125 783	101,262	0·251	1·015 812 376	126,747
0·202	1·010 227 045	770	0·252	1·015 939 123	127,259
0·203	1·010 328 815	102,277	0·253	1·016 066 382	771
0·204	1·010 431 092	785	0·254	1·016 194 153	128,283
0·205	1·010 533 877	103,294	0·255	1·016 322 436	795
0·206	1·010 637 171	802	0·256	1·016 451 231	129,308
0·207	1·010 740 973	104,309	0·257	1·016 580 539	820
0·208	1·010 845 282	817	0·258	1·016 710 359	130,333
0·209	1·010 950 099	105,326	0·259	1·016 840 692	845
0·210	1·011 055 425	105,834	0·260	1·016 971 537	131,358
0·211	1·011 161 259	106,342	0·261	1·017 102 895	131,871
0·212	1·011 267 601	851	0·262	1·017 234 766	132,384
0·213	1·011 374 452	107,360	0·263	1·017 367 150	896
0·214	1·011 481 812	867	0·264	1·017 500 046	133,410
0·215	1·011 589 679	108,378	0·265	1·017 633 456	923
0·216	1·011 698 057	885	0·266	1·017 767 379	134,437
0·217	1·011 806 942	109,394	0·267	1·017 901 816	949
0·218	1·011 916 336	903	0·268	1·018 036 765	135,464
0·219	1·012 026 239	110,413	0·269	1·018 172 229	977
0·220	1·012 136 652	110,922	0·270	1·018 308 206	136,491
0·221	1·012 247 574	111,429	0·271	1·018 444 697	137,005
0·222	1·012 359 003	940	0·272	1·018 581 702	518
0·223	1·012 470 943	112,450	0·273	1·018 719 220	138,033
0·224	1·012 583 393	959	0·274	1·018 857 253	547
0·225	1·012 696 352	113,467	0·275	1·018 995 800	139,061
0·226	1·012 809 819	978	0·276	1·019 134 861	575
0·227	1·012 923 797	114,488	0·277	1·019 274 436	140,090
0·228	1·013 038 285	997	0·278	1·019 414 526	604
0·229	1·013 153 282	115,507	0·279	1·019 555 130	141,119
0·230	1·013 268 789	116,018	0·280	1·019 696 249	141,635
0·231	1·013 384 807	116,527	0·281	1·019 837 884	142,148
0·232	1·013 501 334	117,037	0·282	1·019 980 032	664
0·233	1·013 618 371	548	0·283	1·020 122 696	143,179
0·234	1·013 735 919	118,057	0·284	1·020 265 875	694
0·235	1·013 853 976	569	0·285	1·020 409 569	144,209
0·236	1·013 972 545	119,078	0·286	1·020 553 778	725
0·237	1·014 091 623	589	0·287	1·020 698 503	145,241
0·238	1·014 211 212	120,100	0·288	1·020 843 744	756
0·239	1·014 331 312	611	0·289	1·020 989 500	146,271
0·240	1·014 451 923	121,122	0·290	1·021 135 771	146,788
0·241	1·014 573 045	121,632	0·291	1·021 282 559	147,304
0·242	1·014 694 677	122,144	0·292	1·021 429 863	820
0·243	1·014 816 821	654	0·293	1·021 577 683	148,334
0·244	1·014 939 475	123,166	0·294	1·021 726 017	853
0·245	1·015 062 641	677	0·295	1·021 874 870	149,368
0·246	1·015 186 318	124,189	0·296	1·022 024 238	886
0·247	1·015 310 507	700	0·297	1·022 174 124	150,402
0·248	1·015 435 207	125,211	0·298	1·022 324 526	919
0·249	1·015 560 418	723	0·299	1·022 475 445	151,434
0·250	1·015 686 141	126,235	0·300	1·022 626 879	151,952

x	I_0x	Difference	x	I_0x	Difference
0·300	1·022 626 879	151,952	0·350	1·030 860 272	177,956
0·301	1·022 778 831	152,471	0·351	1·031 038 228	178,478
0·302	1·022 931 302	986	0·352	1·031 216 706	179,001
0·303	1·023 084 288	153,504	0·353	1·031 395 707	525
0·304	1·023 237 792	154,021	0·354	1·031 575 232	180,049
0·305	1·023 391 813	539	0·355	1·031 755 281	573
0·306	1·023 546 352	155,057	0·356	1·031 935 854	181,097
0·307	1·023 701 409	575	0·357	1·032 116 951	621
0·308	1·023 856 984	156,091	0·358	1·032 298 572	182,145
0·309	1·024 013 075	611	0·359	1·032 480 717	670
0·310	1·024 169 686	157,129	0·360	1·032 663 387	183,193
0·311	1·024 326 815	157,646	0·361	1·032 846 580	183,720
0·312	1·024 484 461	158,165	0·362	1·033 030 300	184,244
0·313	1·024 642 626	684	0·363	1·033 214 544	767
0·314	1·024 801 310	159,202	0·364	1·033 399 311	185,294
0·315	1·024 960 512	721	0·365	1·033 584 605	819
0·316	1·025 120 233	160,241	0·366	1·033 770 424	186,345
0·317	1·025 280 474	758	0·367	1·033 956 769	869
0·318	1·025 441 232	161,278	0·368	1·034 143 638	187,394
0·319	1·025 602 510	797	0·369	1·034 331 032	922
0·320	1·025 764 307	162,316	0·370	1·034 518 954	188,447
0·321	1·025 926 623	162,836	0·371	1·034 707 401	188,972
0·322	1·026 089 459	163,356	0·372	1·034 896 373	189,500
0·323	1·026 252 815	875	0·373	1·035 085 873	190,025
0·324	1·026 416 690	164,395	0·374	1·035 275 898	552
0·325	1·026 581 085	915	0·375	1·035 466 450	191,079
0·326	1·026 746 000	165,435	0·376	1·035 657 529	606
0·327	1·026 911 435	955	0·377	1·035 849 135	192,132
0·328	1·027 077 390	166,475	0·378	1·036 041 267	658
0·329	1·027 243 865	997	0·379	1·036 233 925	193,187
0·330	1·027 410 862	167,517	0·380	1·036 427 112	193,714
0·331	1·027 578 379	168,036	0·381	1·036 620 826	194,241
0·332	1·027 746 415	559	0·382	1·036 815 067	769
0·333	1·027 914 974	169,079	0·383	1·037 009 836	195,298
0·334	1·028 084 053	600	0·384	1·037 205 134	824
0·335	1·028 253 653	170,121	0·385	1·037 400 958	196,353
0·336	1·028 423 774	643	0·386	1·037 597 311	881
0·337	1·028 594 417	171,164	0·387	1·037 794 192	197,409
0·338	1·028 765 581	686	0·388	1·037 991 601	938
0·339	1·028 937 267	172,207	0·389	1·038 189 539	198,467
0·340	1·029 109 474	172,730	0·390	1·038 388 006	198,996
0·341	1·029 282 204	173,252	0·391	1·038 587 002	199,524
0·342	1·029 455 456	773	0·392	1·038 786 526	200,053
0·343	1·029 629 229	174,295	0·393	1·038 986 579	583
0·344	1·029 803 524	817	0·394	1·039 187 162	201,113
0·345	1·029 978 341	175,342	0·395	1·039 388 275	642
0·346	1·030 153 683	863	0·396	1·039 589 917	202,171
0·347	1·030 329 546	176,385	0·397	1·039 792 088	701
0·348	1·030 505 931	909	0·398	1·039 994 789	203,232
0·349	1·030 682 840	177,432	0·399	1·040 198 021	761
0·350	1·030 860 272	177,956	0·400	1·040 401 782	204,292

x	I_0x	Difference	x	I_0x	Difference
0·400	1·040 401 782	204,292	0·450	1·051 269 338	231,013
0·401	1·040 606 074	204,823	0·451	1·051 500 351	231,552
0·402	1·040 810 897	205,352	0·452	1·051 731 903	232,090
0·403	1·041 016 249	884	0·453	1·051 963 993	629
0·404	1·041 222 133	206,415	0·454	1·052 196 622	233,169
0·405	1·041 428 548	946	0·455	1·052 429 791	708
0·406	1·041 635 494	207,477	0·456	1·052 663 499	234,247
0·407	1·041 842 971	208,009	0·457	1·052 897 746	788
0·408	1·042 050 980	540	0·458	1·053 132 534	235,327
0·409	1·042 259 520	209,072	0·459	1·053 367 861	867
0·410	1·042 468 592	209,604	0·460	1·053 603 728	236,408
0·411	1·042 678 196	210,136	0·461	1·053 840 136	236,948
0·412	1·042 888 332	668	0·462	1·054 077 084	237,488
0·413	1·043 099 000	211,200	0·463	1·054 314 572	238,030
0·414	1·043 310 200	733	0·464	1·054 552 602	570
0·415	1·043 521 933	212,266	0·465	1·054 791 172	239,112
0·416	1·043 734 199	798	0·466	1·055 030 284	653
0·417	1·043 946 997	213,332	0·467	1·055 269 937	240,194
0·418	1·044 160 329	865	0·468	1·055 510 131	736
0·419	1·044 374 194	214,397	0·469	1·055 750 867	241,278
0·420	1·044 588 591	214,932	0·470	1·055 992 145	241,820
0·421	1·044 803 523	215,465	0·471	1·056 233 965	242,362
0·422	1·045 018 988	999	0·472	1·056 476 327	905
0·423	1·045 234 987	216,533	0·473	1·056 719 232	243,447
0·424	1·045 451 520	217,067	0·474	1·056 962 679	990
0·425	1·045 668 587	601	0·475	1·057 206 669	244,533
0·426	1·045 886 188	218,136	0·476	1·057 451 202	245,076
0·427	1·046 104 324	670	0·477	1·057 696 278	620
0·428	1·046 322 994	219,205	0·478	1·057 941 898	246,163
0·429	1·046 542 199	740	0·479	1·058 188 061	707
0·430	1·046 761 939	220,275	0·480	1·058 434 768	247,250
0·431	1·046 982 214	220,811	0·481	1·058 682 018	247,795
0·432	1·047 203 025	221,346	0·482	1·058 929 813	248,339
0·433	1·047 424 371	881	0·483	1·059 178 152	884
0·434	1·047 646 252	222,418	0·484	1·059 427 036	249,428
0·435	1·047 868 670	953	0·485	1·059 676 464	973
0·436	1·048 091 623	223,490	0·486	1·059 926 437	250,518
0·437	1·048 315 113	224,025	0·487	1·060 176 955	251,063
0·438	1·048 539 138	562	0·488	1·060 428 018	608
0·439	1·048 763 700	225,099	0·489	1·060 679 626	252,154
0·440	1·048 988 799	225,636	0·490	1·060 931 780	252,700
0·441	1·049 214 435	226,172	0·491	1·061 184 480	253,246
0·442	1·049 440 607	710	0·492	1·061 437 726	792
0·443	1·049 667 317	227,247	0·493	1·061 691 518	254,339
0·444	1·049 894 564	785	0·494	1·061 945 857	884
0·445	1·050 122 349	228,322	0·495	1·062 200 741	255,432
0·446	1·050 350 671	860	0·496	1·062 456 173	979
0·447	1·050 579 531	229,398	0·497	1·062 712 152	256,525
0·448	1·050 808 929	936	0·498	1·062 968 677	257,073
0·449	1·051 038 865	230,473	0·499	1·063 225 750	621
0·450	1·051 269 338	231,013	0·500	1·063 483 371	258,169

x	I_0x	Difference	x	I_0x	Difference
0·500	1·063 483 371	258,169	0·550	1·077 066 856	285,810
0·501	1·063 741 540	258,716	0·551	1·077 352 666	286,367
0·502	1·064 000 256	259,264	0·552	1·077 639 033	926
0·503	1·064 259 520	812	0·553	1·077 925 959	287,484
0·504	1·064 519 332	260,361	0·554	1·078 213 443	288,044
0·505	1·064 779 693	909	0·555	1·078 501 487	602
0·506	1·065 040 602	261,459	0·556	1·078 790 089	289,161
0·507	1·065 302 061	262,007	0·557	1·079 079 250	721
0·508	1·065 564 068	557	0·558	1·079 368 971	290,281
0·509	1·065 826 625	263,106	0·559	1·079 659 252	840
0·510	1·066 089 731	263,657	0·560	1·079 950 092	291,400
0·511	1·066 353 388	264,205	0·561	1·080 241 492	291,962
0·512	1·066 617 593	756	0·562	1·080 533 454	292,520
0·513	1·066 882 349	265,306	0·563	1·080 825 974	293,082
0·514	1·067 147 655	856	0·564	1·081 119 056	643
0·515	1·067 413 511	266,407	0·565	1·081 412 699	294,204
0·516	1·067 679 918	958	0·566	1·081 706 903	766
0·517	1·067 946 876	267,510	0·567	1·082 001 669	295,328
0·518	1·068 214 386	268,060	0·568	1·082 296 997	889
0·519	1·068 482 446	611	0·569	1·082 592 886	296,451
0·520	1·068 751 057	269,164	0·570	1·082 889 337	297,013
0·521	1·069 020 221	269,715	0·571	1·083 186 350	297,576
0·522	1·069 289 936	270,267	0·572	1·083 483 926	298,139
0·523	1·069 560 203	820	0·573	1·083 782 065	702
0·524	1·069 831 023	271,373	0·574	1·084 080 767	299,265
0·525	1·070 102 396	925	0·575	1·084 380 032	828
0·526	1·070 374 321	272,476	0·576	1·084 679 860	300,392
0·527	1·070 646 797	273,031	0·577	1·084 980 252	955
0·528	1·070 919 828	584	0·578	1·085 281 207	301,521
0·529	1·071 193 412	274,138	0·579	1·085 582 728	302,085
0·530	1·071 467 550	274,691	0·580	1·085 884 813	302,649
0·531	1·071 742 241	275,246	0·581	1·086 187 462	303,213
0·532	1·072 017 487	799	0·582	1·086 490 675	779
0·533	1·072 293 286	276,353	0·583	1·086 794 454	304,345
0·534	1·072 569 639	909	0·584	1·087 098 799	909
0·535	1·072 846 548	277,462	0·585	1·087 403 708	305,475
0·536	1·073 124 010	278,018	0·586	1·087 709 183	306,041
0·537	1·073 402 028	574	0·587	1·088 015 224	607
0·538	1·073 680 602	279,128	0·588	1·088 321 831	307,174
0·539	1·073 959 730	683	0·589	1·088 629 005	740
0·540	1·074 239 413	280,240	0·590	1·088 936 745	308,308
0·541	1·074 519 653	280,796	0·591	1·089 245 053	308,873
0·542	1·074 800 449	281,352	0·592	1·089 553 926	309,442
0·543	1·075 081 801	909	0·593	1·089 863 368	310,009
0·544	1·075 363 710	282,465	0·594	1·090 173 377	578
0·545	1·075 646 175	283,021	0·595	1·090 483 955	311,144
0·546	1·075 929 196	579	0·596	1·090 795 099	714
0·547	1·076 212 775	284,137	0·597	1·091 106 813	312,281
0·548	1·076 496 912	693	0·598	1·091 419 094	851
0·549	1·076 781 605	285,251	0·599	1·091 731 945	313,419
0·550	1·077 066 856	285,810	0·600	1·092 045 364	313,989

x	I_0x	Difference	x	I_0x	Difference
0·600	1·092 045 364	313,989	0·650	1·108 447 111	342,760
0·601	1·092 359 353	314,558	0·651	1·108 789 871	343,342
0·602	1·092 673 911	315,127	0·652	1·109 133 213	923
0·603	1·092 989 038	699	0·653	1·109 477 136	344,506
0·604	1·093 304 737	316,267	0·654	1·109 821 642	345,089
0·605	1·093 621 004	839	0·655	1·110 166 731	672
0·606	1·093 937 843	317,408	0·656	1·110 512 403	346,254
0·607	1·094 255 251	980	0·657	1·110 858 657	838
0·608	1·094 573 231	318,551	0·658	1·111 205 495	347,421
0·609	1·094 891 782	319,122	0·659	1·111 552 916	348,006
0·610	1·095 210 904	319,694	0·660	1·111 900 922	348,590
0·611	1·095 530 598	320,266	0·661	1·112 249 512	349,174
0·612	1·095 850 864	838	0·662	1·112 598 686	759
0·613	1·096 171 702	321,410	0·663	1·112 948 445	350,343
0·614	1·096 493 112	982	0·664	1·113 298 788	930
0·615	1·096 815 094	322,556	0·665	1·113 649 718	351,514
0·616	1·097 137 650	323,128	0·666	1·114 001 232	352,100
0·617	1·097 460 778	702	0·667	1·114 353 332	687
0·618	1·097 784 480	324,275	0·668	1·114 706 019	353,272
0·619	1·098 108 755	849	0·669	1·115 059 291	860
0·620	1·098 433 604	325,423	0·670	1·115 413 151	354,446
0·621	1·098 759 027	325,997	0·671	1·115 767 597	355,033
0·622	1·099 085 024	326,573	0·672	1·116 122 630	620
0·623	1·099 411 597	327,146	0·673	1·116 478 250	356,210
0·624	1·099 738 743	721	0·674	1·116 834 460	795
0·625	1·100 066 464	328,297	0·675	1·117 191 255	357,384
0·626	1·100 394 761	873	0·676	1·117 548 639	972
0·627	1·100 723 634	329,448	0·677	1·117 906 611	358,562
0·628	1·101 053 082	330,024	0·678	1·118 265 173	359,151
0·629	1·101 383 106	600	0·679	1·118 624 324	739
0·630	1·101 713 706	331,176	0·680	1·118 984 063	360,329
0·631	1·102 044 882	331,754	0·681	1·119 344 392	360,919
0·632	1·102 376 636	332,331	0·682	1·119 705 311	361,509
0·633	1·102 708 967	908	0·683	1·120 066 820	362,100
0·634	1·103 041 875	333,485	0·684	1·120 428 920	689
0·635	1·103 375 360	334,063	0·685	1·120 791 609	363,281
0·636	1·103 709 423	641	0·686	1·121 154 890	872
0·637	1·104 044 064	335,220	0·687	1·121 518 762	364,463
0·638	1·104 379 284	797	0·688	1·121 883 225	365,056
0·639	1·104 715 081	336,377	0·689	1·122 248 281	646
0·640	1·105 051 458	336,955	0·690	1·122 613 927	366,239
0·641	1·105 388 413	337,535	0·691	1·122 980 166	366,832
0·642	1·105 725 948	338,114	0·692	1·123 346 998	367,426
0·643	1·106 064 062	695	0·693	1·123 714 424	368,017
0·644	1·106 402 757	339,273	0·694	1·124 082 441	612
0·645	1·106 742 030	856	0·695	1·124 451 053	369,204
0·646	1·107 081 886	340,434	0·696	1·124 820 257	799
0·647	1·107 422 320	341,015	0·697	1·125 190 056	370,393
0·648	1·107 763 335	598	0·698	1·125 560 449	987
0·649	1·108 104 933	342,178	0·699	1·125 931 436	371,582
0·650	1·108 447 111	342,760	0·700	1·126 303 018	372,178

x	I_0x	Difference	x	J_0x	Difference
0·700	1·126 303 018	372,178	0·750	1·145 646 778	402,298
0·701	1·126 675 196	372,773	0·751	1·146 049 076	402,907
0·702	1·127 047 969	373,367	0·752	1·146 451 983	403,517
0·703	1·127 421 336	964	0·753	1·146 855 500	404,128
0·704	1·127 795 300	374,560	0·754	1·147 259 628	739
0·705	1·128 169 860	375,157	0·755	1·147 664 367	405,350
0·706	1·128 545 017	754	0·756	1·148 069 717	962
0·707	1·128 920 771	376,350	0·757	1·148 475 679	406,574
0·708	1·129 297 121	949	0·758	1·148 882 253	407,186
0·709	1·129 674 070	377,544	0·759	1·149 289 439	797
0·710	1·130 051 614	378,144	0·760	1·149 697 236	408,411
0·711	1·130 429 758	378,741	0·761	1·150 105 647	409,023
0·712	1·130 808 499	379,340	0·762	1·150 514 670	638
0·713	1·131 187 839	939	0·763	1·150 924 308	410,251
0·714	1·131 567 778	380,537	0·764	1·151 334 559	865
0·715	1·131 948 315	381,137	0·765	1·151 745 424	411,479
0·716	1·132 329 452	736	0·766	1·152 156 903	412,094
0·717	1·132 711 188	382,337	0·767	1·152 568 997	707
0·718	1·133 093 525	937	0·768	1·152 981 704	413,324
0·719	1·133 476 462	383,537	0·769	1·153 395 028	939
0·720	1·133 859 999	384,136	0·770	1·153 808 967	414,555
0·721	1·134 244 135	384,740	0·771	1·154 223 522	415,170
0·722	1·134 628 875	385,340	0·772	1·154 638 692	789
0·723	1·135 014 215	942	0·773	1·155 054 481	416,403
0·724	1·135 400 157	386,544	0·774	1·155 470 884	417,022
0·725	1·135 786 701	387,146	0·775	1·155 887 906	639
0·726	1·136 173 847	748	0·776	1·156 305 545	418,257
0·727	1·136 561 595	388,351	0·777	1·156 723 802	874
0·728	1·136 949 946	954	0·778	1·157 142 676	419,493
0·729	1·137 338 900	389,558	0·779	1·157 562 169	420,111
0·730	1·137 728 458	390,162	0·780	1·157 982 280	420,730
0·731	1·138 118 620	390,765	0·781	1·158 403 010	421,351
0·732	1·138 509 385	391,370	0·782	1·158 824 361	969
0·733	1·138 900 755	973	0·783	1·159 246 330	422,590
0·734	1·139 292 728	392,580	0·784	1·159 668 920	423,209
0·735	1·139 685 308	393,184	0·785	1·160 092 129	830
0·736	1·140 078 492	790	0·786	1·160 515 959	424,452
0·737	1·140 472 282	394,395	0·787	1·160 940 411	425,071
0·738	1·140 866 677	395,001	0·788	1·161 365 482	694
0·739	1·141 261 678	608	0·789	1·161 791 176	426,316
0·740	1·141 657 286	396,215	0·790	1·162 217 492	426,938
0·741	1·142 053 501	396,821	0·791	1·162 644 430	427,560
0·742	1·142 450 322	397,429	0·792	1·163 071 990	428,183
0·743	1·142 847 751	398,036	0·793	1·163 500 173	807
0·744	1·143 245 787	643	0·794	1·163 928 980	429,430
0·745	1·143 644 430	399,252	0·795	1·164 358 410	430,054
0·746	1·144 043 682	861	0·796	1·164 788 464	678
0·747	1·144 443 543	400,470	0·797	1·165 219 142	431,301
0·748	1·144 844 013	401,078	0·798	1·165 650 443	928
0·749	1·145 245 091	687	0·799	1·166 082 371	432,552
0·750	1·145 646 778	402,298	0·800	1·166 514 923	433,178

x	I_0x	Difference	x	I_0x	Difference
0·800	1·166 514 923	433,178	0·850	1·188 946 902	464,878
0·801	1·166 948 101	433,803	0·851	1·189 411 780	465,520
0·802	1·167 381 904	434,429	0·852	1·189 877 300	466,163
0·803	1·167 816 333	435,057	0·853	1·190 343 463	806
0·804	1·168 251 390	682	0·854	1·190 810 269	467,450
0·805	1·168 687 072	436,310	0·855	1·191 277 719	468,095
0·806	1·169 123 382	936	0·856	1·191 745 814	739
0·807	1·169 560 318	437,565	0·857	1·192 214 553	469,384
0·808	1·169 997 883	438,194	0·858	1·192 683 937	470,029
0·809	1·170 436 077	820	0·859	1·193 153 966	674
0·810	1·170 874 897	439,451	0·860	1·193 624 640	471,321
0·811	1·171 314 348	440,078	0·861	1·194 095 961	471,967
0·812	1·171 754 426	709	0·862	1·194 567 928	472,614
0·813	1·172 195 135	441,339	0·863	1·195 040 542	473,260
0·814	1·172 636 474	967	0·864	1·195 513 802	908
0·815	1·173 078 441	442,599	0·865	1·195 987 710	474,556
0·816	1·173 521 040	443,229	0·866	1·196 462 266	475,204
0·817	1·173 964 269	861	0·867	1·196 937 470	852
0·818	1·174 408 130	444,493	0·868	1·197 413 322	476,501
0·819	1·174 852 623	445,122	0·869	1·197 889 823	477,151
0·820	1·175 297 745	445,756	0·870	1·198 366 974	477,800
0·821	1·175 743 501	446,388	0·871	1·198 844 774	478,450
0·822	1·176 189 889	447,021	0·872	1·199 323 224	479,100
0·823	1·176 636 910	654	0·873	1·199 802 324	750
0·824	1·177 084 564	448,288	0·874	1·200 282 074	480,402
0·825	1·177 532 852	921	0·875	1·200 762 476	481,053
0·826	1·177 981 773	449,555	0·876	1·201 243 529	705
0·827	1·178 431 328	450,190	0·877	1·201 725 234	482,357
0·828	1·178 881 518	824	0·878	1·202 207 591	483,009
0·829	1·179 332 342	451,460	0·879	1·202 690 600	662
0·830	1·179 783 802	452,095	0·880	1·203 174 262	484,316
0·831	1·180 235 897	452,731	0·881	1·203 658 578	484,969
0·832	1·180 688 628	453,367	0·882	1·204 143 547	485,622
0·833	1·181 141 995	454,004	0·883	1·204 629 169	486,277
0·834	1·181 595 999	640	0·884	1·205 115 446	932
0·835	1·182 050 639	455,278	0·885	1·205 602 378	487,587
0·836	1·182 505 917	915	0·886	1·206 089 965	488,242
0·837	1·182 961 832	456,553	0·887	1·206 578 207	898
0·838	1·183 418 385	457,191	0·888	1·207 067 105	489,554
0·839	1·183 875 576	830	0·889	1·207 556 659	490,211
0·840	1·184 333 406	458,469	0·890	1·208 046 870	490,867
0·841	1·184 791 875	459,108	0·891	1·208 537 737	491,525
0·842	1·185 250 983	748	0·892	1·209 029 262	492,183
0·843	1·185 710 731	460,387	0·893	1·209 521 445	840
0·844	1·186 171 118	461,028	0·894	1·210 014 285	493,499
0·845	1·186 632 146	669	0·895	1·210 507 784	494,157
0·846	1·187 093 815	462,309	0·896	1·211 001 941	817
0·847	1·187 556 124	951	0·897	1·211 496 758	495,476
0·848	1·188 019 075	463,593	0·898	1·211 992 234	496,136
0·849	1·188 482 668	464,234	0·899	1·212 488 370	796
0·850	1·188 946 902	464,878	0·900	1·212 985 166	497,457

x	I_0x	Difference	x	I_0x	Difference
0·900	1·212 985 166	497,457	0·950	1·238 675 250	530,980
0·901	1·213 482 623	498,117	0·951	1·239 206 230	531,661
0·902	1·213 980 740	780	0·952	1·239 737 891	532,339
0·903	1·214 479 520	499,441	0·953	1·240 270 230	533,023
0·904	1·214 978 961	500,103	0·954	1·240 803 253	704
0·905	1·215 479 064	766	0·955	1·241 336 957	534,386
0·906	1·215 979 830	501,428	0·956	1·241 871 343	535,068
0·907	1·216 481 258	502,092	0·957	1·242 406 411	752
0·908	1·216 983 350	754	0·958	1·242 942 163	536,435
0·909	1·217 486 104	503,420	0·959	1·243 478 598	537,118
0·910	1·217 989 524	504,084	0·960	1·244 015 716	537,803
0·911	1·218 493 608	504,748	0·961	1·244 553 519	538,488
0·912	1·218 998 356	505,415	0·962	1·245 092 007	539,172
0·913	1·219 503 771	506,080	0·963	1·245 631 179	858
0·914	1·220 009 851	745	0·964	1·246 171 037	540,543
0·915	1·220 516 596	507,412	0·965	1·246 711 580	541,230
0·916	1·221 024 008	508,077	0·966	1·247 252 810	916
0·917	1·221 532 085	746	0·967	1·247 794 726	542,603
0·918	1·222 040 831	509,413	0·968	1·248 337 329	543,291
0·919	1·222 550 244	510,081	0·969	1·248 880 620	979
0·920	1·223 060 325	510,749	0·970	1·249 424 599	544,667
0·921	1·223 571 074	511,419	0·971	1·249 969 266	545,355
0·922	1·224 082 493	512,086	0·972	1·250 514 621	546,045
0·923	1·224 594 579	757	0·973	1·251 060 666	734
0·924	1·225 107 336	513,426	0·974	1·251 607 400	547,424
0·925	1·225 620 762	514,095	0·975	1·252 154 824	548,115
0·926	1·226 134 857	767	0·976	1·252 702 939	805
0·927	1·226 649 624	515,439	0·977	1·253 251 744	549,496
0·928	1·227 165 063	516,109	0·978	1·253 801 240	550,188
0·929	1·227 681 172	780	0·979	1·254 351 428	880
0·930	1·228 197 952	517,453	0·980	1·254 902 308	551,573
0·931	1·228 715 405	518,126	0·981	1·255 453 881	552,265
0·932	1·229 233 531	799	0·982	1·256 006 146	958
0·933	1·229 752 330	519,473	0·983	1·256 559 104	553,652
0·934	1·230 271 803	520,145	0·984	1·257 112 756	554,347
0·935	1·230 791 948	819	0·985	1·257 667 103	555,041
0·936	1·231 312 767	521,495	0·986	1·258 222 144	736
0·937	1·231 834 262	522,169	0·987	1·258 777 880	556,431
0·938	1·232 356 431	844	0·988	1·259 334 311	557,127
0·939	1·232 879 275	523,521	0·989	1·259 891 438	823
0·940	1·233 402 796	524,196	0·990	1·260 449 261	558,520
0·941	1·233 926 992	524,873	0·991	1·261 007 781	559,217
0·942	1·234 451 865	525,550	0·992	1·261 566 998	914
0·943	1·234 977 415	526,228	0·993	1·262 126 912	560,612
0·944	1·235 503 643	905	0·994	1·262 687 524	561,311
0·945	1·236 030 548	527,583	0·995	1·263 248 835	562,009
0·946	1·236 558 131	528,260	0·996	1·263 810 844	709
0·947	1·237 086 391	940	0·997	1·264 373 553	563,408
0·948	1·237 615 331	529,620	0·998	1·264 936 961	564,108
0·949	1·238 144 951	530,299	0·999	1·265 501 069	809
0·950	1·238 675 250	530,980	1·000	1·266 065 878	565,509

x	I_0x	Difference	x	I_0x	Difference
1·000	1·266 065 878	565,509	1·050	1·295 209 055	601,113
1·001	1·266 631 387	566,211	1·051	1·295 810 168	601,839
1·002	1·267 197 598	913	1·052	1·296 412 007	602,562
1·003	1·267 764 511	567,615	1·053	1·297 014 569	603,286
1·004	1·268 332 126	568,318	1·054	1·297 617 855	604,011
1·005	1·268 900 444	569,020	1·055	1·298 221 866	736
1·006	1·269 469 464	724	1·056	1·298 826 602	605,462
1·007	1·270 039 188	570,428	1·057	1·299 432 064	606,189
1·008	1·270 609 616	571,133	1·058	1·300 038 253	915
1·009	1·271 180 749	837	1·059	1·300 645 168	607,643
1·010	1·271 752 586	572,542	1·060	1·301 252 811	608,370
1·011	1·272 325 128	573,248	1·061	1·301 861 181	609,097
1·012	1·272 898 376	954	1·062	1·302 470 278	828
1·013	1·273 472 330	574,661	1·063	1·303 080 106	610,556
1·014	1·274 046 991	575,368	1·064	1·303 690 662	611,285
1·015	1·274 622 359	576,075	1·065	1·304 301 947	612,015
1·016	1·275 198 434	783	1·066	1·304 913 962	746
1·017	1·275 775 217	577,491	1·067	1·305 526 708	613,476
1·018	1·276 352 708	578,200	1·068	1·306 140 184	614,210
1·019	1·276 930 908	909	1·069	1·306 754 394	939
1·020	1·277 509 817	579,620	1·070	1·307 369 333	615,672
1·021	1·278 089 437	580,329	1·071	1·307 985 005	616,405
1·022	1·278 669 766	581,039	1·072	1·308 601 410	617,137
1·023	1·279 250 805	750	1·073	1·309 218 547	872
1·024	1·279 832 555	582,461	1·074	1·309 836 419	618,607
1·025	1·280 415 016	583,174	1·075	1·310 455 026	619,341
1·026	1·280 998 190	885	1·076	1·311 074 367	620,076
1·027	1·281 582 075	584,598	1·077	1 311 694 443	812
1·028	1·282 166 673	585,311	1·078	1·312 315 255	621,548
1·029	1·282 751 984	586,026	1·079	1·312 936 803	622,285
1·030	1·283 338 010	586,739	1·080	1·313 559 088	623,021
1·031	1·283 924 749	587,454	1·081	1·314 182 109	623,759
1·032	1·284 512 203	588,168	1·082	1·314 805 868	624,497
1·033	1·285 100 371	884	1·083	1 315 430 365	625,234
1·034	1·285 689 255	589,599	1·084	1·316 055 599	975
1·035	1·286 278 854	590,316	1·085	1·316 681 574	626,713
1·036	1·286 869 170	591,033	1·086	1·317 308 287	627,454
1·037	1·287 460 203	751	1·087	1·317 935 741	628,194
1·038	1·288 051 954	592,466	1·088	1·318 563 935	935
1·039	1·288 644 420	593,186	1·089	1·319 192 870	629,675
1·040	1·289 237 606	593,904	1·090	1·319 822 545	630,41[illegible]
1·041	1·289 831 510	594,623	1·091	1·320 452 963	631,160
1·042	1·290 426 133	595,343	1·092	1·321 084 123	903
1·043	1·291 021 476	596,062	1·093	1·321 716 026	632,646
1·044	1·291 617 538	783	1·094	1·322 348 672	633,390
1·045	1·292 214 321	597,503	1·095	1·322 982 062	634,133
1·046	1·292 811 824	598,225	1·096	1·323 616 195	879
1·047	1·293 410 049	946	1·097	1·324 251 074	635,625
1·048	1·294 008 995	599,669	1·098	1·324 886 699	636,369
1·049	1·294 608 664	600,391	1·099	1·325 523 068	637,116
1·050	1·295 209 055	601,113	1·100	1 326 160 184	637,862

x	I_0x	Difference	x	I_0x	Difference
1·100	1·326 160 184	637,862	1·150	1·358 978 177	675,826
1·101	1·326 798 046	638,609	1·151	1·359 654 003	676,597
1·102	1·327 436 655	639,357	1·152	1·360 330 600	677,370
1·103	1·328 076 012	640,105	1·153	1·361 007 970	678,143
1·104	1·328 716 117	854	1·154	1·361 686 113	918
1·105	1·329 356 971	641,603	1·155	1·362 365 031	679,690
1·160	1·329 998 574	642,352	1·156	1·363 044 721	680,466
1·107	1·330 640 926	643,102	1·157	1·363 725 187	681,242
1·108	1·331 284 028	853	1·158	1·364 406 429	682,017
1·109	1·331 927 881	644,604	1·159	1·365 088 446	793
1·110	1·332 572 485	645,355	1·160	1·365 771 239	683,570
1·111	1·333 217 840	646,107	1·161	1·366 454 809	684,347
1·112	1·333 863 947	860	1·162	1·367 139 156	685,125
1·113	1·334 510 807	647,613	1·163	1·367 824 281	904
1·114	1·335 158 420	648,366	1·164	1·368 510 185	686,683
1·115	1·335 806 786	649,121	1·165	1·369 196 868	687,461
1·116	1·336 455 907	875	1·166	1·369 884 329	688,243
1·117	1·337 105 782	650,629	1·167	1·370 572 572	689,022
1·118	1·337 756 411	651,385	1·168	1·371 261 594	804
1·119	1·338 407 796	652,142	1·169	1·371 951 398	690,585
1·120	1·339 059 938	652,897	1·170	1·372 641 983	691,367
1·121	1·339 712 835	653,655	1·171	1·373 333 350	692,150
1·122	1·340 366 490	654,412	1·172	1·374 025 500	933
1·123	1·341 020 902	655,170	1·173	1·374 718 433	693,716
1·124	1·341 676 072	928	1·174	1·375 412 149	694,500
1·125	1·342 332 000	656,687	1·175	1·376 106 649	695,286
1·126	1·342 988 687	657,447	1·176	1·376 801 935	696,071
1·127	1·343 646 134	658,207	1·177	1·377 498 006	856
1·128	1·344 304 341	967	1·178	1·378 194 862	697,643
1·129	1·344 963 308	659,728	1·179	1·378 892 505	698,429
1·130	1·345 623 036	660,490	1·180	1·379 590 934	699,217
1·131	1·346 283 526	661,251	1·181	1·380 290 151	700,004
1·132	1·346 944 777	662,014	1·182	1·380 990 155	793
1·133	1·347 606 791	777	1·183	1·381 690 948	701,582
1·134	1·348 269 568	663,540	1·184	1·382 392 530	702,372
1·135	1·348 933 108	664,305	1·185	1·383 094 902	703,162
1·136	1·349 597 413	665,069	1·186	1·383 798 064	953
1·137	1·350 262 482	834	1·187	1·384 502 017	704,743
1·138	1·350 928 316	666,599	1·188	1·385 206 760	705,535
1·139	1·351 594 915	667,366	1·189	1·385 912 295	706,327
1·140	1·352 262 281	668,132	1·190	1·386 618 622	707,120
1·141	1·352 930 413	668,899	1·191	1·387 325 742	707,913
1·142	1·353 599 312	669,667	1·192	1·388 033 655	708,708
1·143	1·354 268 979	670,433	1·193	1·388 742 363	709,501
1·144	1·354 939 412	671,203	1·194	1·389 451 864	710,296
1·145	1·355 610 615	973	1·195	1·390 162 160	711,092
1·146	1·356 282 588	672,741	1·196	1·390 873 252	888
1·147	1·356 955 329	673,512	1·197	1·391 585 140	712,684
1·148	1·357 628 841	674,283	1·198	1·392 297 824	713,481
1·149	1·358 303 124	675,053	1·199	1·393 011 305	714,279
1·150	1·358 978 177	675,826	1·200	1·393 725 584	715,078

x	I_0x	Difference	x	I_0x	Difference
1·200	1·393 725 584	715,078	1·250	1·430 468 718	755,695
1·201	1·394 440 662	715,875	1·251	1·431 224 413	756,521
1·202	1·395 156 537	716,676	1·252	1·431 980 934	757,349
1·203	1·395 873 213	717,474	1·253	1·432 738 283	758,176
1·204	1·396 590 687	718,274	1·254	1·433 496 459	759,005
1·205	1·397 308 961	719,077	1·255	1·434 255 464	835
1·206	1·398 028 038	878	1·256	1·435 015 299	760,665
1·207	1·398 747 916	720,680	1·257	1·435 775 964	761,495
1·208	1·399 468 596	721,482	1·258	1·436 537 459	762,325
1·209	1·400 190 078	722,285	1·259	1·437 299 784	763,157
1·210	1·400 912 363	723,089	1·260	1·438 062 941	763,989
1·211	1·401 635 452	723,893	1·261	1·438 826 930	764,821
1·212	1·402 359 345	724,697	1·262	1·439 591 751	765,655
1·213	1·403 084 042	725,505	1·263	1·440 357 406	766,489
1·214	1·403 809 547	726,308	1·264	1·441 123 895	767,323
1·215	1·404 535 855	727,115	1·265	1·441 891 218	768,158
1·216	1·405 262 970	922	1·266	1·442 659 376	994
1·217	1·405 990 892	728,730	1·267	1·443 428 370	769,830
1·218	1·406 719 622	729,539	1·268	1·444 198 200	770,665
1·219	1·407 449 161	730,346	1·269	1·444 968 865	771,504
1·220	1·408 179 507	731,156	1·270	1·445 740 369	772,343
1·221	1·408 910 663	731,965	1·271	1·446 512 712	773,180
1·222	1·409 642 628	732,777	1·272	1·447 285 892	774,018
1·223	1·410 375 405	733,586	1·273	1·448 059 910	860
1·224	1·411 108 991	734,399	1·274	1·448 834 770	775,699
1·225	1·411 843 390	735,210	1·275	1·449 610 469	776,541
1·226	1·412 578 600	736,023	1·276	1·450 387 010	777,381
1·227	1·413 314 623	835	1·277	1·451 164 391	778,224
1·228	1·414 051 458	737,650	1·278	1·451 942 615	779,067
1·229	1·414 789 108	738,464	1·279	1·452 721 682	909
1·230	1·415 527 572	739,279	1·280	1·453 501 591	780,754
1·231	1·416 266 851	740,094	1·281	1·454 282 345	781,598
1·232	1·417 006 945	910	1·282	1·455 063 943	782,443
1·233	1·417 747 855	741,726	1·283	1·455 846 386	783,289
1·234	1·418 489 581	742,545	1·284	1·456 629 675	784,135
1·235	1·419 232 126	743,361	1·285	1·457 413 810	982
1·236	1·419 975 487	744,179	1·286	1·458 198 792	785,829
1·237	1·420 719 666	998	1·287	1·458 984 621	786,678
1·238	1·421 464 664	745,818	1·288	1·459 771 299	787,527
1·239	1·422 210 482	746,638	1·289	1·460 558 826	788,375
1·240	1·422 957 120	747,458	1·290	1·461 347 201	789,224
1·241	1·423 704 578	748,279	1·291	1·462 136 425	790,076
1·242	1·424 452 857	749,100	1·292	1·462 926 501	927
1·243	1·425 201 957	924	1·293	1·463 717 428	791,780
1·244	1·425 951 881	750,746	1·294	1·464 509 208	792,630
1·245	1·426 702 627	751,569	1·295	1·465 301 838	793,484
1·246	1·427 454 196	752,392	1·296	1·466 095 322	794,338
1·247	1·428 206 588	753,218	1·297	1·466 889 660	795,191
1·248	1·428 959 806	754,044	1·298	1·467 684 851	796,045
1·249	1·429 713 850	868	1·299	1·468 480 896	902
1·250	1·430 468 718	755,695	1·300	1·469 277 798	797,758

x	I_0x	Difference	x	I_0x	Difference
1·300	1·469 277 798	797,758	1·350	1·510 227 098	841,348
1·301	1·470 075 556	798,613	1·351	1·511 068 446	842,235
1·302	1·470 874 169	799,471	1·352	1·511 910 681	843,126
1·303	1·471 673 640	800,329	1·353	1·512 753 807	844,014
1·304	1·472 473 969	801,188	1·354	1·513 597 821	903
1·305	1·473 275 157	802,047	1·355	1·514 442 724	845,794
1·306	1·474 077 204	905	1·356	1·515 288 518	846,687
1·307	1·474 880 109	803,766	1·357	1·516 135 205	847,576
1·308	1·475 683 875	804,627	1·358	1·516 982 781	848,471
1·309	1·476 488 502	805,489	1·359	1·517 831 252	849,363
1·310	1·477 293 991	806,351	1·360	1·518 680 615	850,257
1·311	1·478 100 342	807,213	1·361	1·519 530 872	851,150
1·312	1·478 907 555	808,076	1·362	1·520 382 022	852,047
1·313	1·479 715 631	940	1·363	1·521 234 069	942
1·314	1·480 524 571	809,806	1·364	1·522 087 011	853,839
1·315	1·481 334 377	810,670	1·365	1·522 940 850	854,736
1·316	1·482 145 047	811,536	1·366	1·523 795 586	855,634
1·317	1·482 956 583	812,403	1·367	1·524 651 220	856,532
1·318	1·483 768 986	813,269	1·368	1·525 507 752	857,431
1·319	1·484 582 255	814,138	1·369	1·526 365 183	858,331
1·320	1·485 396 393	815,005	1·370	1·527 223 514	859,231
1·321	1·486 211 398	815,874	1·371	1·528 082 745	860,133
1·322	1·487 027 272	816,744	1·372	1·528 942 878	861,033
1·323	1·487 844 016	817,614	1·373	1·529 803 911	937
1·324	1·488 661 630	818,486	1·374	1·530 665 848	862,839
1·325	1·489 480 116	819,356	1·375	1·531 528 687	863,743
1·326	1·490 299 472	820,229	1·376	1·532 392 430	864,646
1·327	1·491 119 701	821,100	1·377	1·533 257 076	865,553
1·328	1·491 940 801	975	1·378	1·534 122 629	866,458
1·329	1·492 762 776	822,849	1·379	1·534 989 087	867,365
1·330	1·493 585 625	823,723	1·380	1·535 856 452	868,271
1·331	1·494 409 348	824,598	1·381	1·536 724 723	869,179
1·332	1·495 233 946	825,474	1·382	1·537 593 902	870,087
1·333	1·496 059 420	826,351	1·383	1·538 463 989	997
1·334	1·496 885 771	827,227	1·384	1·539 334 986	871,906
1·335	1·497 712 998	828,106	1·385	1·540 206 892	872,817
1·336	1·498 541 104	983	1·386	1·541 079 709	873,727
1·337	1·499 370 087	829,863	1·387	1·541 953 436	874,639
1·338	1·500 199 950	830,743	1·388	1·542 828 075	875,551
1·339	1·501 030 693	831,622	1·389	1·543 703 626	876,464
1·340	1·501 862 315	832,503	1·390	1·544 580 090	877,378
1·341	1·502 694 818	833,386	1·391	1·545 457 468	878,293
1·342	1·503 528 204	834,267	1·392	1·546 335 761	879,207
1·343	1·504 362 471	835,150	1·393	1·547 214 968	880,124
1·344	1·505 197 621	836,033	1·394	1·548 095 092	881,039
1·345	1·506 033 654	919	1·395	1·548 976 131	957
1·346	1·506 870 573	837,802	1·396	1·549 858 088	882,875
1·347	1·507 708 375	838,688	1·397	1·550 740 963	883,793
1·348	1·508 547 063	839,575	1·398	1·551 624 756	884,712
1·349	1·509 386 638	840,460	1·399	1·552 509 468	885,632
1·350	1·510 227 098	841,348	1·400	1·553 395 100	886,552

x	I_0x	Difference	x	I_0x	Difference
1·400	1·553 395 100	886,552	1·450	1·598 864 661	933,460
1·401	1·554 281 652	887,473	1·451	1·599 798 121	934,416
1·402	1·555 169 125	888,396	1·452	1·600 732 537	935,372
1·403	1·556 057 521	889,318	1·453	1·601 667 909	936,330
1·404	1·556 946 839	890,240	1·454	1·602 604 239	937,289
1·405	1·557 837 079	891,165	1·455	1·603 541 528	938,248
1·406	1·558 728 244	892,090	1·456	1·604 479 776	939,207
1·407	1·559 620 334	893,014	1·457	1·605 418 983	940,168
1·408	1·560 513 348	941	1·458	1·606 359 151	941,129
1·409	1·561 407 289	894,868	1·459	1·607 300 280	942,091
1·410	1·562 302 157	895,795	1·460	1·608 242 371	943,053
1·411	1·563 197 952	896,723	1·461	1·609 185 424	944,017
1·412	1·564 094 675	897,651	1·462	1·610 129 441	981
1·413	1·564 992 326	898,580	1·463	1·611 074 422	945,946
1·414	1·565 890 906	899,511	1·464	1·612 020 368	946,912
1·415	1·566 790 417	900,442	1·465	1·612 967 280	947,877
1·416	1·567 690 859	901,373	1·466	1·613 915 157	948,845
1·417	1·568 592 232	902,304	1·467	1·614 864 002	949,811
1·418	1·569 494 536	903,238	1·468	1·615 813 813	950,781
1·419	1·570 397 774	904,172	1·469	1·616 764 594	951,751
1·420	1·571 301 946	905,106	1·470	1·617 716 345	952,720
1·421	1·572 207 052	906,041	1·471	1·618 669 065	953,691
1·422	1·573 113 093	976	1·472	1·619 622 756	954,662
1·423	1·574 020 069	907,913	1·473	1·620 577 418	955,634
1·424	1·574 927 982	908,850	1·474	1·621 533 052	956,607
1·425	1·575 836 832	909,787	1·475	1·622 489 659	957,580
1·426	1·576 746 619	910,726	1·476	1·623 447 239	958,556
1·427	1·577 657 345	911,664	1·477	1·624 405 795	959,530
1·428	1·578 569 009	912,605	1·478	1·625 365 325	960,506
1·429	1·579 481 614	913,546	1·479	1·626 325 831	961,483
1·430	1·580 395 160	914,486	1·480	1·627 287 314	962,460
1·431	1·581 309 646	915,429	1·481	1·628 249 774	963,438
1·432	1·582 225 075	916,370	1·482	1·629 213 212	964,417
1·433	1·583 141 445	917,314	1·483	1·630 177 629	965,396
1·434	1·584 058 759	918,259	1·484	1·631 143 025	966,376
1·435	1·584 977 018	919,203	1·485	1·632 109 401	967,358
1·436	1·585 896 221	920,149	1·486	1·633 076 759	968,339
1·437	1·586 816 370	921,095	1·487	1·634 045 098	969,322
1·438	1·587 737 465	922,042	1·488	1·635 014 420	970,305
1·439	1·588 659 507	989	1·489	1·635 984 725	971,289
1·440	1·589 582 496	923,937	1·490	1·636 956 014	972,274
1·441	1·590 506 433	924,887	1·491	1·637 928 288	973,259
1·442	1·591 431 320	925,836	1·492	1·638 901 547	974,246
1·443	1·592 357 156	926,787	1·493	1·639 875 793	975,232
1·444	1·593 283 943	927,738	1·494	1·640 851 025	976,220
1·445	1·594 211 681	928,689	1·495	1·641 827 245	977,209
1·446	1·595 140 370	929,642	1·496	1·642 804 454	978,198
1·447	1·596 070 012	930,596	1·497	1·643 782 652	979,189
1·448	1·597 000 608	931,550	1·498	1·644 761 841	980,178
1·449	1·597 932 158	932,503	1·499	1·645 742 019	981,171
1·450	1·598 864 661	933,460	1·500	1·646 723 190	982,163

x	I_0x	Difference	x	I_0x	Difference
1·500	1·646 723 190	982,163	1·550	1·697 062 826	1,032,758
1·501	1·647 705 353	983,156	1·551	1·698 095 584	1,033,791
1·502	1·648 688 509	984,149	1·552	1·699 129 375	34,822
1·503	1·649 672 658	985,144	1·553	1·700 164 197	35,856
1·504	1·650 657 802	986,139	1·554	1·701 200 053	36,891
1·505	1·651 643 941	987,136	1·555	1·702 236 944	37,926
1·506	1·652 631 077	988,132	1·556	1·703 274 870	38,962
1·507	1·653 619 209	989,130	1·557	1·704 313 832	39,998
1·508	1·654 608 339	990,128	1·558	1·705 353 830	41,035
1·509	1·655 598 467	991,127	1·559	1·706 394 865	42,074
1·510	1·656 589 594	992,127	1·560	1·707 436 939	1,043,113
1·511	1·657 581 721	993,128	1·561	1·708 480 052	1,044,153
1·512	1·658 574 849	994,129	1·562	1·709 524 205	45,194
1·513	1·659 568 978	995,132	1·563	1·710 569 399	46,236
1·514	1·660 564 110	996,134	1·564	1·711 615 635	47,278
1·515	1·661 560 244	997,139	1·565	1·712 662 913	48,321
1·516	1·662 557 383	998,142	1·566	1·713 711 234	49,364
1·517	1·663 555 525	999,148	1·567	1·714 760 598	50,409
1·518	1·664 554 673	1,000,155	1·568	1·715 811 007	51,455
1·519	1·665 554 828	1,160	1·569	1·716 862 462	52,502
1·520	1·666 555 988	1,002,168	1·570	1·717 914 964	1,053,549
1·521	1·667 558 156	1,003,176	1·571	1·718 968 513	1,054,596
1·522	1·668 561 332	4,186	1·572	1·720 023 109	55,646
1·523	1·669 565 518	5,196	1·573	1·721 078 755	56,695
1·524	1·670 570 714	6,206	1·574	1·722 135 450	57,745
1·525	1·671 576 920	7,218	1·575	1·723 193 195	58,797
1·526	1·672 584 138	8,230	1·576	1·724 251 992	59,849
1·527	1·673 592 368	9,243	1·577	1·725 311 841	60,902
1·528	1·674 601 611	10,257	1·578	1·726 372 743	61,956
1·529	1·675 611 868	11,271	1·579	1·727 434 699	63,010
1·530	1·676 623 139	1,012,287	1·580	1·728 497 709	1,064,067
1·531	1·677 635 426	1,013,303	1·581	1·729 561 776	1,065,121
1·532	1·678 648 729	14,319	1·582	1·730 626 897	66,178
1·533	1·679 663 048	15,337	1·583	1·731 693 075	67,237
1·534	1·680 678 385	16,356	1·584	1·732 760 312	68,296
1·535	1·681 694 741	17,375	1·585	1·733 828 608	69,355
1·536	1·682 712 116	18,395	1·586	1·734 897 963	70,415
1·537	1·683 730 511	19,415	1·587	1·735 968 378	71,476
1·538	1·684 749 926	20,437	1·588	1·737 039 854	72,538
1·539	1·685 770 363	21,460	1·589	1·738 112 392	73,601
1·540	1·686 791 823	1,022,483	1·590	1·739 185 993	1,074,664
1·541	1·687 814 306	1,023,507	1·591	1·740 260 657	1,075,729
1·542	1·688 837 813	24,532	1·592	1·741 336 386	76,795
1·543	1·689 862 345	25,557	1·593	1·742 413 181	77,860
1·544	1·690 887 902	26,584	1·594	1·743 491 041	78,927
1·545	1·691 914 486	27,611	1·595	1·744 569 968	79,996
1·546	1·692 942 097	28,638	1·596	1·745 649 964	81,064
1·547	1·693 970 735	29,668	1·597	1·746 731 028	82,133
1·548	1·695 000 403	30,696	1·598	1·747 813 161	83,204
1·549	1·696 031 099	31,727	1·599	1·748 896 365	84,275
1·550	1·697 062 826	1,032,758	1·600	1·749 980 640	1,085,347

x	I_0x	Difference	x	I_0x	Difference
1·600	1·749 980 640	1,085,347	1·650	1·805 578 834	1,140,033
1·601	1·751 065 987	1,086,419	1·651	1·806 718 867	1,141,149
1·602	1·752 152 406	87,493	1·652	1·807 860 016	142,266
1·603	1·753 239 899	88,568	1·653	1·809 002 282	143,384
1·604	1·754 328 467	89,643	1·654	1·810 145 666	144,502
1·605	1·755 418 110	90,719	1·655	1·811 290 168	145,621
1·606	1·756 508 829	91,796	1·656	1·812 435 789	146,741
1·607	1·757 600 625	92,874	1·657	1·813 582 530	147,863
1·608	1·758 693 499	93,953	1·658	1·814 730 393	148,986
1·609	1·759 787 452	95,033	1·659	1·815 879 379	150,108
1·610	1·760 882 485	1,096,113	1·660	1·817 029 487	1,151,231
1·611	1·761 978 598	1,097,194	1·661	1·818 180 718	1,152,356
1·612	1·763 075 792	98,276	1·662	1·819 333 074	153,482
1·613	1·764 174 068	99,359	1·663	1·820 486 556	154,610
1·614	1·765 273 427	100,443	1·664	1·821 641 166	155,736
1·615	1·766 373 870	101,528	1·665	1·822 796 902	156,864
1·616	1·767 475 398	102,613	1·666	1·823 953 766	157,994
1·617	1·768 578 011	103,699	1·667	1·825 111 760	159,124
1·618	1·769 681 710	104,786	1·668	1·826 270 884	160,255
1·619	1·770 786 496	105,875	1·669	1·827 431 139	161,386
1·620	1·771 892 371	1,106,964	1·670	1·828 592 525	1,162,520
1·621	1·772 999 335	1,108,053	1·671	1·829 755 045	1,163,654
1·622	1·774 107 388	109,144	1·672	1·830 918 699	164,787
1·623	1·775 216 532	110,236	1·673	1·832 083 486	165,924
1·624	1·776 326 768	111,327	1·674	1·833 249 410	167,060
1·625	1·777 438 095	112,421	1·675	1·834 416 470	168,197
1·626	1·778 550 516	113,515	1·676	1·835 584 667	169,334
1·627	1·779 664 031	114,610	1·677	1·836 754 001	170,475
1·628	1·780 778 641	115,706	1·678	1·837 924 476	171,615
1·629	1·781 894 347	116,803	1·679	1·839 096 091	172,755
1·630	1·783 011 150	1,117,900	1·680	1·840 268 846	1,173,897
1·631	1·784 129 050	1,118,998	1·681	1·841 442 743	1,175,040
1·632	1·785 248 048	120,097	1·682	1·842 617 783	176,184
1·633	1·786 368 145	121,198	1·683	1·843 793 967	177,328
1·634	1·787 489 343	122,299	1·684	1·844 971 295	178.474
1·635	1·788 611 642	123,401	1·685	1·846 149 769	179,621
1·636	1·789 735 043	124,504	1·686	1·847 329 390	180,767
1·637	1·790 859 547	125,606	1·687	1·848 510 157	181,916
1·638	1·791 985 153	126,711	1·688	1·849 692 073	183,065
1·639	1·793 111 864	127,817	1·689	1·850 875 138	184,216
1·640	1·794 239 681	1,128,923	1·690	1·852 059 354	1,185,366
1·641	1·795 368 604	1,130,030	1·691	1·853 244 720	1,186,517
1·642	1·796 498 634	131,138	1·692	1·854 431 237	187,671
1·643	1·797 629 772	132,246	1·693	1·855 618 908	188,825
1·644	1·798 762 018	133,357	1·694	1·856 807 733	189,980
1·645	1·799 895 375	134,467	1·695	1·857 997 713	191,135
1·646	1·801 029 842	135,579	1·696	1·859 188 848	192,291
1·647	1·802 165 421	136,691	1·697	1·860 381 139	193,449
1·648	1·803 302 112	137,804	1·698	1·861 574 588	194,607
1·649	1·804 439 916	138,918	1·699	1·862 769 195	195,767
1·650	1·805 578 834	1,140,033	1·700	1·863 964 962	1,196,927

x	I_0x	Difference	x	I_0x	Difference
1·700	1·863 964 962	1,196,927	1·750	1·925 252 154	1,256,142
1·701	1·865 161 889	1,198,088	1·751	1·926 508 296	1,257,350
1·702	1·866 359 977	199,251	1·752	1·927 765 646	258,560
1·703	1·867 559 228	200,412	1·753	1·929 024 206	259,771
1·704	1·868 759 640	201,577	1·754	1·930 283 977	260,982
1·705	1·869 961 217	202,742	1·755	1·931 544 959	262,196
1·706	1·871 163 959	203,908	1·756	1·932 807 155	263,409
1·707	1·872 367 867	205,074	1·757	1·934 070 564	264,623
1·708	1·873 572 941	206,242	1·758	1·935 335 187	265,839
1·709	1·874 779 183	207,411	1·759	1·936 601 026	267,056
1·710	1·875 986 594	1,208,581	1·760	1·937 868 082	1,268,273
1·711	1·877 195 175	1,209,751	1·761	1·939 136 355	1,269,493
1·712	1·878 404 926	210,922	1·762	1·940 405 848	270,712
1·713	1·879 615 848	212,094	1·763	1·941 676 560	271,932
1·714	1·880 827 942	213,269	1·764	1·942 948 492	273,153
1·715	1·882 041 211	214,442	1·765	1·944 221 645	274,376
1·716	1·883 255 653	215,617	1·766	1·945 496 021	275,600
1·717	1·884 471 270	216,793	1·767	1·946 771 621	276,825
1·718	1·885 688 063	217,971	1·768	1·948 048 446	278,049
1·719	1·886 906 034	219,149	1·769	1·949 326 495	279,276
1·720	1·888 125 183	1,220,328	1·770	1·950 605 771	1,280,504
1·721	1·889 345 511	1,221,507	1·771	1·951 886 275	1,281,733
1·722	1·890 567 018	222,689	1·772	1·953 168 008	282,962
1·723	1·891 789 707	223,870	1·773	1·954 450 970	284,192
1·724	1·893 013 577	225,053	1·774	1·955 735 162	285,424
1·725	1·894 238 630	226,236	1·775	1·957 020 586	286,656
1·726	1·895 464 866	227,422	1·776	1·958 307 242	287,890
1·727	1·896 692 288	228,608	1·777	1·959 595 132	289,124
1·728	1·897 920 896	229,793	1·778	1·960 884 256	290,360
1·729	1·899 150 689	230,981	1·779	1·962 174 616	291,596
1·730	1·900 381 670	1,232,170	1·780	1·963 466 212	1,292,834
1·731	1·901 613 840	1,233,359	1·781	1·964 759 046	1,294,072
1·732	1·902 847 199	234,549	1·782	1·966 053 118	295,312
1·733	1·904 081 748	235,741	1·783	1·967 348 430	296,552
1·734	1·905 317 489	236,933	1·784	1·968 644 982	297,794
1·735	1·906 554 422	238,127	1·785	1·969 942 776	299,036
1·736	1·907 792 549	239,321	1·786	1·971 241 812	300,280
1·737	1·909 031 870	240,516	1·787	1·972 542 092	301,525
1·738	1·910 272 386	241,712	1·788	1·973 843 617	302,771
1·739	1·911 514 098	242,909	1·789	1·975 146 388	304,016
1·740	1·912 757 007	1,244,107	1·790	1·976 450 404	1,305,264
1·741	1·914 001 114	1,245,307	1·791	1·977 755 668	1,306,513
1·742	1·915 246 421	246,506	1·792	1·979 062 181	307,763
1·743	1·916 492 927	247,707	1·793	1·980 369 944	309,012
1·744	1·917 740 634	248,909	1·794	1·981 678 956	310,265
1·745	1·918 989 543	250,113	1·795	1·982 989 221	311,518
1·746	1·920 239 656	251,316	1·796	1·984 300 739	312,772
1·747	1·921 490 972	252,521	1·797	1·985 613 511	314,026
1·748	1·922 743 493	253,727	1·798	1·986 927 537	315,282
1·749	1·923 997 220	254,934	1·799	1·988 242 819	316,538
1·750	1·925 252 154	1,256,142	1·800	1·989 559 357	1,317,796

x	I_0x	Difference	x	I_0x	Difference
1·800	1·989 559 357	1,317,796	1·850	2·057 011 587	1,382,015
1·801	1·990 877 153	1,319,055	1·851	2·058 393 602	1,383,326
1·802	1·992 196 208	320,315	1·852	2·059 776 928	384,639
1·803	1·993 516 523	321,576	1·853	2·061 161 567	385,952
1·804	1·994 838 099	322,838	1·854	2·062 547 519	387,267
1·805	1·996 160 937	324,101	1·855	2·063 934 786	388,583
1·806	1·997 485 038	325,364	1·856	2·065 323 369	389,900
1·807	1·998 810 402	326,629	1·857	2·066 713 269	391,218
1·808	2·000 137 031	327,896	1·858	2·068 104 487	392,537
1·809	2·001 464 927	329,163	1·859	2·069 497 024	393,856
1·810	2·002 794 090	1,330,431	1·860	2·070 890 880	1,395,178
1·811	2·004 124 521	1,331,700	1·861	2·072 286 058	1,396,500
1·812	2·005 456 221	332,970	1·862	2·073 682 558	397,823
1·813	2·006 789 191	334,242	1·863	2·075 080 381	399,148
1·814	2·008 123 433	335,513	1·864	2·076 479 529	400,474
1·815	2·009 458 946	336,787	1·865	2·077 880 003	401,799
1·816	2·010 795 733	338,062	1·866	2·079 281 802	403,128
1·817	2·012 133 795	339,336	1·867	2·080 684 930	404,456
1·818	2·013 473 131	340,613	1·868	2·082 089 386	405,786
1·819	2·014 813 744	341,891	1·869	2·083 495 172	407,117
1·820	2·016 155 635	1,343,169	1·870	2·084 902 289	1,408,450
1·821	2·017 498 804	1,344,448	1·871	2·086 310 739	1,409,782
1·822	2·018 843 252	345,729	1·872	2·087 720 521	411,117
1·823	2·020 188 981	347,011	1·873	2·089 131 638	412,452
1·824	2·021 535 992	348,294	1·874	2·090 544 090	413,788
1·825	2·022 884 286	349,577	1·875	2·091 957 878	415,127
1·826	2·024 233 863	350,862	1·876	2·093 373 005	416,464
1·827	2·025 584 725	352,147	1·877	2·094 789 469	417,805
1·828	2·026 936 872	353,435	1·878	2·096 207 274	419,146
1·829	2·028 290 307	354,723	1·879	2·097 626 420	420,488
1·830	2·029 645 030	1,356,012	1·880	2·099 046 908	1,421,831
1·831	2·031 001 042	1,357,301	1·881	2·100 468 739	1,423,175
1·832	2·032 358 343	358,593	1·882	2·101 891 914	424,520
1·833	2·033 716 936	359,885	1·883	2·103 316 434	425,867
1·834	2·035 076 821	361,179	1·884	2·104 742 301	427,214
1·835	2·036 438 000	362,472	1·885	2·106 169 515	428,563
1·836	2·037 800 472	363,768	1·886	2·107 598 078	429,912
1·837	2·039 164 240	365,065	1·887	2·109 027 990	431,264
1·838	2·040 529 305	366,362	1·888	2·110 459 254	432,615
1·839	2·041 895 667	367,660	1·889	2·111 891 869	433,969
1·840	2·043 263 327	1,368,960	1·890	2·113 325 838	1,435,322
1·841	2·044 632 287	1,370,261	1·891	2·114 761 160	1,436,679
1·842	2·046 002 548	371,562	1·892	2·116 197 839	438,035
1·843	2·047 374 110	372,866	1·893	2·117 635 874	439,392
1·844	2·048 746 976	374,169	1·894	2·119 075 266	440,752
1·845	2·050 121 145	375,474	1·895	2·120 516 018	442,110
1·846	2·051 496 619	376,780	1·896	2·121 958 128	443,472
1·847	2·052 873 399	378,087	1·897	2·123 401 600	444,835
1·848	2·054 251 486	379,396	1·898	2·124 846 435	446,197
1·849	2·055 630 882	380,705	1·899	2·126 292 632	447,562
1·850	2·057 011 587	1,382,015	1·900	2·127 740 194	1,448,927

x	I_0x	Difference	x	I_0x	Difference
1·900	2·127 740 194	1,448,927	1·950	2·201 883 143	1,518,668
1·901	2·129 189 121	1,450,295	1·951	2·203 401 811	1,520,093
1·902	2·130 639 416	451,661	1·952	2·204 921 904	521,518
1·903	2·132 091 077	453,030	1·953	2·206 443 422	522,946
1·904	2·133 544 107	454,401	1·954	2·207 966 368	524,374
1·905	2·134 998 508	455,772	1·955	2·209 490 742	525,803
1·906	2·136 454 280	457,144	1·956	2·211 016 545	527,234
1·907	2·137 911 424	458,518	1·957	2·212 543 779	528,666
1·908	2·139 369 942	459,892	1·958	2·214 072 445	530,099
1·909	2·140 829 834	461,268	1·959	2·215 602 544	531,533
1·910	2·142 291 102	1,462,645	1·960	2·217 134 077	1,532,968
1·911	2·143 753 747	1,464,022	1·961	2·218 667 045	1,534,405
1·912	2·145 217 769	465,403	1·962	2·220 201 450	535,843
1·913	2·146 683 172	466,782	1·963	2·221 737 293	537,281
1·914	2·148 149 954	468,164	1·964	2·223 274 574	538,722
1·915	2·149 618 118	469,546	1·965	2·224 813 296	540,163
1·916	2·151 087 664	470,930	1·966	2·226 353 459	541,606
1·917	2·152 558 594	472,315	1·967	2·227 895 065	543,050
1·918	2·154 030 909	473,701	1·968	2·229 438 115	544,494
1·919	2·155 504 610	475,088	1·969	2·230 982 609	545,941
1·920	2·156 979 698	1,476,476	1·970	2·232 528 550	1,547,388
1·921	2·158 456 174	1,477,866	1·971	2·234 075 938	1,548,837
1·922	2·159 934 040	479,257	1·972	2·235 624 775	550,286
1·923	2·161 413 297	480,648	1·973	2·237 175 061	551,737
1·924	2·162 893 945	482,042	1·974	2·238 726 798	553,190
1·925	2·164 375 987	483,436	1·975	2·240 279 988	554,644
1·926	2·165 859 423	484,831	1·976	2·241 834 632	556,098
1·927	2·167 344 254	486,226	1·977	2·243 390 730	557,554
1·928	2·168 830 480	487,625	1·978	2·244 948 284	559,011
1·929	2·170 318 105	489,024	1·979	2·246 507 295	560,470
1·930	2·171 807 129	1,490,423	1·980	2·248 067 765	1,561,929
1·931	2·173 297 552	1,491,825	1·981	2·249 629 694	1,563,390
1·932	2·174 789 377	493,227	1·982	2·251 193 084	564,852
1·933	2·176 282 604	494,630	1·983	2·252 757 936	566,315
1·934	2·177 777 234	496,035	1·984	2·254 324 251	567,780
1·935	2·179 273 269	497,441	1·985	2·255 892 031	569,245
1·936	2·180 770 710	498,847	1·986	2·257 461 276	570,712
1·937	2·182 269 557	500,256	1·987	2·259 031 988	572,181
1·938	2·183 769 813	501,665	1·988	2·260 604 169	573,650
1·939	2·185 271 478	503,076	1·989	2·262 177 819	575,121
1·940	2·186 774 554	1,504,487	1·990	2·263 752 940	1,576,592
1·941	2·188 279 041	1,505,900	1·991	2·265 329 532	1,578,066
1·942	2·189 784 941	507,314	1·992	2·266 907 598	579,540
1·943	2·191 292 255	508,729	1·993	2·268 487 138	581,016
1·944	2·192 800 984	510,145	1·994	2·270 068 154	582,492
1·945	2·194 311 129	511,563	1·995	2·271 650 646	583,970
1·946	2·195 822 692	512,982	1·996	2·273 234 616	585,450
1·947	2·197 335 674	514,401	1·997	2·274 820 066	586,930
1·948	2·198 850 075	515,823	1·998	2·276 406 996	588,412
1·949	2·200 365 898	517,245	1·999	2·277 995 408	589,894
1·950	2·201 883 143	1,518,668	2·000	2·279 585 302	1,591,379

x	I_0x	Difference	x	I_0x	Difference
2·000	2·279 585 302	1,591,379	2·050	2·360 998 757	1,667,207
2·001	2·281 176 681	1,592,865	2·051	2·362 665 964	1,668,757
2·002	2·282 769 546	594,352	2·052	2·364 334 721	670,308
2·003	2·284 363 898	595,839	2·053	2·366 005 029	671,860
2·004	2·285 959 737	597,329	2·054	2·367 676 889	673,413
2·005	2·287 557 066	598,819	2·055	2·369 350 302	674,968
2·006	2·289 155 885	600,311	2·056	2·371 025 270	676,524
2·007	2·290 756 196	601,804	2·057	2·372 701 794	678,081
2·008	2·292 358 000	603,298	2·058	2·374 379 875	679,639
2·009	2·293 961 298	604,794	2·059	2·376 059 514	681,200
2·010	2·295 566 092	1,606,291	2·060	2·377 740 714	1,682,761
2·011	2·297 172 383	1,607,788	2·061	2·379 423 475	1,684,323
2·012	2·298 780 171	609,288	2·062	2·381 107 798	685,887
2·013	2·300 389 459	610,789	2·063	2·382 793 685	687,453
2·014	2·302 000 248	612,290	2·064	2·384 481 138	689,019
2·015.	2·303 612 538	613,794	2·065	2·386 170 157	690,587
2·016	2·305 226 332	615,298	2·066	2·387 860 744	692,156
2·017	2·306 841 630	616,803	2·067	2·389 552 900	693,727
2·018	2·308 458 433	618,311	2·068	2·391 246 627	695,298
2·019	2·310 076 744	619,818	2·069	2·392 941 925	696,871
2·020	2·311 696 562	1,621,328	2·070	2·394 638 796	1,698,446
2·021	2·313 317 890	1,622,839	2·071	2·396 337 242	1,700,023
2·022	2·314 940 729	624,350	2·072	2·398 037 265	701,599
2·023	2·316 565 079	625,864	2·073	2·399 738 864	703,177
2·024	2·318 190 943	627,379	2·074	2·401 442 041	704,758
2·025	2·319 818 322	628,894	2·075	2·403 146 799	706,338
2·026	2·321 447 216	630,411	2·076	2·404 853 137	707,921
2·027	2·323 077 627	631,930	2·077	2·406 561 058	709,506
2·028	2·324 709 557	633,449	2·078	2·408 270 564	711,090
2·029	2·326 343 006	634,971	2·079	2·409 981 654	712,677
2·030	2·327 977 977	1,636,492	2·080	2·411 694 331	1,714,265
2·031	2·329 614 469	1,638,016	2·081	2·413 408 596	1,715,854
2·032	2·331 252 485	639,541	2·082	2·415 124 450	717,445
2·033	2·332 892 026	641,067	2·083	2·416 841 895	719,037
2·034	2·334 533 093	642,594	2·084	2·418 560 932	720,629
2·035	2·336 175 687	644,122	2·085	2·420 281 561	722,225
2·036	2·337 819 809	645,652	2·086	2·422 003 786	723,821
2·037	2·339 465 461	647,184	2·087	2·423 727 607	725,416
2·038	2·341 112 645	648,717	2·088	2·425 453 023	727,017
2·039	2·342 761 362	650,250	2·089	2·427 180 040	728,618
2·040	2·344 411 612	1,651,785	2·090	2·428 908 658	1,730,219
2·041	2·346 063 397	1,653,322	2·091	2·430 638 877	1,731,821
2·042	2·347 716 719	654,859	2·092	2·432 370 698	733,425
2·043	2·349 371 578	656,399	2·093	2·434 104 123	735,031
2·044	2·351 027 977	657,939	2·094	2·435 839 154	736,638
2·045	2·352 685 916	659,479	2·095	2·437 575 792	738,246
2·046	2·354 345 395	661,023	2·096	2·439 314 038	739,855
2·047	2·356 006 418	662,567	2·097	2·441 053 893	741,466
2·048	2·357 668 985	664,113	2·098	2·442 795 359	743,078
2·049	2·359 333 098	665,659	2·099	2·444 538 437	744,692
2·050	2·360 998 757	1,667,207	2·100	2·446 283 129	1,746,308

x	I_0x	Difference	x	I_0x	Difference
2·100	2·446 283 129	1,746,308	2·150	2·535 605 920	1,828,840
2·101	2·448 029 437	1,747,924	2·151	2·537 434 760	1,830,527
2·102	2·449 777 361	749,542	2·152	2·539 265 287	832,216
2·103	2·451 526 903	751,161	2·153	2·541 097 503	833,905
2·104	2·453 278 064	752,781	2·154	2·542 931 408	835,596
2·105	2·455 030 845	754,404	2·155	2·544 767 004	837,289
2·106	2·456 785 249	756,027	2·156	2·546 604 293	838,983
2·107	2·458 541 276	757,652	2·157	2·548 443 276	840,678
2·108	2·460 298 928	759,278	2·158	2·550 283 954	842,376
2·109	2·462 058 206	760,905	2·159	2·552 126 330	844,074
2·110	2·463 819 111	1,762,534	2·160	2·553 970 404	1,845,773
2·111	2·465 581 645	1,764,165	2·161	2·555 816 177	1,847,474
2·112	2·467 345 810	765,796	2·162	2·557 663 651	849,178
2·113	2·469 111 606	767,429	2·163	2·559 512 829	850,882
2·114	2·470 879 035	769,064	2·164	2·561 363 711	852,588
2·115	2·472 648 099	770,699	2·165	2·563 216 299	854,295
2·116	2·474 418 798	772,337	2·166	2·565 070 594	856,003
2·117	2·476 191 135	773,975	2·167	2·566 926 597	857,713
2·118	2·477 965 110	775,615	2·168	2·568 784 310	859,424
2·119	2·479 740 725	777,258	2·169	2·570 643 734	861,138
2·120	2·481 517 983	1,778,899	2·170	2·572 504 872	1,862,852
2·121	2·483 296 882	1,780,544	2·171	2·574 367 724	1,864,568
2·122	2·485 077 426	782,189	2·172	2·576 232 292	866,286
2·123	2·486 859 615	783,836	2·173	2·578 098 578	868,005
2·124	2·488 643 451	785,485	2·174	2·579 966 583	869,724
2·125	2·490 428 936	787,135	2·175	2·581 836 307	871,446
2·126	2·492 216 071	788,786	2·176	2·583 707 753	873,169
2·127	2·494 004 857	790,438	2·177	2·585 580 922	874,895
2·128	2·495 795 295	792,092	2·178	2·587 455 817	876,621
2·129	2·497 587 387	793,748	2·179	2·589 332 438	878,349
2·130	2·499 381 135	1,795,405	2·180	2·591 210 787	1,880,078
2·131	2·501 176 540	1,797,063	2·181	2·593 090 865	1,881,808
2·132	2·502 973 603	798,722	2·182	2·594 972 673	883,540
2·133	2·504 772 325	800,384	2·183	2·596 856 213	885,274
2·134	2·506 572 709	802,047	2·184	2·598 741 487	887,009
2·135	2·508 374 756	803,710	2·185	2·600 628 496	888,746
2·136	2·510 178 466	805,376	2·186	2·602 517 242	890,484
2·137	2·511 983 842	807,042	2·187	2·604 407 726	892,223
2·138	2·513 790 884	808,710	2·188	2·606 299 949	893,965
2·139	2·515 599 594	810,380	2·189	2·608 193 914	895,707
2·140	2·517 409 974	1,812,051	2·190	2·610 089 621	1,897,451
2·141	2·519 222 025	1,813,724	2·191	2·611 987 072	1,899,197
2·142	2·521 035 749	815,398	2·192	2·613 886 269	900,944
2·143	2·522 851 147	817,073	2·193	2·615 787 213	902,693
2·144	2·524 668 220	818,750	2·194	2·617 689 906	904,442
2·145	2·526 486 970	820,427	2·195	2·619 594 348	906,194
2·146	2·528 307 397	822,108	2·196	2·621 500 542	907,947
2·147	2·530 129 505	823,789	2·197	2·623 408 489	909,701
2·148	2·531 953 294	825,471	2·198	2·625 318 190	911,458
2·149	2·533 778 765	827,155	2·199	2·627 229 648	913,216
2·150	2·535 605 920	1,828,840	2·200	2·629 142 864	1,914,974

x	I_0x	Difference	x	I_0x	Difference
2·200	2·629 142 864	1,914,974	2·250	2·727 078 307	2,004,886
2·201	2·631 057 838	1,916,735	2·251	2·729 083 193	2,006,724
2·202	2·632 974 573	918,497	2·252	2·731 089 917	8,563
2·203	2·634 893 070	920,261	2·253	2·733 098 480	10,405
2·204	2·636 813 331	922,026	2·254	2·735 108 885	12,248
2·205	2·638 735 357	923,792	2·255	2·737 121 133	14,091
2·206	2·640 659 149	925,561	2·256	2·739 135 224	15,938
2·207	2·642 584 710	927,332	2·257	2·741 151 162	17,786
2·208	2·644 512 042	929,101	2·258	2·743 168 948	19,634
2·209	2·646 441 143	930,874	2·259	2·745 188 582	21,486
2·210	2·648 372 017	1,932,649	2·260	2·747 210 068	2,023,337
2·211	2·650 304 666	1,934,425	2·261	2·749 233 405	2,025,192
2·212	2·652 239 091	936,201	2·262	2·751 258 597	27,047
2·213	2·654 175 292	937,981	2·263	2·753 285 644	28,904
2·214	2·656 113 273	939,761	2·264	2·755 314 548	30,763
2·215	2·658 053 034	941,544	2·265	2·757 345 311	32,623
2·216	2·659 994 578	943,326	2·266	2·759 377 934	34,485
2·217	2·661 937 904	945,111	2·267	2·761 412 419	36,350
2·218	2·663 883 015	946,898	2·268	2·763 448 769	38,214
2·219	2·665 829 913	948,686	2·269	2·765 486 983	40,080
2·220	2·667 778 599	1,950,476	2·270	2·767 527 063	2,041,949
2·221	2·669 729 075	1,952,266	2·271	2·769 569 012	2,043,819
2·222	2·671 681 341	954,060	2·272	2·771 612 831	45,691
2·223	2·673 635 401	955,854	2·273	2·773 658 522	47,564
2·224	2·675 591 255	957,649	2·274	2·775 706 086	49,439
2·225	2·677 548 904	959,447	2·275	2·777 755 525	51,315
2·226	2·679 508 351	961,246	2·276	2·779 806 840	53,194
2·227	2·681 469 597	963,045	2·277	2·781 860 034	55,074
2·228	2·683 432 642	964,848	2·278	2·783 915 108	56,954
2·229	2·685 397 490	966,652	2·279	2·785 972 062	58,838
2·230	2·687 364 142	1,968,457	2·280	2·788 030 900	2,060,722
2·231	2·689 332 599	1,970,263	2·281	2·790 091 622	2,062,609
2·232	2·691 302 862	972,070	2·282	2·792 154 231	64,496
2·233	2·693 274 932	973,881	2·283	2·794 218 727	66,386
2·234	2·695 248 813	975,693	2·284	2·796 285 113	68,277
2·235	2·697 224 506	977,505	2·285	2·798 353 390	70,170
2·236	2·699 202 011	979,318	2·286	2·800 423 560	72,064
2·237	2·701 181 329	981,137	2·287	2·802 495 624	73,961
2·238	2·703 162 466	982,953	2·288	2·804 569 585	75,858
2·239	2·705 145 419	984,772	2·289	2·806 645 443	77,757
2·240	2·707 130 191	1,986,592	2·290	2·808 723 200	2,079,658
2·241	2·709 116 783	1,988,415	2·291	2·810 802 858	2,081,562
2·242	2·711 105 198	990,239	2·292	2·812 884 420	83,465
2·243	2·713 095 437	992,064	2·293	2·814 967 885	85,371
2·244	2·715 087 501	993,892	2·294	2·817 053 256	87,279
2·245	2·717 081 393	995,720	2·295	2·819 140 535	89,188
2·246	2·719 077 113	997,548	2·296	2·821 229 723	91,098
2·247	2·721 074 661	999,382	2·297	2·823 320 821	93,012
2·248	2·723 074 043	2,001,215	2·298	2·825 413 833	94,926
2·249	2·725 075 258	3,049	2·299	2·827 508 759	96,842
2·250	2·727 078 307	2,004,886	2·300	2·829 605 601	2,098,759

x	I_0x	Difference	x	I_0x	Difference
2·300	2·829 605 601	2,098,759	2·350	2·936 927 511	2,196,787
2·301	2·831 704 360	2,100,678	2·351	2·939 124 298	2,198,791
2·302	2·833 805 038	102,599	2·352	2·941 323 089	200,796
2·303	2·835 907 637	104,521	2·353	2·943 523 885	202,805
2·304	2·838 012 158	106,446	2·354	2·945 726 690	204,814
2·305	2·840 118 604	108,372	2·355	2·947 931 504	206,825
2·306	2·842 226 976	110,299	2·356	2·950 138 329	208,839
2·307	2·844 337 275	112,229	2·357	2·952 347 168	210,854
2·308	2·846 449 504	114,159	2·358	2·954 558 022	212,870
2·309	2·848 563 663	116,091	2·359	2·956 770 892	214,888
2·310	2·850 679 754	2,118,026	2·360	2·958 985 780	2,216,907
2·311	2·852 797 780	2,119,962	2·361	2·961 202 687	2,218,930
2·312	2·854 917 742	121,900	2·362	2·963 421 617	220,954
2·313	2·857 039 642	123,838	2·363	2·965 642 571	222,979
2·314	2·859 163 480	125,779	2·364	2·967 865 550	225,006
2·315	2·861 289 259	127,722	2·365	2·970 090 556	227,034
2·316	2·863 416 981	129,667	2·366	2·972 317 590	229,067
2·317	2·865 546 648	131,613	2·367	2·974 546 657	231,097
2·318	2·867 678 261	133,559	2·368	2·976 777 754	233,131
2·319	2·869 811 820	135,510	2·369	2·979 010 885	235,169
2·320	2·871 947 330	2,137,461	2·370	2·981 246 054	2,237,206
2·321	2·874 084 791	2,139,413	2·371	2·983 483 260	2,239,245
2·322	2·876 224 204	141,367	2·372	2·985 722 505	241,286
2·323	2·878 365 571	143,323	2·373	2·987 963 791	243,329
2·324	2·880 508 894	145,282	2·374	2·990 207 120	245,374
2·325	2·882 654 176	147,242	2·375	2·992 452 494	247,421
2·326	2·884 801 418	149,202	2·376	2·994 699 915	249,470
2·327	2·886 950 620	151,165	2·377	2·996 949 385	251,519
2·328	2·889 101 785	153,130	2·378	2·999 200 904	253,571
2·329	2·891 254 915	155,096	2·379	3·001 454 475	255,625
2·330	2·893 410 011	2,157,064	2·380	3·003 710 100	2,257,680
2·331	2·895 567 075	2,159,035	2·381	3·005 967 780	2,259,739
2·332	2·897 726 110	161,006	2·382	3·008 227 519	261,797
2·333	2·899 887 116	162,978	2·383	3·010 489 316	263,858
2·334	2·902 050 094	164,954	2·384	3·012 753 174	265,921
2·335	2·904 215 048	166,930	2·385	3·015 019 095	267,984
2·336	2·906 381 978	168,908	2·386	3·017 287 079	270,052
2·337	2·908 550 886	170,889	2·387	3·019 557 131	272,120
2·338	2·910 721 775	172,871	2·388	3·021 829 251	274,189
2·339	2·912 894 646	174,854	2·389	3·024 103 440	276,262
2·340	2·915 069 500	2,176,839	2·390	3·026 379 702	2,278,334
2·341	2·917 246 339	2,178,826	2·391	3·028 658 036	2,280,410
2·342	2·919 425 165	180,815	2·392	3·030 938 446	282,488
2·343	2·921 605 980	182,804	2·393	3·033 220 934	284,566
2·344	2·923 788 784	184,798	2·394	3·035 505 500	286,647
2·345	2·925 973 582	186,792	2·395	3·037 792 147	288,730
2·346	2·928 160 374	188,786	2·396	3·040 080 877	290,814
2·347	2·930 349 160	190,784	2·397	3·042 371 691	292,900
2·348	2·932 539 944	192,783	2·398	3·044 664 591	294,988
2·349	2·934 732 727	194,784	2·399	3·046 959 579	297,079
2·350	2·936 927 511	2,196,787	2·400	3·049 256 658	2,299,170

x	I_0x	Difference	x	I_0x	Difference
2·400	3·049 256 658	2,299,170	2·450	3·166 815 966	2,406,120
2·401	3·051 555 828	2,301,263	2·451	3·169 222 086	2,408,308
2·402	3·053 857 091	303,359	2·452	3·171 630 394	410,496
2·403	3·056 160 450	305,456	2·453	3·174 040 890	412,687
2·404	3·058 465 906	307,555	2·454	3·176 453 577	414,880
2·405	3·060 773 461	309,656	2·455	3·178 868 457	417,075
2·406	3·063 083 117	311,759	2·456	3·181 285 532	419,272
2·407	3·065 394 876	313,864	2·457	3·183 704 804	421,470
2·408	3·067 708 740	315,969	2·458	3·186 126 274	423,671
2·409	3·070 024 709	318,077	2·459	3·188 549 945	425,873
2·410	3·072 342 786	2,320,188	2·460	3·190 975 818	2,428,077
2·411	3·074 662 974	2,322,300	2·461	3·193 403 895	2,430,284
2·412	3·076 985 274	324,413	2·462	3·195 834 179	432,493
2·413	3·079 309 687	326,529	2·463	3·198 266 672	434,702
2·414	3·081 636 216	328,646	2·464	3·200 701 374	436,914
2·415	3·083 964 862	330,766	2·465	3·203 138 288	439,129
2·416	3·086 295 628	332,887	2·466	3·205 577 417	441,345
2·417	3·088 628 515	335,010	2·467	3·208 018 762	443,562
2·418	3·090 963 525	337,135	2·468	3·210 462 324	445,782
2·419	3·093 300 660	339,261	2·469	3·212 908 106	448,005
2·420	3·095 639 921	2,341,389	2·470	3·215 356 111	2,450,228
2·421	3·097 981 310	2,343,521	2·471	3·217 806 339	2,452,454
2·422	3·100 324 831	345,654	2·472	3·220 258 793	454,682
2·423	3·102 670 485	347,786	2·473	3·222 713 475	456,912
2·424	3·105 018 271	349,922	2·474	3·225 170 387	459,142
2·425	3·107 368 193	352,061	2·475	3·227 629 529	461,377
2·426	3·109 720 254	354,201	2·476	3·230 090 906	463,613
2·427	3·112 074 455	356,342	2·477	3·232 554 519	465,849
2·428	3·114 430 797	358,485	2·478	3·235 020 368	468,089
2·429	3·116 789 282	360,631	2·479	3·237 488 457	470,330
2·430	3·119 149 913	2,362,778	2·480	3·239 958 787	2,472,574
2·431	3·121 512 691	2,364,928	2·481	3·242 431 361	2,474,819
2·432	3·123 877 619	367,079	2·482	3·244 906 180	477,067
2·433	3·126 244 698	369,230	2·483	3·247 383 247	479,317
2·434	3·128 613 928	371,386	2·484	3·249 862 564	481,567
2·435	3·130 985 314	373,543	2·485	3·252 344 131	483,820
2·436	3·133 358 857	375,702	2·486	3·254 827 951	486,075
2·437	3·135 734 559	377,862	2·487	3·257 314 026	488,334
2·438	3·138 112 421	380,024	2·488	3·259 802 360	490,593
2·439	3·140 492 445	382,188	2·489	3·262 292 953	492,853
2·440	3·142 874 633	2,384,354	2·490	3·264 785 806	2,495,116
2·441	3·145 258 987	2,386,523	2·491	3·267 280 922	2,497,382
2·442	3·147 645 510	388,693	2·492	3·269 778 304	499,649
2·443	3·150 034 203	390,863	2·493	3·272 277 953	501,918
2·444	3·152 425 066	393,037	2·494	3·274 779 871	504,189
2·445	3·154 818 103	395,214	2·495	3·277 284 060	506,463
2·446	3·157 213 317	397,392	2·496	3·279 790 523	508,738
2·447	3·159 610 709	399,570	2·497	3·282 299 261	511,014
2·448	3·162 010 279	401,752	2·498	3·284 810 275	513,294
2·449	3·164 412 031	403,935	2·499	3·287 323 569	515,575
2·450	3·166 815 966	2,406,120	2·500	3·289 839 144	2,517,858

x	I_0x	Difference	x	I_0x	Difference
2·500	3·289 839 144	2,517,858	2·550	3·418 571 188	2,634,614
2·501	3·292 357 002	2,520,143	2·551	3·421 205 802	2,637,002
2·502	3·294 877 145	522,431	2·552	3·423 842 804	639,393
2·503	3·297 399 576	524,719	2·553	3·426 482 197	641,786
2·504	3·299 924 295	527,011	2·554	3·429 123 983	644,179
2·505	3·302 451 306	529,304	2·555	3·431 768 162	646,575
2·506	3·304 980 610	531,599	2·556	3·434 414 737	648,973
2·507	3·307 512 209	533,896	2·557	3·437 063 710	651,375
2·508	3·310 046 105	536,197	2·558	3·439 715 085	653,778
2·509	3·312 582 302	538,497	2·559	3·442 368 863	656,183
2·510	3·315 120 799	2,540,800	2·560	3·445 025 046	2,658,589
2·511	3·317 661 599	2,543,106	2·561	3·447 683 635	2,660,998
2·512	3·320 204 70	545,413	2·562	3·450 344 633	663,410
2·513	3·322 750 118	547,722	2·563	3·453 008 043	665,823
2·514	3·325 297 840	550,034	2·564	3·455 673 866	668,238
2·515	3·327 847 874	552,348	2·565	3·458 342 104	670,656
2·516	3·330 400 222	554,662	2·566	3·461 012 760	673,076
2·517	3·332 954 884	556,981	2·567	3·463 685 836	675,497
2·518	3·335 511 865	559,300	2·568	3·466 361 333	677,922
2·519	3·338 071 165	561,622	2·569	3·469 039 255	680,348
2·520	3·340 632 787	2,563,945	2·570	3·471 719 603	2,682,776
2·521	3·343 196 732	2,566,271	2·571	3·474 402 379	2,685,207
2·522	3·345 763 003	568,599	2·572	3·477 087 586	687,639
2·523	3·348 331 602	570,928	2·573	3·479 775 225	690,074
2·524	3·350 902 530	573,260	2·574	3·482 465 299	692,511
2·525	3·353 475 790	575,594	2·575	3·485 157 810	694,950
2·526	3·356 051 384	577,930	2·576	3·487 852 760	697,391
2·527	3·358 629 314	580,268	2·577	3·490 550 151	699,835
2·528	3·361 209 582	582,609	2·578	3·493 249 986	702,281
2·529	3·363 792 191	584,951	2·579	3·495 952 267	704,727
2·530	3·366 377 142	2,587,294	2·580	3·498 656 994	2,707,177
2·531	3·368 964 436	2,589,641	2·581	3·501 364 171	2,709,629
2·532	3·371 554 077	591,990	2·582	3·504 073 800	712,083
2·533	3·374 146 067	594,339	2·583	3·506 785 883	714,541
2·534	3·376 740 406	596,692	2·584	3·509 500 424	716,999
2·535	3·379 337 098	599,046	2·585	3·512 217 423	719,459
2·536	3·381 936 144	601,403	2·586	3·514 936 882	721,922
2·537	3·384 537 547	603,762	2·587	3·517 658 804	724,387
2·538	3·387 141 309	606,123	2·588	3·520 383 191	726,855
2·539	3·389 747 432	608,486	2·589	3·523 110 046	729,324
2·540	3·392 355 918	2,610,851	2·590	3·525 839 370	2,731,795
2·541	3·394 966 769	2,613,217	2·591	3·528 571 165	2,734,269
2·542	3·397 579 986	615,586	2·592	3·531 305 434	736,745
2·543	3·400 195 572	617,958	2·593	3·534 042 179	739,223
2·544	3·402 813 530	620,331	2·594	3·536 781 402	741,703
2·545	3·405 433 861	622,706	2·595	3·539 523 105	744,186
2·546	3·408 056 567	625,083	2·596	3·542 267 291	746,671
2·547	3·410 681 650	627,464	2·597	3·545 013 962	749,157
2·548	3·413 309 114	629,846	2·598	3·547 763 119	751,647
2·549	3·415 938 960	632,228	2·599	3·550 514 766	754,138
2·550	3·418 571 188	2,634,614	2·600	3·553 268 904	2,756,632

x	I_0x	Difference	x	I_0x	Difference
2·600	3·553 268 904	2,756,632	2·650	3·694 201 463	2,884,162
2·601	3·556 025 536	2,759,127	2·651	3·697 085 625	2,886,771
2·602	3·558 784 663	761,625	2·652	3·699 972 396	889,381
2·603	3·561 546 288	764,125	2·653	3·702 861 777	891,994
2·604	3·564 310 413	766,628	2·654	3·705 753 771	894,611
2·605	3·567 077 041	769,132	2·655	3·708 648 382	897,227
2·606	3·569 846 173	771,639	2·656	3·711 545 609	899,848
2·607	3·572 617 812	774,148	2·657	3·714 445 457	902,471
2·608	3·575 391 960	776,659	2·658	3·717 347 928	905,096
2·609	3·578 168 619	779,172	2·659	3·720 253 024	907,723
2·610	3·580 947 791	2,781,688	2·660	3·723 160 747	2,910,352
2·611	3·583 729 479	2,784,206	2·661	3·726 071 099	2,912,985
2·612	3·586 513 685	786,726	2·662	3·728 984 084	915,619
2·613	3·589 300 411	789,248	2·663	3·731 899 703	918,255
2·614	3·592 089 659	791,774	2·664	3·734 817 958	920,894
2·615	3·594 881 433	794,299	2·665	3·737 738 852	923,535
2·616	3·597 675 732	796,829	2·666	3·740 662 387	926,179
2·617	3·600 472 561	799,361	2·667	3·743 588 566	928,824
2·618	3·603 271 922	801,893	2·668	3·746 517 390	931,473
2·619	3·606 073 815	804,430	2·669	3·749 448 863	934,124
2·620	3·608 878 245	2,806,966	2·670	3·752 382 987	2,936,777
2·621	3·611 685 211	2,809,508	2·671	3·755 319 764	2,939,431
2·622	3·614 494 719	812,050	2·672	3·758 259 195	942,089
2·623	3·617 306 769	814,596	2·673	5·761 201 284	944,750
2·624	3·620 121 365	817,141	2·674	3·764 146 034	947,412
2·625	3·622 938 506	819,691	2·675	3·767 093 446	950,077
2·626	3·625 758 197	822,243	2·676	3·770 043 523	952,744
2·627	3·628 580 440	824,796	2·677	3·772 996 267	955,413
2·628	3·631 405 236	827,352	2·678	3·775 951 680	958,085
2·629	3·634 232 588	829,912	2·679	3·778 909 765	960,760
2·630	3·637 062 500	2,832,471	2·680	3·781 870 525	2,963,436
2·631	3·639 894 971	2,835,034	2·681	3·784 833 961	2,966,115
2·632	3·642 730 005	837,600	2·682	3·787 800 076	968,796
2·633	3·645 567 605	840,166	2·683	3·790 768 872	971,480
2·634	3·648 407 771	842,737	2·684	3·793 740 352	974,167
2·635	3·651 250 508	845,308	2·685	3·796 714 519	976,855
2·636	3·654 095 816	847,882	2·686	3·799 691 374	979,546
2·637	3·656 943 698	850,459	2·687	3·802 670 920	982,238
2·638	3·659 794 157	853,038	2·688	3·805 653 158	984,935
2·639	3·662 647 195	855,619	2·689	3·808 638 093	987,633
2·640	3·665 502 814	2,858,201	2·690	3·811 625 726	2,990,333
2·641	3·668 361 015	2,860,788	2·691	3·814 616 059	2,993,036
2·642	3·671 221 803	863,375	2·692	3·817 609 095	995,742
2·643	3·674 085 178	865,966	2·693	3·820 604 837	998,449
2·644	3·676 951 144	868,559	2·694	3·823 603 286	3,001,159
2·645	3·679 819 703	871,153	2·695	3·826 604 445	3,871
2·646	3·682 690 856	873,750	2·696	3·829 608 316	6,586
2·647	3·685 564 606	876,350	2·697	3·832 614 902	9,304
2·648	3·688 440 956	878,951	2·698	3·835 624 206	12,024
2·649	3·691 319 907	881,556	2·699	3·838 636 230	14,747
2·650	3·694 201 463	2,884,162	2·700	3·841 650 977	3,017,471

x	I_0x	Difference	x	I_0x	Difference
2·700	3·841 650 977	3,017,471	2·750	3·995 913 107	3,156,835
2·701	3·844 668 448	3,020,197	2·751	3·999 069 942	159,686
2·702	3·847 688 645	22,926	2·752	4·002 229 628	162,539
2·703	3·850 711 571	25,659	2·753	4·005 392 167	165,396
2·704	3·853 737 230	28,393	2·754	4·008 557 563	168,254
2·705	3·856 765 623	31,129	2·755	4·011 725 817	171,115
2·706	3·859 796 752	33,869	2·756	4·014 896 932	173,979
2·707	3·862 830 621	36,611	2·757	4·018 070 911	176,846
2·708	3·865 867 232	39,354	2·758	4·021 247 757	179,714
2·709	3·868 906 586	42,101	2·759	4·024 427 471	182,586
2·710	3·871 948 687	3,044,849	2·760	4·027 610 057	3,185,460
2·711	3·874 993 536	3,047,601	2·761	4·030 795 517	3,188,336
2·712	3·878 041 137	50,356	2·762	4·033 983 853	191,215
2·713	3·881 091 493	53,110	2·763	4·037 175 068	194,097
2·714	3·884 144 603	55,870	2·764	4·040 369 165	196,981
2·715	3·887 200 473	58,631	2·765	4·043 566 146	199,869
2·716	3·890 259 104	61,395	2·766	4·046 766 015	202,757
2·717	3·893 320 499	64,160	2·767	4·049 968 772	205,650
2·718	3·896 384 659	66,929	2·768	4·053 174 422	208,544
2·719	3·899 451 588	69,700	2·769	4·056 382 966	211,441
2·720	3·902 521 288	3,072,474	2·770	4·059 594 407	3,214,340
2·721	3·905 593 762	3,075,249	2·771	4·062 808 747	3,217,243
2·722	3·908 669 011	78,028	2·772	4·066 025 990	220,148
2·723	3·911 747 039	80,808	2·773	4·069 246 138	223,056
2·724	3·914 827 847	83,592	2·774	4·072 469 194	225,966
2·725	3·917 911 439	86,378	2·775	4·075 695 160	228,878
2·726	3·920 997 817	89,166	2·776	4·078 924 038	231,793
2·727	3·924 086 983	91,957	2·777	4·082 155 831	234,711
2·728	3·927 178 940	94,750	2·778	4·085 390 542	237,632
2·729	3·930 273 690	97,546	2·779	4·088 628 174	240,555
2·730	3·933 371 236	3,100,344	2·780	4·091 868 729	3,243,481
2·731	3·936 471 580	3,103,145	2·781	4·095 112 210	3,246,408
2·732	3·939 574 725	105,948	2·782	4·098 358 618	249,339
2·733	3·942 680 673	108,754	2·783	4·101 607 957	252,274
2·734	3·945 789 427	111,561	2·784	4·104 860 231	255,209
2·735	3·948 900 988	114,373	2·785	4·108 115 440	258,148
2·736	3·952 015 361	117,186	2·786	4·111 373 588	261,090
2·737	3·955 132 547	120,001	2·787	4·114 634 678	264,033
2·738	3·958 252 548	122,820	2·788	4·117 898 711	266,980
2·739	3·961 375 368	125,641	2·789	4·121 165 691	269,930
2·740	3·964 501 009	3,128,463	2·790	4·124 435 621	3,272,881
2·741	3·967 629 472	3,131,290	2·791	4·127 708 502	3,275,835
2·742	3·970 760 762	134,118	2·792	4·130 984 337	278,793
2·743	3·973 894 880	136,948	2·793	4·134 263 130	281,753
2·744	3·977 031 828	139,782	2·794	4·137 544 883	284,715
2·745	3·980 171 610	142,617	2·795	4·140 829 598	287,681
2·746	3·983 314 227	145,456	2·796	4·144 117 279	290,648
2·747	3·986 459 683	148,297	2·797	4·147 407 927	293,618
2·748	3·989 607 980	151,141	2·798	4·150 701 545	296,592
2·749	3·992 759 121	153,986	2·799	4·153 998 137	299,567
2·750	3·995 913 107	3,156,835	2·800	4·157 297 704	3,302,545

x	I_0x	Difference	x	I_0x	Difference
2·800	4·157 297 704	3,302,545	2·850	4·326 126 469	3,454,906
2·801	4·160 600 249	3,305,527	2·851	4·329 584 375	3,458,024
2·802	4·163 905 776	308,510	2·852	4·333 042 399	461,143
2·803	4·167 214 286	311,496	2·853	4·336 503 542	464,267
2·804	4·170 525 782	314,486	2·854	4·339 967 809	467,393
2·805	4·173 840 268	317,476	2·855	4·343 435 202	470,519
2·806	4·177 157 744	320,472	2·856	4·346 905 721	473,652
2·807	4·180 478 216	323,469	2·857	4·350 379 373	476,785
2·808	4·183 801 685	326,468	2·858	4·353 856 158	479,922
2·809	4·187 128 153	329,470	2·859	4·357 336 080	483,063
2·810	4·190 457 623	3,332,476	2·860	4·360 819 143	3,486,204
2·811	4·193 790 099	3,335,484	2·861	4·364 305 347	3,489,350
2·812	4·197 125 583	338,493	2·862	4·367 794 697	492,498
2·813	4·200 464 076	341,507	2·863	4·371 287 195	495,648
2·814	4·203 805 583	344,523	2·864	4·374 782 843	498,802
2·815	4·207 150 106	347,542	2·865	4·378 281 645	501,959
2 816	4·210 497 648	350,562	2·866	4·381 783 604	505,118
2·817	4·213 848 210	353,586	2·867	4·385 288 722	508,280
2·818	4·217 201 796	356,613	2·868	4·388 797 002	511,446
2·819	4·220 558 409	359,642	2·869	4·392 308 448	514,613
2·820	4·223 918 051	3,362,674	2·870	4·395 823 061	3,517,784
2·821	4·227 280 725	3,365,709	2·871	4·399 340 845	3,520,956
2·822	4·230 646 434	368,746	2·872	4·402 861 801	524,134
2·823	4·234 015 180	371,787	2·873	4·406 385 935	527,313
2·824	4·237 386 967	374,830	2·874	4·409 913 248	530,495
2·825	4·240 761 797	377,875	2·875	4·413 443 743	533,680
2·826	4·244 139 672	380,923	2·876	4·416 977 423	536,867
2·827	4·247 520 595	383,974	2·877	4·420 514 290	540,058
2·828	4·250 904 569	387,029	2·878	4·424 054 348	543,252
2·829	4·254 291 598	390,085	2·879	4·427 597 600	546,448
2·830	4·257 681 683	3,393,143	2·880	4·431 144 048	3,549,646
2·831	4·261 074 826	3,396,206	2·881	4·434 693 694	3,552,850
2·832	4·264 471 032	399.271	2·882	4·438 246 544	556,054
2·833	4·267 870 303	402,338	2·883	4·441 802 598	559,261
2·834	4·271 272 641	405,408	2·884	4·445 361 859	562,473
2·835	4·274 678 049	408,481	2·885	4·448 924 332	565,686
2·836	4·278 086 530	411,557	2·886	4·452 490 018	568,902
2·837	4·281 498 087	414,635	2·887	4·456 058 920	572,122
2·838	4·284 912 722	417,717	2·888	4·459 631 042	575,344
2·839	4·288 330 439	420,801	2·889	4·463 206 386	578,569
2·840	4·291 751 240	3,423,886	2·890	4·466 784 955	3,581,797
2·841	4·295 175 126	3,426,977	2·891	4·470 366 752	3,585,028
2·842	4·298 602 103	430,069	2·892	4·473 951 780	588,261
2·843	4·302 032 172	433,163	2·893	4·477 540 041	591,498
2·844	4·305 465 335	436,262	2·894	4·481 131 539	594,738
2·845	4·308 901 597	439,362	2·895	4·484 726 277	597,980
2·846	4·312 340 959	442,466	2·896	4·488 324 257	601,226
2·847	4·315 783 425	445,571	2·897	4·491 925 483	604,474
2·848	4·319 228 996	448,681	2·898	4·495 529 957	607,725
2·849	4·322 677 677	451,792	2·899	4·499 137 682	610,979
2·850	4·326 129 469	3,454,906	2·900	4·502 748 661	3,614,236

x	I_0x	Difference	x	I_0x	Difference
2·900	4·502 748 661	3,614,236	2·950	4·687 511 830	3,780,869
2·901	4·506 362 897	3,617,496	2·951	4·691 292 699	3,784,277
2·902	4·509 980 393	620,760	2·952	4·695 076 976	787,690
2·903	4·513 601 153	624,025	2·953	4·698 864 666	791,107
2·904	4·517 225 178	627,293	2·954	4·702 655 773	794,525
2·905	4·520 852 471	630,566	2·955	4·706 450 298	797,947
2·906	4·524 483 037	633,839	2·956	4·710 248 245	801,370
2·907	4·528 116 876	637,117	2·957	4·714 049 615	804,800
2·908	4·531 753 993	640,398	2·958	4·717 854 415	808,231
2·909	4·535 394 391	643,681	2·959	4·721 662 646	811,664
2·910	4·539 038 072	3,646,968	2·960	4·725 474 310	3,815,102
2·911	4·542 685 040	3,650,256	2·961	4·729 289 412	3,818,541
2·912	4·546 335 296	653,550	2·962	4·733 107 953	821,985
2·913	4·549 988 846	656,844	2·963	4·736 929 938	825,432
2·914	4·553 645 690	660,142	2·964	4·740 755 370	828,881
2·915	4·557 305 832	663,443	2·965	4·744 584 251	832,334
2·916	4·560 969 275	666,748	2·966	4·748 416 585	835,790
2·917	4·564 636 023	670,055	2·967	4·752 252 375	839,248
2·918	4·568 306 078	673,364	2·968	4·756 091 623	842,710
2·919	4·571 979 442	676,678	2·969	4·759 934 333	846,176
2·920	4·575 656 120	3,679,994	2·970	4·763 780 509	3,849,643
2·921	4·579 336 114	3,683,312	2·971	4·767 630 152	3,853,115
2·922	4·583 019 426	686,635	2·972	4·771 483 267	856,590
2·923	4·586 706 061	689,959	2·973	4·775 339 857	860,066
2·924	4·590 396 020	693,287	2·974	4·779 199 923	863,548
2·925	4·594 089 307	696,618	2·975	4·783 063 471	867,032
2·926	4·597 785 925	699,952	2·976	4·786 930 503	870,518
2·927	4·601 485 877	703,289	2·977	4·790 801 021	874,008
2·928	4·605 189 166	706,629	2·978	4·794 675 029	877,502
2·929	4·608 895 795	709,971	2·979	4·798 552 531	880,998
2·930	4·612 605 766	3,713,317	2·980	4·802 433 529	3,884,497
2·931	4·616 319 083	3,716,666	2·981	4·806 318 026	3,888,000
2·932	4·620 035 749	720,018	2·982	4·810 206 026	891,506
2·933	4·623 755 767	723,373	2·983	4·814 097 532	895,015
2·934	4·627 479 140	726,731	2·984	4·817 992 547	898,527
2·935	4·631 205 871	730,092	2·985	4·821 891 074	902,042
2·936	4·634 935 963	733,455	2·986	4·825 793 116	905,560
2·937	4·638 669 418	736,822	2·987	4·829 698 676	909,082
2·938	4·642 406 240	740,192	2·988	4·833 607 758	912,608
2·939	4·646 146 432	743,565	2·989	4·837 520 366	916,135
2·940	4·649 889 997	3,746,942	2·990	4·841 436 501	3,919,666
2·941	4·653 636 939	3,750,320	2·991	4·845 356 167	3,923,200
2·942	4·657 387 259	753,702	2·992	4·849 279 367	926,738
2·943	4·661 140 961	757,088	2·993	4·853 206 105	930,278
2·944	4·664 898 049	760,475	2·994	4·857 136 383	933,823
2·945	4·668 658 524	763,866	2·995	4·861 070 206	937,369
2·946	4·672 422 390	767,261	2·996	4·865 007 575	940,919
2·947	4·676 189 651	770,659	2·997	4·868 948 494	944,473
2·948	4·679 960 310	774,058	2·998	4·872 892 967	948,029
2·949	4·683 734 368	777,462	2·999	4·876 840 996	951,590
2·950	4·687 511 830	3,780,869	3·000	4·880 792 586	3,955,152

x	I_0x	Difference	x	I_0x	Difference
3·000	4·880 792 586	3,955,152	3·050	5·082 982 407	4,137,453
3·001	4·884 747 738	3,958,718	3·051	5·087 119 860	4,141,184
3·002	4·888 706 456	962,288	3·052	5·091 261 044	144,918
3·003	4·892 668 744	965,861	3·053	5·095 405 962	148,656
3·004	4·896 634 605	969,437	3·054	5·099 554 618	152,396
3·005	4·900 604 042	973,015	3·055	5·103 707 014	156,139
3·006	4·904 577 057	976,597	3·056	5·107 863 153	159,886
3·007	4·908 553 654	980,183	3·057	5·112 023 039	163,637
3·008	4·912 533 837	983,772	3·058	5·116 186 676	167,392
3·009	4·916 517 609	987,365	3·059	5·120 354 068	171,149
3·010	4·920 504 974	3,990,959	3·060	5·124 525 217	4,174,909
3·011	4·924 495 933	3,994,557	3·061	5·128 700 126	4,178,674
3·012	4·928 490 490	998,160	3·062	5·132 878 800	182,442
3·013	4·932 488 650	4,001,764	3·063	5·137 061 242	186,213
3·014	4·936 490 414	5,372	3·064	5·141 247 455	189,986
3·015	4·940 495 786	8,984	3·065	5·145 437 441	193,764
3·016	4·944 504 770	12,598	3·066	5·149 631 205	197,546
3·017	4·948 517 368	16,216	3·067	5·153 828 751	201,330
3·018	4·952 533 584	19,838	3·068	5·158 030 081	205,118
3·019	4·956 553 422	23,462	3·069	5·162 235 199	208,910
3·020	4·960 576 884	4,027,090	3·070	5·166 444 109	4,212,704
3·021	4·964 603 974	4,030,721	3·071	5·170 656 813	4,216,503
3·022	4·968 634 695	34,354	3·072	5·174 873 316	220,304
3·023	4·972 669 049	37,993	3·073	5·179 093 620	224,110
3·024	4·976 707 042	41,633	3·074	5·183 317 730	227,918
3·025	4·980 748 675	45,277	3·075	5·187 545 648	231,730
3·026	4·984 793 952	48,924	3·076	5·191 777 378	235,546
3·027	4·988 842 876	52,575	3·077	5·196 012 924	239,364
3·028	4·992 895 451	56,230	3·078	5·200 252 288	243,187
3·029	4·996 951 681	59,886	3·079	5·204 495 475	247,013
3·030	5·001 011 567	4,063,547	3·080	5·208 742 488	4,250,841
3·031	5·005 075 114	4,067,211	3·081	5·212 993 329	4,254,675
3·032	5·009 142 325	70,878	3·082	5·217 248 004	258,510
3·033	5·013 213 203	74,548	3·083	5·221 506 514	262,351
3·034	5·017 287 751	78,222	3·084	5·225 768 865	266,194
3·035	5·021 365 973	81,899	3·085	5·230 035 059	270,039
3·036	5·025 447 872	85,579	3·086	5·234 305 098	273,889
3·037	5·029 533 451	89,263	3·087	5·238 578 987	277,743
3·038	5·033 622 714	92,951	3·088	5·242 856 730	281,600
3·039	5·037 715 665	96,640	3·089	5·247 138 330	285,461
3·040	5·041 812 305	4,100,333	3·090	5·251 423 791	4,289,325
3·041	5·045 912 638	4,104,031	3·091	5·255 713 116	4,293,192
3·042	5·050 016 669	107,731	3·092	5·260 006 308	297,063
3·043	5·054 124 400	111,435	3·093	5·264 303 371	300,937
3·044	5·058 235 835	115,142	3·094	5·268 604 308	304,815
3·045	5·062 350 977	118,852	3·095	5·272 909 123	308,697
3·046	5·066 469 829	122,565	3·096	5·277 217 820	312,581
3·047	5·070 592 394	126,282	3·097	5·281 530 401	316,469
3·048	5·074 718 676	130,004	3·098	5·285 846 870	320,362
3·049	5·078 848 680	133,727	3·099	5·290 167 232	324,258
3·050	5·082 982 407	4,137,453	3·100	5·294 491 490	4,328,156

x	I_0x	Difference	x	I_0x	Difference
3·100	5·294 491 490	4,328,156	3·150	5·515 749 636	4 527,661
3·101	5·298 819 646	4,332,058	3·151	5·520 277 297	4,531,743
3·102	5·303 151 704	335,965	3·152	5·524 809 040	535,831
3·103	5·307 487 669	339,874	3·153	5·529 344 871	539,920
3·104	5·311 827 543	343,787	3·154	5·533 884 791	544,014
3·105	5·316 171 330	347,704	3·155	5·538 428 805	548,111
3·106	5·320 519 034	351,623	3·156	5·542 976 916	552,213
3·107	5·324 870 657	355,548	3·157	5·547 529 129	556,317
3·108	5·329 226 205	359,475	3·158	5·552 085 446	560,426
3·109	5·333 585 680	363,405	3·159	5·556 645 872	564,539
3·110	5·337 949 085	4,367,340	3·160	5·561 210 411	4,568,655
3·111	5·342 316 425	4,371,277	3·161	5·565 779 066	4,572,774
3·112	5·346 687 702	375,219	3·162	5·570 351 840	576,898
3·113	5·351 062 921	379,164	3·163	5·574 928 738	581,025
3·114	5·355 442 085	383,112	3·164	5·579 509 763	585,156
3·115	5·359 825 197	387,064	3·165	5·584 094 919	589,292
3·116	5·364 212 261	391,021	3·166	5·588 684 211	593,429
3·117	5·368 603 282	394,979	3·167	5·593 277 640	597,572
3·118	5·372 998 261	398,942	3·168	5·597 875 212	601,717
3·119	5·377 397 203	402,909	3·169	5·602 476 929	605,868
3·120	5·381 800 112	4,406,879	3·170	5·607 082 797	4,610,021
3·121	5·386 206 991	4,410,851	3·171	5·611 692 818	4,614,178
3·122	5·390 617 842	414,830	3·172	5·616 306 996	618,339
3·123	5·395 032 672	418,810	3·173	5·620 925 335	622,504
3·124	5·399 451 482	422,795	3·174	5·625 547 839	626,672
3·125	5·403 874 277	426,782	3·175	5·630 174 511	630,845
3·126	5·408 301 059	430,774	3·176	5·634 805 356	635,021
3·127	5·412 731 833	434,769	3·177	5·639 440 377	639,200
3·128	5·417 166 602	438,768	3·178	5·644 079 577	643,384
3·129	5·421 605 370	442,769	3·179	5·648 722 961	647,572
3·130	5·426 048 139	4,446,776	3·180	5·653 370 533	4,651,763
3·131	5·430 494 915	4,450,786	3·181	5·658 022 296	4,655,957
3·132	5·434 945 701	454,799	3·182	5·662 678 253	660,157
3·133	5·439 400 500	458,815	3·183	5·667 338 410	664,359
3·134	5·443 859 315	462,837	3·184	5·672 002 769	668,566
3·135	5·448 322 152	466,860	3·185	5·676 671 335	672,776
3·136	5·452 789 012	470,889	3·186	5·681 344 111	676,990
3·137	5·457 259 901	474,920	3·187	5·686 021 101	681,207
3·138	5·461 734 821	478,954	3·188	5·690 702 308	685,430
3·139	5·466 213 775	482,994	3·189	5·695 387 738	689,656
3·140	5·470 696 769	4,487,036	3·190	5·700 077 394	4,693,884
3·141	5·475 183 805	4,491,081	3·191	5·704 771 278	4,698,117
3·142	5·479 674 886	495,132	3·192	5·709 469 395	702,354
3·143	5·484 170 018	499,185	3·193	5·714 171 749	706,596
3·144	5·488 669 203	503,242	3·194	5·718 878 345	710,839
3·145	5·493 172 445	507,302	3·195	5·723 589 184	715,088
3·146	5·497 679 747	511,367	3·196	5·728 304 272	719,341
3·147	5·502 191 114	515,434	3·197	5·733 023 613	723,597
3·148	5·506 706 548	519,506	3·198	5 737 747 210	727,857
3·149	5·511 226 054	523,582	3·199	5·742 475 067	732,120
3·150	5·515 749 636	4,527,661	3·200	5·747 207 187	4,736,388

x	I_0x	Difference	x	I_0x	Difference
3·200	5·747 207 187	4,736,388	3·250	5·989 335 998	4,954,779
3·201	5·751 943 575	4,740,661	3·251	5·994 290 777	4,959,250
3·202	5·756 684 236	744,936	3·252	5·999 250 027	963,723
3·203	5·761 429 172	749,214	3·253	6·004 213 750	968,200
3·204	5·766 178 386	753,498	3·254	6·009 181 950	972,682
3·205	5·770 931 884	757,785	3·255	6·014 154 632	977,168
3·206	5·775 689 669	762,077	3·256	6·019 131 800	981,657
3·207	5·780 451 746	766,371	3·257	6·024 113 457	986,151
3·208	5·785 218 117	770,669	3·258	6·029 099 608	990,650
3·209	5·789 988 786	774,973	3·259	6·034 090 258	995,152
3·210	5·794 763 759	4,779,279	3·260	6·039 085 410	4,999,657
3·211	5·799 543 038	4,783,590	3·261	6·044 085 067	5,004,168
3·212	5·804 326 628	787,904	3·262	6·049 089 235	8,682
3·213	5·809 114 532	792,222	3·263	6·054 097 917	13,200
3·214	5·813 906 754	796,545	3·264	6·059 111 117	17,724
3·215	5·818 703 299	800,870	3·265	6·064 128 841	22,250
3·216	5·823 504 169	805,200	3·266	6·069 151 091	26,780
3·217	5·828 309 369	809,535	3·267	6·074 177 871	31,316
3·218	5·833 118 904	813,872	3·268	6·079 209 187	35,855
3·219	5·837 932 776	818,214	3·269	6·084 245 042	40,396
3·220	5·842 750 990	4,822,560	3·270	6·089 285 438	5,044,944
3·221	5·847 573 550	4,826,910	3·271	6·094 330 382	5,049,496
3·222	5·852 400 460	831,263	3·272	6·099 379 878	54,051
3·223	5·857 231 723	835,621	3·273	6·104 433 929	58,611
3·224	5·862 067 344	839,982	3·274	6·109 492 540	63,175
3·225	5·866 907 326	844,347	3·275	6·114 555 715	67,742
3·226	5·871 751 673	848,718	3·276	6·119 623 457	72,314
3·227	5·876 600 391	853,091	3·277	6·124 695 771	76,891
3·228	5·881 453 482	857,467	3·278	6·129 772 662	81,471
3·229	5·886 310 949	861,849	3·279	6·134 854 133	86,056
3·230	5·891 172 798	4,866,235	3·280	6·139 940 189	5,090,644
3·231	5·896 039 033	4,870,623	3·281	6·145 030 833	5,095,236
3·232	5·900 909 656	875,017	3·282	6·150 126 069	99,834
3·233	5·905 784 673	879,414	3·283	6·155 225 903	104,435
3·234	5·910 664 087	883,815	3·284	6·160 330 338	109,039
3·235	5·915 547 902	888,221	3·285	6·165 439 377	113,650
3·236	5·920 436 123	892,630	3·286	6·170 553 027	118,263
3·237	5·925 328 753	897,043	3·287	6·175 671 290	122,881
3·238	5·930 225 796	901,460	3·288	6·180 794 171	127,503
3·239	5·935 127 256	905,881	3·289	6·185 921 674	132,130
3·240	5·940 033 137	4,910,306	3·290	6·191 053 804	5,136,760
3·241	5·944 943 443	4,914,736	3·291	6·196 190 564	5,141,394
3·242	5·949 858 179	919,168	3·292	6·201 331 958	146,033
3·243	5·954 777 347	923,607	3·293	6·206 477 991	150,676
3·244	5·959 700 954	928,048	3·294	6·211 628 667	155,324
3·245	5·964 629 002	932,493	3·295	6·216 783 991	159,975
3·246	5·969 561 495	936,941	3·296	6·221 943 966	164,631
3·247	5·974 498 436	941,395	3·297	6·227 108 597	169,290
3·248	5·979 439 831	945,853	3·298	6·232 277 887	173,955
3·249	5·984 385 684	950,314	3·299	6·237 451 842	178,623
3·250	5·989 335 998	4,954,779	3·300	6·242 630 465	5,183,296

x	I_0x	Difference	x	I_0x	Difference
3·300	6·242 630 465	5,183,296	3·350	6·507 608 601	5,422,421
3·301	6·247 813 761	5,187,973	3·351	6·513 031 022	5,427,315
3·302	6·253 001 734	192,654	3·352	6·518 458 337	432,214
3·303	6·258 194 388	197,340	3·353	6·523 890 551	437,117
3·304	6·263 391 728	202,028	3·354	6·529 327 668	442,024
3·305	6·268 593 756	206,723	3·355	6·534 769 692	446,936
3·306	6·273 800 479	211,421	3·356	6·540 216 628	451,853
3·307	6·279 011 900	216,123	3·357	6·545 668 481	456,774
3·308	6·284 228 023	220,830	3·358	6·551 125 255	461,698
3·309	6·289 448 853	225,541	3 359	6·556 586 953	466,629
3·310	6·294 674 394	5,230,257	3·360	6·562 053 582	5,471,564
3·311	6·299 904 651	5,234,976	3·361	6·567 525 146	5,476,501
3·312	6·305 139 627	239,699	3 362	6·573 001 647	481,445
3·313	6·310 379 326	244,428	3·363	6·578 483 092	486,394
3·314	6·315 623 754	249,160	3·364	6·583 969 486	491,346
3·315	6·320 872 914	253,897	3·365	6·589 460 832	496.302
3·316	6·326 126 811	258,638	3·366	6·594 957 134	501,264
3·317	6·331 385 449	263,383	3·367	6·600 458 398	506,230
3·318	6·336 648 832	268,133	3·368	6 605 964 628	511,200
3·319	6·341 916 965	272,887	3·369	6·611 475 828	516,174
3·320	6·347 189 852	5,277,644	3·370	6·616 992 002	5,521,154
3·321	6·352 467 496	5,282,408	3·371	6·622 513 156	5,526,138
3·322	6·357 749 904	287,175	3·372	6·628 039 294	531,127
3·323	6·363 037 079	291,946	3·373	6·633 570 421	536,119
3·324	6·368 329 025	296,721	3·374	6·639 106 540	541,116
3·325	6·373 625 746	301,501	3·375	6·644 647 656	546,120
3·326	6·378 927 247	306,285	3·376	6·650 193 776	551,126
3·327	6·384 233 532	311,074	3·377	6·655 744 902	556,137
3·328	6·389 544 606	315,867	3·378	6·661 301 039	561,152
3·329	6·394 860 473	320,665	3·379	6·666 862 191	566,174
3·330	6·400 181 138	5,325,466	3·380	6·672 428 365	5,571,198
3·331	6·405 506 604	5,330,272	3·381	6·677 999 563	5,576,227
3·332	6·410 836 876	335,083	3·382	6 683 575 790	581,262
3·333	6·416 171 959	339,897	3·383	6·689 157 052	586,301
3·334	6·421 511 856	344,716	3·384	6·694 743 353	591,343
3·335	6·426 856 572	349,539	3·385	6·700 334 696	596,391
3·336	6·432 206 111	354,368	3·386	6·705 931 087	601,443
3·337	6·437 560 479	359,200	3·387	6·711 532 530	606,500
3·338	6·442 919 679	364,036	3·388	6·717 139 030	611,563
3·339	6·448 283 715	368,879	3·389	6·722 750 593	616,628
3·340	6·453 652 594	5,373,723	3·390	6·728 367 221	5,621,699
3·341	6·459 026 317	5,378,573	3·391	6·733 988 920	5,626,775
3·342	6·464 404 890	383,428	3 392	6·739 615 695	631,855
3·343	6·469 788 318	388,286	3·393	6·745 247 550	636,939
3·344	6·475 176 604	393,149	3·394	6·750 884 489	642,028
3·345	6·480 569 753	398,017	3·395	6·756 526 517	647,122
3·346	6·485 967 770	402,889	3·396	6 762 173 639	652,221
3·347	6·491 370 659	407,765	3·397	6·767 825 860	657,324
3·348	6·496 778 424	412,646	3·398	6·773 483 184	662,432
3·349	6·502 191 070	417,531	3 399	6·779 145 616	667,544
3·350	6·507 608 601	5,422,421	3·400	6·784 813 160	5,672,662

x	I_0x	Difference	x	I_0x	Difference
3·400	6·784 813 160	5,672,662	3·450	7·074 812 823	5,934,549
3·401	6·790 485 822	5,677,783	3·451	7·080 747 372	5,939,908
3·402	6·796 163 605	682,910	3·452	7·086 687 280	945,274
3·403	6·801 846 515	688,041	3·453	7·092 632 554	950,644
3·404	6·807 534 556	693,176	3·454	7·098 583 198	956,019
3·405	6·813 227 732	698,318	3·455	7·104 539 217	961,399
3·406	6·818 926 050	703,463	3·456	7·110 500 616	966,784
3·407	6·824 629 513	708,611	3·457	7·116 467 400	972,173
3·408	6·830 338 124	713,766	3·458	7·122 439 573	977,569
3·409	6·836 051 890	718,927	3·459	7·128 417 142	982,968
3·410	6·841 770 817	5,724,090	3·460	7·134 400 110	5,988,371
3·411	6·847 494 907	5,729,258	3·461	7·140 388 481	5,993,781
3·412	6·853 224 165	734,432	3·462	7·146 382 262	999,197
3·413	6·858 958 597	739,609	3·463	7·152 381 459	6,004,615
3·414	6·864 698 206	744,793	3·464	7·158 386 074	10,039
3·415	6·870 442 999	749,980	3·465	7·164 396 113	15,468
3·416	6·876 192 979	755,173	3·466	7·170 411 581	20,902
3·417	6·881 948 152	760,369	3·467	7·176 432 483	26,341
3·418	6·887 708 521	765,570	3·468	7·182 458 824	31,785
3·419	6·893 474 091	770,777	3·469	7·188 490 609	37,235
3·420	6·899 244 868	5,775,988	3·470	7·194 527 844	6,042,689
3·421	6·905 020 856	5,781,203	3·471	7·200 570 533	6,048,146
3·422	6·910 802 059	786,425	3·472	7·206 618 679	53,610
3·423	6·916 588 484	791,651	3·473	7·212 672 289	59,080
3·424	6·922 380 135	796,880	3·474	7·218 731 369	64,554
3·425	6·928 177 015	802,115	3·475	7·224 795 923	70,032
3·426	6·933 979 130	807,355	3·476	7·230 865 955	75,516
3·427	6·939 786 485	812,599	3·477	7·236 941 471	81,005
3·428	6·945 599 084	817,848	3·478	7·243 022 476	86,499
3·429	6·951 416 932	823,103	3·479	7·249 108 975	91,997
3·430	6·957 240 035	5,828,361	3·480	7·255 200 972	6,097,502
3·431	6·963 068 396	5,833,625	3·481	7·261 298 474	6,103,010
3·432	6·968 902 021	838,893	3·482	7·267 401 484	108,524
3·433	6·974 740 914	844,166	3·483	7·273 510 008	114,043
3·434	6·980 585 080	849,445	3·484	7·279 624 051	119,567
3·435	6·986 434 525	854,727	3·485	7·285 743 618	125,096
3·436	6·992 289 252	860,014	3·486	7·291 868 714	130,630
3·437	6·998 149 266	865,307	3·487	7·297 999 344	136,169
3·438	7·004 014 573	870,604	3·488	7·304 135 513	141,714
3·439	7·009 885 177	875,906	3·489	7·310 277 227	147,262
3·440	7·015 761 083	5,881,213	3·490	7·316 424 489	6,152,816
3·441	7·021 642 296	5,886,525	3·491	7·322 577 305	6,158,376
3·442	7·027 528 821	891,842	3·492	7·328 735 681	163,941
3·443	7·033 420 663	897,163	3·493	7·334 899 622	169,510
3·444	7·039 317 826	902,489	3·494	7·341 069 132	175,084
3·445	7·045 220 315	907,820	3·495	7·347 244 216	180,663
3·446	7·051 128 135	913,156	3·496	7·353 424 879	186,248
3·447	7·057 041 291	918,496	3·497	7·359 611 127	191,839
3·448	7·062 959 787	923,842	3·498	7·365 802 966	197,433
3·449	7·068 883 629	929,194	3·499	7·372 000 399	203,033
3·450	7·074 812 823	5,934,549	3·500	7·378 203 432	6,208,639

x	I_0x	Difference	x	I_0x	Difference
3·500	7·378 203 432	6,208,639	3·550	7·695 609 296	6,495,512
3·501	7·384 412 071	6,214,248	3·551	7·702 104 808	6,501,387
3·502	7·390 626 319	219,864	3·552	7·708 606 195	507,264
3·503	7·396 846 183	225,484	3·553	7·715 113 459	513,146
3·504	7·403 071 667	231,110	3·554	7·721 626 605	519,034
3·505	7·409 302 777	236,741	3·555	7·728 145 639	524,927
3·506	7·415 539 518	242,376	3·556	7·734 670 566	530,828
3·507	7·421 781 894	248,017	3·557	7·741 201 394	536,731
3·508	7·428 029 911	253,665	3·558	7·747 738 125	542,641
3·509	7·434 283 576	259,315	3·559	7·754 280 766	548,556
3·510	7·440 542 891	6,264,971	3·560	7·760 829 322	6,554,476
3·511	7·446 807 862	6,270,632	3·561	7·767 383 798	6,560,403
3·512	7·453 078 494	276,301	3·562	7·773 944 201	566,334
3·513	7·459 354 795	281,972	3·563	7·780 510 535	572,270
3·514	7·465 636 767	287,649	3·564	7·787 082 805	578,212
3·515	7·471 924 416	293,331	3·565	7·793 661 017	584,161
3·516	7·478 217 747	299,019	3·566	7·800 245 178	590,113
3·517	7·484 516 766	304,711	3·567	7·806 835 291	596,072
3·518	7·490 821 477	310,410	3·568	7·813 431 363	602,036
3·519	7·497 131 887	316,112	3·569	7·820 033 399	608,005
3·520	7·503 447 999	6,321,820	3·570	7·826 641 404	6,613,980
3·521	7·509 769 819	6,327,534	3·571	7·833 255 384	6,619,960
3·522	7·516 097 353	333,253	3·572	7·839 875 344	625,946
3·523	7·522 430 606	338,977	3·573	7·846 501 290	631,937
3·524	7·528 769 583	344,706	3·574	7·853 133 227	637,934
3·525	7·535 114 289	350,440	3·575	7·859 771 161	643,936
3·526	7·541 464 729	356,180	3·576	7·866 415 097	649,943
3·527	7·547 820 909	361,926	3·577	7·873 065 040	655,957
3·528	7·554 182 835	367,675	3·578	7·879 720 997	661,976
3·529	7·560 550 510	373,430	3·579	7·886 382 973	667,999
3·530	7·566 923 940	6,379,190	3·580	7·893 050 972	6,674,029
3·531	7·573 303 130	6,384,957	3·581	7·899 725 001	6,680,065
3·532	7·579 688 087	390,728	3·582	7·906 405 066	686,105
3·533	7·586 078 815	396,505	3·583	7·913 091 171	692,151
3·534	7·592 475 320	402,286	3·584	7·919 783 322	698,203
3·535	7·598 877 606	408,073	3·585	7·926 481 525	704,260
3·536	7·605 285 679	413,865	3·586	7·933 185 785	710,323
3·537	7·611 699 544	419,662	3·587	7·939 896 108	716,391
3·538	7·618 119 206	425,465	3·588	7·946 612 499	722,465
3·539	7·624 544 671	431,274	3·589	7·953 334 964	728,545
3·540	7·630 975 945	6,437,087	3·590	7·960 063 509	6,734,630
3·541	7·637 413 032	6,442,905	3·591	7·966 798 139	6,740,720
3·542	7·643 855 937	448,730	3·592	7·973 538 859	746,816
3·543	7·650 304 667	454,559	3·593	7·980 285 675	752,917
3·544	7·656 759 226	460,394	3·594	7·987 038 592	759,025
3·545	7·663 219 620	466,234	3·595	7·993 797 617	765,138
3·546	7·669 685 854	472,078	3·596	8·000 562 755	771,257
3·547	7·676 157 932	477,930	3·597	8·007 334 012	777,380
3·548	7·682 635 862	483,787	3·598	8·014 111 392	783,510
3·549	7·689 119 649	489,647	3·599	8·020 894 902	789,645
3·550	7 695 609 296	6,495,512	3·600	8·027 684 547	6,795,786

x	I_0x	Difference	x	I_0x	Difference
3·600	8·027 684 547	6,795,786	3·650	8·375 114 576	7,110,095
3·601	8·034 480 333	6,801,932	3·651	8·382 224 671	7,116,528
3·602	8·041 282 265	808,085	3·652	8·389 341 199	122,968
3·603	8·048 090 350	814,242	3·653	8·396 464 167	129,414
3·604	8·054 904 592	820,405	3·654	8·403 593 581	135,866
3·605	8·061 724 997	826,575	3·655	8·410 729 447	142,323
3·606	8·068 551 572	832,749	3·656	8·417 871 770	148,788
3·607	8·075 384 321	838,929	3·657	8·425 020 558	155,256
3·608	8·082 223 250	845,115	3·658	8·432 175 814	161,731
3·609	8·089 068 365	851,306	3·659	8·439 337 545	168,212
3·610	8·095 919 671	6,857,504	3·660	8·446 505 757	7,174,700
3·611	8·102 777 175	6,863,707	3·661	8·453 680 457	7,181,192
3·612	8·109 640 882	869,915	3·662	8·460 861 649	187,692
3·613	8·116 510 797	876,129	3·663	8·468 049 341	194,196
3·614	8·123 386 926	882,350	3·664	8·475 243 537	200,707
3·615	8·130 269 276	888,575	3·665	8·482 444 244	207,224
3·616	8·137 157 851	894,806	3·666	8·489 651 468	213,747
3·617	8·144 052 657	901,043	3·667	8·496 865 215	220,276
3·618	8·150 953 700	907,285	3·668	8·504 085 491	226,811
3·619	8·157 860 985	913,534	3·669	8·511 312 302	233,351
3·620	8·164 774 519	6,919,789	3·670	8·518 545 653	7,239,898
3·621	8·171 694 308	6,926,048	3·671	8·525 785 551	7,246,450
3·622	8·178 620 356	932,313	3·672	8·533 032 001	253,009
3·623	8·185 552 669	938,585	3·673	8·540 285 010	259,574
3·624	8·192 491 254	944,862	3·674	8·547 544 584	266,145
3·625	8·199 436 116	951,145	3·675	8·554 810 729	272,722
3·626	8·206 387 261	957,433	3·676	8·562 083 451	279,304
3·627	8·213 344 694	963,727	3·677	8·569 362 755	285,893
3·628	8·220 308 421	970,027	3·678	8·576 648 648	292,488
3·629	8·227 278 448	976,333	3·679	8·583 941 136	299,088
3·630	8·234 254 781	6,982,645	3·680	8·591 240 224	7,305,696
3·631	8·241 237 426	6,988,962	3·681	8·598 545 920	7,312,308
3·632	8·248 226 388	995,285	3·682	8·605 858 228	318,927
3·633	8·255 221 673	7,001,614	3·683	8·613 177 155	325,553
3·634	8·262 223 287	7,948	3·684	8·620 502 708	332,184
3·635	8·269 231 235	14,289	3·685	8·627 834 892	338,821
3·636	8·276 245 524	20,636	3·686	8·635 173 713	345,464
3·637	8·283 266 160	26,987	3·687	8·642 519 177	352,113
3·638	8·290 293 147	33,345	3·688	8·649 871 290	358,769
3·639	8·297 326 492	39,709	3·689	8·657 230 059	365,431
3·640	8·304 366 201	7,046,078	3·690	8·664 595 490	7,372,098
3·641	8·311 412 279	7,052,454	3·691	8·671 967 588	7,378,772
3·642	8·318 464 733	58,835	3·692	8·679 346 360	385,451
3·643	8·325 523 568	65,222	3·693	8·686 731 811	392,138
3·644	8·332 588 790	71,614	3·694	8·694 123 949	398,830
3·645	8·339 660 404	78,014	3·695	8·701 522 779	405,528
3·646	8·346 738 418	84,418	3·696	8·708 928 307	412,232
3·647	8·353 822 836	90,828	3·697	8·716 340 539	418,943
3·648	8·360 913 664	97,245	3·698	8·723 759 482	425,660
3·649	8·368 010 909	103,667	3·699	8·731 185 142	432,382
3·650	8·375 114 576	7,110,095	3·700	8·738 617 524	7,439,112

x	I_0x	Difference	x	I_0x	Difference
3·700	8·738 617 524	7,439,112	3·750	9·118 945 861	7,783,538
3·701	8·746 056 636	7,445,846	3·751	9·126 729 399	7,790,589
3·702	8·753 502 482	452,587	3·752	9·134 519 988	797,647
3·703	8·760 955 069	459,335	3·753	9·142 317 635	804,710
3·704	8·768 414 404	466,089	3·754	9·150 122 345	811,780
3·705	8·775 880 493	472,849	3·755	9·157 934 125	818,857
3·706	8·783 353 342	479,615	3·756	9·165 752 982	825,940
3·707	8·790 832 957	486,387	3·757	9·173 578 922	833,029
3·708	8·798 319 344	493,165	3·758	9·181 411 951	840,126
3·709	8·805 812 509	499,950	3·759	9·189 252 077	847,228
3·710	8·813 312 459	7,506,741	3·760	9·197 099 305	7,854,337
3·711	8·820 819 200	7,513,538	3·761	9·204 953 642	7,861,453
3·712	8·828 332 738	520,341	3·762	9·212 815 095	868,576
3·713	8·835 853 079	527,151	3·763	9·220 683 671	875,704
3·714	8·843 380 230	533,966	3·764	9·228 559 375	882,839
3·715	8·850 914 196	540,789	3·765	9·236 442 214	889,981
3·716	8·858 454 985	547,616	3·766	9·244 332 195	897,129
3·717	8·866 002 601	554,452	3·767	9·252 229 324	904,284
3·718	8·873 557 053	561,292	3·768	9·260 133 608	911,445
3·719	8·881 118 345	568,139	3·769	9·268 045 053	918,614
3·720	8·888 686 484	7,574,992	3·770	9·275 963 667	7,925,788
3·721	8·896 261 476	7,581,852	3·771	9·283 889 455	7,932,970
3·722	8·903 843 328	588,718	3·772	9·291 822 425	940,156
3·723	8·911 432 046	595,590	3·773	9·299 762 581	947,351
3·724	8·919 027 636	602,468	3·774	9·307 709 932	954,553
3·725	8·926 630 104	609,353	3·775	9·315 664 485	961,760
3·726	8·934 239 457	616,245	3·776	9·323 626 245	968,974
3·727	8·941 855 702	623,143	3·777	9·331 595 219	976,195
3·728	8·949 478 845	630,045	3·778	9·339 571 414	983,423
3·729	8·957 108 890	636,955	3·779	9·347 554 837	990,656
3·730	8·964 745 845	7,643,872	3·780	9·355 545 493	7,997,897
3·731	8·972 389 717	7,650,794	3·781	9·363 543 390	8,005,144
3·732	8·980 040 511	657,724	3·782	9·371 548 534	12,398
3·733	8·987 698 235	664,660	3·783	9·379 560 932	19,658
3·734	8·995 362 895	671,600	3·784	9·387 580 590	26,926
3·735	9·003 034 495	678,549	3·785	9·395 607 516	34,200
3·736	9·010 713 044	685,504	3·786	9·403 641 716	41,480
3·737	9·018 398 548	692,464	3·787	9·411 683 196	48,769
3·738	9·026 091 012	699,432	3·788	9·419 731 965	56,062
3·739	9·033 790 444	706,405	3·789	9·427 788 027	63,362
3·740	9·041 496 849	7,713,385	3·790	9·435 851 389	8,070,670
3·741	9·049 210 234	7,720,372	3·791	9·443 922 059	8,077,984
3·742	9·056 930 606	727,364	3·792	9·452 000 043	85,304
3·743	9·064 657 970	734,364	3·793	9·460 085 347	92,632
3·744	9·072 392 334	741,370	3·794	9·468 177 979	99,967
3·745	9·080 133 704	748,382	3·795	9·476 277 946	107,307
3·746	9·087 882 086	755,400	3·796	9·484 385 253	114,655
3·747	9·095 637 486	762,424	3·797	9·492 499 908	122,009
3·748	9·103 399 910	769,457	3·798	9·500 621 917	129,371
3·749	9·111 169 367	776,494	3·799	9·508 751 288	136,738
3·750	9·118 945 861	7,783,538	3·800	9·516 888 026	8,144,113

x	I_0x	Difference	x	I_0x	Difference
3·800	9·516 888 026	8,144,113	3·850	9·933 270 161	8,521,607
3·801	9·525 032 139	8,151,495	3·851	9·941 791 768	8,529,336
3·802	9·533 183 634	158,883	3·852	9·950 321 104	537,070
3·803	9·541 342 517	166,277	3·853	9·958 858 174	544,812
3·804	9·549 508 794	173,680	3·854	9·967 402 986	552,562
3·805	9·557 682 474	181,088	3·855	9·975 955 548	560,318
3·806	9·565 863 562	188,503	3·856	9·984 515 866	568,081
3·807	9·574 052 065	195,926	3·857	9·993 083 947	575,853
3·808	9·582 247 991	203,354	3·858	10·001 659 800	583,630
3·809	9·590 451 345	210,790	3·859	10·010 243 430	591,415
3·810	9·598 662 135	8,218,233	3·860	10·018 834 845	8,599,207
3·811	9·606 880 368	8,225,683	3·861	10·027 434 052	8,607,006
3·812	9·615 106 051	233,138	3·862	10·036 041 058	614,812
3·813	9·623 339 189	240,602	3·863	10·044 655 870	622,627
3·814	9·631 579 791	248,072	3·864	10·053 278 497	630,447
3·815	9·639 827 863	255,548	3·865	10·061 908 944	638,274
3 816	9·648 083 411	263,033	3·866	10·070 547 218	646,110
3·817	9·656 346 444	270,523	3·867	10·079 193 328	653,953
3·818	9·664 616 967	278,020	3·868	10·087 847 281	661,802
3·819	9·672 894 987	285,525	3·869	10·096 509 083	669,658
3·820	9·681 180 512	8,293,036	3·870	10·105 178 741	8,677,523
3·821	9·689 473 548	8,300,554	3·871	10·113 856 264	8,685,394
3·822	9·697 774 102	308,079	3·872	10·122 541 658	693,271
3·823	9·706 082 181	315,611	3·873	10·131 234 929	701,158
3·824	9·714 397 792	323,150	3·874	10·139 936 087	709,051
3·825	9·722 720 942	330,695	3·875	10·148 645 138	716,950
3·826	9·731 051 637	338,248	3·876	10·157 362 088	724,858
3·827	9·739 389 885	345,808	3·877	10·166 086 946	732,774
3 828	9·747 735 693	353,375	3·878	10·174 819 720	740,694
3·829	9·756 089 068	360,948	3·879	10·183 560 414	748,624
3·830	9·764 450 016	8,368,528	3·880	10·192 309 038	8,756,560
3·831	9·772 818 544	8,376,115	3·881	10·201 065 598	8,764,504
3·832	9·781 194 659	383,710	3·882	10·209 830 102	772,455
3·833	9·789 578 369	391,312	3·883	10·218 602 557	780,414
3·834	9·797 969 681	398,919	3·884	10·227 382 971	788,379
3·835	9·806 368 600	406,535	3·885	10·236 171 350	796,353
3·836	9 814 775 135	414,158	3·886	10·244 967 703	804,332
3·837	9·823 189 293	421,787	3·887	10·253 772 035	812,321
3·838	9·831 611 080	429,423	3·888	10·262 584 356	820,315
3 839	9 840 040 503	437,066	3·889	10·271 404 671	828,318
3·840	9·848 477 569	8,444,717	3·890	10·280 232 989	8,836,327
3·841	9·856 922 286	8,452,374	3·891	10·289 069 316	8,844,344
3·842	9·865 374 660	460,038	3·892	10·297 913 660	852,369
3·843	9·873 834 698	467,710	3·893	10·306 766 029	860,401
3·844	9·882 302 408	475,388	3·894	10·315 626 430	868,440
3·845	9·890 777 796	483,073	3·895	10·324 494 870	876,487
3·846	9·899 260 869	490,766	3·896	10·333 371 357	884,540
3·847	9·907 751 635	498,467	3·897	10·342 255 897	892,602
3·848	9·916 250 102	506,173	3·898	10·351 148 499	900,671
3·849	9·924 756 275	513,886	3·899	10·360 049 170	908,747
3·850	9·933 270 161	8,521,607	3·900	10·368 957 917	8,916,830

x	I_0x	Difference	x	I_0x	Difference
3·900	10·368 957 917	8,916,830	3·950	10·824 858 358	9,330,631
3·901	10·377 874 747	8,924,922	3·951	10·834 188 989	9,339,102
3·902	10·386 799 669	933,020	3·952	10·843 528 091	347,582
3·903	10·395 732 689	941,126	3·953	10·852 875 673	356,069
3·904	10·404 673 815	949,239	3·954	10·862 231 742	364,563
3·905	10·413 623 054	957,360	3·955	10·871 596 305	373,067
3·906	10·422 580 414	965,489	3·956	10·880 969 372	381,577
3·907	10·431 545 903	973,625	3·957	10·890 350 949	390,096
3·908	10·440 519 528	981,767	3·958	10·899 741 045	398,622
3·909	10·449 501 295	989,918	3·959	10·909 139 667	407,156
3·910	10·458 491 213	8,998,077	3·960	10·918 546 823	9,415,698
3·911	10·467 489 290	9,006,242	3·961	10·927 962 521	9,424,247
3·912	10·476 495 532	14,415	3·962	10·937 386 768	432,806
3·913	10·485 509 947	22,596	3·963	10·946 819 574	441,370
3·914	10·494 532 543	30,785	3·964	10·956 260 944	449,944
3·915	10·503 563 328	38,981	3·965	10·965 710 888	458,525
3·916	10·512 602 309	47,183	3·966	10·975 169 413	467,115
3·917	10·521 649 492	55,395	3·967	10·984 636 528	475,711
3·918	10·530 704 887	63,613	3·968	10·994 112 239	484,317
3·919	10·539 768 500	71,839	3·969	11·003 596 556	492,930
3·920	10·548 840 339	9,080,073	3·970	11·013 089 486	9,501,551
3·921	10·557 920 412	9,088,313	3·971	11·022 591 037	9,510,179
3·922	10·567 008 725	96,562	3·972	11·032 101 216	518,815
3·923	10·576 105 287	104,820	3·973	11·041 620 031	527,460
3·924	10·585 210 107	113,082	3·974	11·051 147 491	536,114
3·925	10·594 323 189	121,354	3·975	11·060 683 605	544,774
3·926	10·603 444 543	129,633	3·976	11·070 228 379	553,442
3·927	10·612 574 176	137,919	3·977	11·079 781 821	562,119
3·928	10·621 712 095	146,215	3·978	11·089 343 940	570,803
3·929	10·630 858 310	154,516	3·979	11·098 914 743	579,496
3·930	10·640 012 826	9,162,824	3·980	11·108 494 239	9,588,197
3·931	10·649 175 650	9,171,143	3·981	11·118 082 436	9,596,904
3·932	10·658 346 793	179,468	3·982	11·127 679 340	605,621
3·933	10 667 526 261	187,800	3·983	11·137 284 961	614,346
3·934	10·676 714 061	196,141	3·984	11·146 899 307	623,078
3·935	10·685 910 202	204,488	3·985	11·156 522 385	631,819
3·936	10·695 114 690	212,844	3·986	11·166 154 204	640,568
3·937	10·704 327 534	221,207	3·987	11·175 794 772	649,325
3·938	10·713 548 741	229,577	3·988	11·185 444 097	658,089
3·939	10·722 778 318	237,956	3·989	11·195 102 186	666,862
3·940	10·732 016 274	9,246,343	3·990	11·204 769 048	9,675,642
3·941	10·741 262 617	9,254,737	3·991	11·214 444 690	9,684,432
3·942	10·750 517 354	263,137	3·992	11·224 129 122	693,229
3·943	10·759 780 491	271,548	3·993	11·233 822 351	702,034
3·944	10·769 052 039	279,965	3·994	11·243 524 385	710,848
3·945	10·778 332 004	288,390	3·995	11·253 235 233	719,669
3·946	10·787 620 394	296,823	3·996	11·262 954 902	728,498
3·947	10·796 917 217	305,263	3·997	11·272 683 400	737,335
3·948	10·806 222 480	313,711	3·998	11·282 420 735	746,182
3·949	10·815 536 191	322,167	3·999	11·292 166 917	755,035
3·950	10·824 858 358	9,330,631	4·000	11·301 921 952	9,763,898

x	I_0x	Difference	x	I_0x	Difference
4·000	11·301 921 952	9,763,898	4·050	11·801 144 658	10,217,562
4·001	11·311 685 850	9,772,767	4·051	11·811 362 220	10,226,850
4·002	11·321 458 617	781,646	4·052	11·821 589 070	236,147
4·003	11·331 240 263	790,533	4·053	11·831 825 217	245,452
4·004	11·341 030 796	799,428	4·054	11·842 070 669	254,765
4·005	11·350 830 224	808,330	4·055	11·852 325 434	264,089
4·006	11·360 638 554	817,241	4·056	11·862 589 523	273,418
4·007	11·370 455 795	826,161	4·057	11·872 862 941	282,758
4·008	11·380 281 956	835,089	4·058	11·883 145 699	292,106
4·009	11·390 117 045	844,024	4·059	11·893 437 805	301,463
4·010	11·399 961 069	9,852,968	4·060	11·903 739 268	10,310,828
4·011	11·409 814 037	9,861,920	4·061	11·914 050 096	10,320,202
4·012	11·419 675 957	870,881	4·062	11·924 370 298	329,584
4·013	11·429 546 838	879,849	4·063	11·934 699 882	338,976
4·014	11·439 426 687	888,826	4·064	11·945 038 858	348,375
4·015	11·449 315 513	897,812	4·065	11·955 387 233	357,785
4·016	11·459 213 325	906,805	4·066	11·965 745 018	367,201
4·017	11·469 120 130	915,807	4·067	11·976 112 219	376,627
4·018	11·479 035 937	924,817	4·068	11·986 488 846	386,062
4·019	11·488 960 754	933,835	4·069	11·996 874 908	395,505
4·020	11·498 894 589	9,942,862	4·070	12·007 270 413	10,404,956
4·021	11·508 837 451	9,951,897	4·071	12·017 675 369	10,414,418
4·022	11·518 789 348	960,940	4·072	12·028 089 787	423,887
4·023	11·528 750 288	969,992	4·073	12·038 513 674	433,365
4·024	11·538 720 280	979,052	4·074	12·048 947 039	442,852
4·025	11·548 699 332	988,120	4·075	12·059 389 891	452,347
4·026	11·558 687 452	997,197	4·076	12·069 842 238	461,852
4·027	11·568 684 649	10,006,282	4·077	12·080 304 090	471,364
4·028	11·578 690 931	15,375	4·078	12·090 775 454	480,886
4·029	11·588 706 306	24,477	4·079	12·101 256 340	490,418
4·030	11·598 730 783	10,033,587	4·080	12·111 746 758	10,499,956
4·031	11·608 764 370	10,042,706	4·081	12·122 246 714	10,509,505
4·032	11·618 807 076	51,833	4·082	12·132 756 219	519,062
4·033	11·628 858 909	60,967	4·083	12·143 275 281	528,627
4·034	11·638 919 876	70,112	4·084	12·153 803 908	538,202
4·035	11·648 989 988	79,264	4·085	12·164 342 110	547,785
4·036	11·659 069 252	88,424	4·086	12·174 889 895	557,379
4·037	11·669 157 676	97,594	4·087	12·185 447 274	566,979
4·038	11·679 255 270	106,771	4·088	12·196 014 253	576,588
4·039	11·689 362 041	115,957	4·089	12·206 590 841	586,208
4·040	11·699 477 998	10,125,151	4·090	12·217 177 049	10,595,836
4·041	11·709 603 149	10,134,354	4·091	12·227 772 885	10,605,471
4·042	11·719 737 503	143,565	4·092	12·238 378 356	615,118
4·043	11·729 881 068	152,786	4·093	12·248 993 474	624,772
4·044	11·740 033 854	162,013	4·094	12·259 618 246	634,435
4·045	11·750 195 867	171,251	4·095	12·270 252 681	644,107
4·046	11·760 367 118	180,495	4·096	12·280 896 788	653,788
4·047	11·770 547 613	189,750	4·097	12·291 550 576	663,478
4·048	11·780 737 363	199,012	4·098	12·302 214 054	673,177
4·049	11·790 936 375	208,283	4·099	12·312 887 231	682,885
4·050	11·801 144 658	10,217,562	4·100	12·323 570 116	10,692,602

x	I_0x	Difference	x	I_0x	Difference
4·100	12·323 570 116	10,692,602	4·150	12·870 291 948	11,190,039
4·101	12·334 262 718	10,702,327	4·151	12·881 481 987	11,200,225
4·102	12·344 965 045	712,062	4·152	12·892 682 212	210,419
4·103	12·355 677 107	721,806	4·153	12·903 892 631	220,621
4·104	12·366 398 913	731,559	4·154	12·915 113 252	230,834
4·105	12·377 130 472	741,320	4·155	12·926 344 086	241,057
4·106	12·387 871 792	751,091	4·156	12·937 585 143	251,288
4·107	12·398 622 883	760,871	4·157	12·948 836 431	261,529
4·108	12·409 383 754	770,659	4·158	12·960 097 960	271,779
4·109	12·420 154 413	780,457	4·159	12·971 369 739	282,039
4·110	12·430 934 870	10,790,264	4·160	12·982 651 778	11,292,309
4·111	12·441 725 134	10,800,080	4·161	12·993 944 087	11,302,588
4·112	12·452 525 214	809,904	4·162	13·005 246 675	312,876
4·113	12·463 335 118	819,739	4·163	13·016 559 551	323,174
4·114	12·474 154 857	829,581	4·164	13·027 882 725	333,481
4·115	12·484 984 438	839,434	4·165	13·039 216 206	343,798
4·116	12·495 823 872	849,294	4·166	13·050 560 004	354,124
4·117	12·506 673 166	859,165	4·167	13·061 914 128	364,460
4·118	12·517 532 331	869,044	4·168	13·073 278 588	374,806
4·119	12·528 401 375	878,933	4·169	13·084 653 394	385,161
4·120	12·539 280 308	10,888,830	4·170	13·096 038 555	11,395,525
4·121	12·550 169 138	10,898,737	4·171	13·107 434 080	11,405,899
4·122	12·561 067 875	908,652	4·172	13·118 839 979	416,283
4·123	12·571 976 527	918,579	4·173	13·130 256 262	426,677
4·124	12·582 895 106	928,511	4·174	13·141 682 939	437,079
4·125	12·593 823 617	938,455	4·175	13·153 120 018	447,491
4·126	12·604 762 072	948,407	4·176	13·164 567 509	457,914
4·127	12·615 710 479	958,369	4·177	13·176 025 423	468,345
4·128	12·626 668 848	968,340	4·178	13·187 493 768	478,787
4·129	12·637 637 188	978,320	4·179	13·198 972 555	489,238
4·130	12·648 615 508	10,988,309	4·180	13·210 461 793	11,499,698
4·131	12·659 603 817	10,998,308	4·181	13·221 961 491	11,510,168
4·132	12·670 602 125	11,008,315	4·182	13·233 471 659	520,649
4·133	12·681 610 440	18,332	4·183	13·244 992 308	531,138
4·134	12·692 628 772	28,358	4·184	13·256 523 446	541,637
4·135	12·703 657 130	38,394	4·185	13·268 065 083	552,146
4·136	12·714 695 524	48,439	4·186	13·279 617 229	562,665
4·137	12·725 743 963	58,492	4·187	13·291 179 894	573,193
4·138	12·736 802 455	68,555	4·188	13·302 753 087	583,731
4·139	12·747 871 010	78,628	4·189	13·314 336 818	594,279
4·140	12·758 949 638	11,088,710	4·190	13 325 931 097	11,604,837
4·141	12·770 038 348	11,098,800	4·191	13·337 535 934	11 615,404
4·142	12·781 137 148	108,901	4·192	13·349 151 338	625,980
4·143	12·792 246 049	119,011	4·193	13·360 777 318	636,568
4·144	12·803 365 060	129,129	4·194	13·372 413 886	647,165
4·145	12·814 494 189	139,258	4·195	13·384 061 051	657,770
4·146	12·825 633 447	149,395	4·196	13·395 718 821	668,386
4·147	12·836 782 842	159,543	4·197	13·407 387 207	679,014
4·148	12·847 942 385	169,699	4·198	13·419 066 221	689,648
4·149	12·859 112 084	179,864	4·199	13·430 755 869	700,294
4·150	12·870 291 948	11,190,039	4·200	13·442 456 163	11,710,950

x	I_0x	Difference	x	I_0x	Difference
4·200	13·442 456 163	11,710,950	4·250	14·041 263 683	12,256,456
4·201	13·454 167 113	11,721,614	4·251	14·053 520 139	12,267,625
4·202	13·465 888 727	732,290	4·252	14·065 787 764	278,804
4·203	13·477 621 017	742,975	4·253	14·078 066 568	289,993
4·204	13·489 363 992	753,670	4·254	14·090 356 561	301,194
4·205	13·501 117 662	764,374	4·255	14·102 657 755	312,404
4·206	13·512 882 036	775,089	4·256	14·114 970 159	323,625
4·207	13·524 657 125	785,813	4·257	14·127 293 784	334,857
4·208	13·536 442 938	796,548	4·258	14·139 628 641	346,097
4·209	13·548 239 486	807,291	4·259	14·151 974 738	357,348
4·210	13·560 046 777	11,818,047	4·260	14·164 332 086	12,368,611
4·211	13·571 864 824	11,828,810	4·261	14·176 700 697	12,379,885
4·212	13·583 693 634	839,584	4·262	14·189 080 582	391,167
4·213	13·595 533 218	850,368	4·263	14·201 471 749	402,460
4·214	13·607 383 586	861,162	4·264	14·213 874 209	413,764
4·215	13·619 244 748	871,966	4·265	14·226 287 973	425,079
4·216	13·631 116 714	882,780	4·266	14·238 713 052	436,404
4·217	13·642 999 494	893 604	4·267	14·251 149 456	447,739
4·218	13·654 893 098	904,438	4·268	14·263 597 195	459,084
4·219	13·666 797 536	915,282	4·269	14·276 056 279	470,441
4·220	13·678 712 818	11,926,136	4·270	14·288 526 720	12,481,808
4·221	13·690 638 954	11,936,999	4·271	14·301 008 528	12,493,185
4·222	13·702 575 953	947,874	4·272	14·313 501 713	504,572
4·223	13·714 523 827	958,757	4·273	14·326 006 285	515,970
4·224	13·726 482 584	969,651	4·274	14·338 522 255	527,380
4·225	13·738 452 235	980,556	4·275	14·351 049 635	538,799
4·226	13·750 432 791	991,470	4·276	14·363 588 434	550,228
4·227	13·762 424 261	12,002,395	4·277	14·376 138 662	561,670
4·228	13·774 426 656	13,328	4·278	14·388 700 332	573,120
4·229	13·786 439 984	24,273	4·279	14·401 273 452	584,582
4·230	13·798 464 257	12,035,227	4·280	14·413 858 034	12,596,054
4·231	13·810 499 484	12,046,192	4·281	14·426 454 088	12,607,537
4·232	13·822 545 676	57,167	4·282	14·439 061 625	619,030
4·233	13·834 602 843	68,151	4·283	14·451 680 655	630,534
4·234	13·846 670 994	79,147	4·284	14·464 311 189	642,049
4·235	13·858 750 141	90,153	4·285	14·476 953 238	653,574
4·236	13·870 840 294	101,168	4·286	14·489 606 812	665,110
4·237	13·882 941 462	112,193	4·287	14·502 271 922	676,657
4·238	13·895 053 655	123,228	4·288	14·514 948 579	688,214
4·239	13·907 176 883	134,275	4·289	14·527 636 793	699,782
4·240	13·919 311 158	12,145,331	4·290	14·540 336 575	12,711,361
4·241	13·931 456 489	12,156,398	4·291	14·553 047 936	12,722,950
4·242	13·943 612 887	167,474	4·292	14·565 770 886	734,550
4·243	13·955 780 361	178,560	4·293	14·578 505 436	746,161
4·244	13·967 958 921	189,658	4·294	14·591 251 597	757,783
4·245	13·980 148 579	200,765	4·295	14·604 009 380	769,415
4·246	13·992 349 344	211,883	4·296	14·616 778 795	781,058
4·247	14·004 561 227	223,010	4·297	14·629 559 853	792,711
4·248	14·016 784 237	234,149	4·298	14·642 352 564	804,376
4·249	14·029 018 386	245,297	4·299	14·655 156 940	816,052
4·250	14·041 263 683	12,256,456	4·300	14·667 972 992	12,827,738

x	I_0x	Difference	x	I_0x	Difference
4·300	14·667 972 992	12,827,738	4·350	15·323 902 914	13,426,031
4·301	14·680 800 730	12,839,434	4·351	15·337 328 945	13,438,282
4·302	14·693 640 164	851,142	4·352	15·350 767 227	450,543
4·303	14·706 491 306	862,861	4·353	15·364 217 770	462,815
4·304	14·719 354 167	874,591	4·354	15·377 680 585	475,100
4·305	14·732 228 758	886,330	4·355	15·391 155 685	487,396
4·306	14·745 115 088	898,082	4·356	15·404 643 081	499,703
4·307	14·758 013 170	909,844	4·357	15·418 142 784	512,021
4·308	14·770 923 014	921,616	4·358	15·431 654 805	524,350
4·309	14·783 844 630	933,400	4·359	15·445 179 155	536,692
4·310	14·796 778 030	12,945,195	4·360	15·458 715 847	13,549,045
4·311	14·809 723 225	12,957,000	4·361	15·472 264 892	13,561,408
4·312	14·822 680 225	968,817	4·362	15·485 826 300	573,784
4·313	14·835 649 042	980,644	4·363	15·499 400 084	586,170
4·314	14·848 629 686	992,483	4·364	15·512 986 254	598,569
4·315	14·861 622 169	13,004,332	4·365	15·526 584 823	610,979
4·316	14·874 626 501	16,192	4·366	15·540 195 802	623,400
4·317	14·887 642 693	28,063	4·367	15·553 819 202	635,834
4·318	14·900 670 756	39,945	4·368	15·567 455 036	648,276
4·319	14·913 710 701	51,839	4·369	15·581 103 312	660,733
4·320	14·926 762 540	13,063,742	4·370	15·594 764 045	13,673,200
4·321	14·939 826 282	13,075,658	4·371	15·608 437 245	13,685,679
4·322	14·952 901 940	87,584	4·372	15·622 122 924	698,170
4·323	14·965 989 524	99,521	4·373	15·635 821 094	710,671
4·324	14·979 089 045	111,469	4·374	15·649 531 765	723,185
4·325	14·992 200 514	123,428	4·375	15·663 254 950	735,710
4·326	15·005 323 942	135,399	4·376	15·676 990 660	748,247
4·327	15·018 459 341	147,380	4·377	15·690 738 907	760,795
4·328	15·031 606 721	159,373	4·378	15·704 499 702	773,355
4·329	15·044 766 094	171,376	4·379	15·718 273 057	785,926
4·330	15·057 937 470	13,183,391	4·380	15·732 058 983	13,798,510
4·331	15·071 120 861	13,195,417	4·381	15·745 857 493	13,811,104
4·332	15·084 316 278	207,453	4·382	15·759 668 597	823,711
4·333	15·097 523 731	219,502	4·383	15·773 492 308	836,329
4·334	15·110 743 233	231,561	4·384	15·787 328 637	848,959
4·335	15·123 974 794	243,631	4·385	15·801 177 596	861,600
4·336	15·137 218 425	255,712	4·386	15·815 039 196	874,253
4·337	15·150 474 137	267,806	4·387	15·828 913 449	886,918
4·338	15·163 741 943	279,909	4·388	15·842 800 367	899,595
4·339	15·177 021 852	292,024	4·389	15·856 699 962	912,283
4·340	15·190 313 876	13,304,150	4·390	15·870 612 245	13,924,984
4·341	15·203 618 026	13,316,288	4·391	15·884 537 229	13,937,695
4·342	15·216 934 314	328,436	4·392	15·898 474 924	950,419
4·343	15·230 262 750	340,597	4·393	15·912 425 343	963,154
4·344	15·243 603 347	352,767	4·394	15·926 388 497	975,901
4·345	15·256 956 114	364,950	4·395	15·940 364 398	988,660
4·346	15·270 321 064	377,144	4·396	15·954 353 058	14,001,431
4·347	15·283 698 208	389,348	4·397	15·968 354 489	14,214
4·348	15·297 087 556	401,565	4·398	15·982 368 703	27,008
4·349	15·310 489 121	413,793	4·399	15·996 395 711	39,814
4·350	15·323 902 914	13,426,031	4·400	16·010 435 525	14,052,632

x	I_0x	Difference	x	I_0x	Difference
4·400	16·010 435 525	14,052,632	4·450	16·729 019 208	14·708,899
4·401	16·024 488 157	14,065,462	4·451	16·743 728 107	14,722,337
4·402	16·038 553 619	78,305	4·452	16·758 450 444	735,787
4·403	16·052 631 924	91,158	4·453	16·773 186 231	749,250
4·404	16·066 723 082	104,023	4·454	16·787 935 481	762,724
4·405	16·080 827 105	116,901	4·455	16·802 698 205	776,212
4·406	16·094 944 006	129,791	4·456	16·817 474 417	789,711
4·407	16·109 073 797	142,692	4·457	16·832 264 128	803,223
4·408	16·123 216 489	155,605	4·458	16·847 067 351	816,749
4·409	16·137 372 094	168,531	4·459	16·861 884 100	830,287
4·410	16·151 540 625	14,181,468	4·460	16·876 714 387	14,843,837
4·411	16·165 722 093	14,194,417	4·461	16·891 558 224	14,857,399
4·412	16·179 916 510	207,378	4·462	16·906 415 623	870,973
4·413	16·194 123 888	220,352	4·463	16·921 286 596	884,563
4·414	16·208 344 240	233,337	4·464	16·936 171 159	898,162
4·415	16·222 577 577	246,334	4·465	16·951 069 321	911,775
4·416	16·236 823 911	259,343	4·466	16·965 981 096	925,401
4·417	16·251 083 254	272,365	4·467	16·980 906 497	939,039
4·418	16·265 355 619	285,398	4·468	16·995 845 536	952,689
4·419	16·279 641 017	298,443	4·469	17·010 798 225	966,353
4·420	16·293 939 460	14,311,501	4·470	17·025 764 578	14,980,029
4·421	16·308 250 961	14,324,570	4·471	17·040 744 607	14,993,718
4·422	16·322 575 531	337,653	4·472	17·055 738 325	15,007,419
4·423	16·336 913 184	350,746	4·473	17·070 745 744	21,133
4·424	16·351 263 930	363,852	4·474	17·085 766 877	34,860
4·425	16·365 627 782	376,970	4·475	17·100 801 737	48,599
4·426	16·380 004 752	390,100	4·476	17·115 850 336	62,352
4·427	16·394 394 852	403,243	4·477	17·130 912 688	76,117
4·428	16·408 798 095	416,397	4·478	17·145 988 805	89,895
4·429	16·423 214 492	429,564	4·479	17·161 078 700	103,685
4·430	16·437 644 056	14,442,743	4·480	17·176 182 385	15,117,488
4·431	16·452 086 799	14,455,934	4·481	17·191 299 873	15,131,304
4·432	16·466 542 733	469,138	4·482	17·206 431 177	145,134
4·433	16·481 011 871	482,353	4·483	17·221 576 311	158,975
4·434	16·495 494 224	495,581	4·484	17·236 735 286	172,829
4·435	16·509 989 805	508,820	4·485	17·251 908 115	186,697
4·436	16·524 498 625	522,073	4 486	17·267 094 812	200,577
4·437	16·539 020 698	535,338	4·487	17·282 295 389	214,470
4·438	16·553 556 036	548,615	4·488	17·297 509 859	228,376
4·439	16·568 104 651	561,903	4·489	17·312 738 235	242,295
4·440	16·582 666 554	14,575,205	4·490	17·327 980 530	15,256,226
4·441	16·597 241 759	14,588,519	4·491	17·343 236 756	15,270,171
4·442	16 611 830 278	601,846	4·492	17·358 506 927	284,129
4·443	16·626 432 124	615,183	4·493	17·373 791 056	298,099
4·444	16·641 047 307	628,534	4·494	17·389 089 155	312,083
4·445	16·655 675 841	641,898	4·495	17·404 401 238	326,079
4·446	16·670 317 739	655,273	4·496	17·419 727 317	340,088
4·447	16·684 973 012	668,661	4·497	17·435 067 405	354,110
4·448	16·699 641 673	682,061	4·498	17·450 421 515	368,146
4·449	16·714 323 734	695,474	4·499	17·465 789 661	382,195
4·450	16·729 019 208	14,708,899	4·500	17·481 171 856	15,396,256

x	I_0x	Difference	x	I_0x	Difference
4·500	17·481 171 856	15,396,256	4·550	18·268 484 229	16,116,194
4·501	17·496 568 112	15,410,330	4·551	18·284 600 423	16,130,936
4·502	17·511 978 442	424,417	4·552	18·300 731 359	145,692
4·503	17·527 402 859	438,517	4·553	18·316 877 051	160,460
4·504	17·542 841 376	452,632	4·554	18·333 037 511	175,244
4·505	17·558 294 008	466,758	4·555	18·349 212 755	190,040
4·506	17·573 760 766	480,898	4·556	18·365 402 795	204,850
4·507	17·589 241 664	495,050	4·557	18·381 607 645	219,674
4·508	17·604 736 714	509,217	4·558	18·397 827 319	234,512
4·509	17·620 245 931	523,395	4·559	18·414 061 831	249,363
4·510	17·635 769 326	15,537,587	4·560	18·430 311 194	16,264,229
4·511	17·651 306 913	15,551,794	4·561	18·446 575 423	16,279,107
4·512	17·666 858 707	566,012	4·562	18·462 854 530	294,000
4·513	17·682 424 719	580,243	4·563	18·479 148 530	308,907
4·514	17·698 004 962	594,488	4·564	18·495 457 437	323,828
4·515	17·713 599 450	608,746	4·565	18·511 781 265	338,761
4·516	17·729 208 196	623,018	4·566	18·528 120 026	353,710
4·517	17·744 831 214	637,302	4·567	18·544 473 736	368,672
4·518	17·760 468 516	651,600	4·568	18·560 842 408	383,647
4·519	17·776 120 116	665,911	4·569	18·577 226 055	398,638
4·520	17·791 786 027	15,680,235	4·570	18·593 624 693	16,413,641
4·521	17·807 466 262	15,694,573	4·571	18·610 038 334	16,428,659
4·522	17·823 160 835	708,924	4·572	18·626 466 993	443,690
4·523	17·838 869 759	723,288	4·573	18·642 910 683	458,735
4·524	17·854 593 047	737,665	4·574	18·659 369 418	473,795
4·525	17·870 330 712	752,056	4·575	18·675 843 213	488,869
4·526	17·886 082 768	766,461	4·576	18·692 332 082	503,956
4·527	17·901 849 229	780,877	4·577	18·708 836 038	519,057
4·528	17·917 630 106	795,309	4·578	18·725 355 095	534,172
4·529	17·933 425 415	809,753	4·579	18·741 889 267	549,302
4·530	17·949 235 168	15,824,211	4·580	18·758 438 569	16,564,444
4·531	17·965 059 379	15,838,681	4·581	18·775 003 013	16,579,603
4·532	17·980 898 060	853,166	4·582	18·791 582 616	594,775
4·533	17·996 751 226	867,664	4·583	18·808 177 391	609,959
4·534	18·012 618 890	882,175	4·584	18·824 787 350	625,160
4·535	18·028 501 065	896,700	4·585	18·841 412 510	640,373
4·536	18·044 397 765	911,238	4·586	18·858 052 883	655,601
4·537	18·060 309 003	925,790	4·587	18·874 708 484	670,843
4·538	18·076 234 793	940,356	4·588	18·891 379 327	686,099
4·539	18·092 175 149	954,933	4·589	18·908 065 426	701,370
4·540	18·108 130 082	15,969,526	4·590	18·924 766 796	16,716,654
4·541	18·124 099 608	15,984,132	4·591	18·941 483 450	16,731,952
4·542	18·140 083 740	998,751	4·592	18·958 215 402	747,265
4·543	18·156 082 491	16,013,384	4·593	18·974 962 667	762,593
4·544	18·172 095 875	28,030	4·594	18·991 725 260	777,934
4·545	18·188 123 905	42,690	4·595	19·008 503 194	793,289
4·546	18·204 166 595	57,364	4·596	19·025 296 483	808,659
4·547	18·220 223 959	72,051	4·597	19·042 105 142	824,043
4·548	18·236 296 010	86,752	4·598	19·058 929 185	839,441
4·549	18·252 382 762	101,467	4·599	19·075 768 626	854,854
4·550	18·268 484 229	16,116,194	4·600	19·092 623 480	16,870,280

x	J_0x	Difference	x	J_0x	Difference
4·600	19·092 623 480	16,870,280	4·650	19·955 336 846	17,660,154
4·601	19·109 493 760	16,885,722	4·651	19·972 997 000	17,676,329
4·602	19·126 379 482	901,177	4·652	19·990 673 329	692,519
4·603	19·143 280 659	916,647	4·653	20·008 365 848	708,722
4·604	19·160 197 306	932,131	4·654	20·026 074 570	724,942
4·605	19·177 129 437	947,630	4·655	20·043 799 512	741,176
4·606	19·194 077 067	963,143	4·656	20·061 540 688	757,425
4·607	19·211 040 210	978,670	4·657	20·079 298 113	773,690
4·608	19·228 018 880	994,212	4·658	20·097 071 803	789,969
4·609	19·245 013 092	17,009,767	4·659	20·114 861 772	806,264
4·610	19·262 022 859	17,025,339	4·660	20·132 668 036	17,822,574
4·611	19·279 048 198	17,040,923	4·661	20·150 490 610	17,838,899
4·612	19·296 089 121	56,523	4·662	20·168 329 509	855,239
4·613	19·313 145 644	72,137	4·663	20·186 184 748	871,594
4·614	19·330 217 781	87,766	4·664	20·204 056 342	887,965
4·615	19·347 305 547	103,408	4·665	20·221 944 307	904,351
4·616	19·364 408 955	119,066	4·666	20·239 848 658	920,751
4·617	19·381 528 021	134,738	4·667	20·257 769 409	937,168
4·618	19·398 662 759	150,424	4·668	20·275 706 577	953,599
4·619	19·415 813 183	166,126	4·669	20·293 660 176	970,045
4·620	19·432 979 309	17,181,841	4·670	20·311 630 221	17,986,508
4·621	19·450 161 150	17,197,571	4·671	20·329 616 729	18,002,984
4·622	19·467 358 721	213,317	4·672	20·347 619 713	19,477
4·623	19·484 572 038	229,075	4·673	20·365 639 190	35,985
4·624	19·501 801 113	244,850	4·674	20·383 675 175	52,508
4·625	19·519 045 963	260,639	4·675	20·401 727 683	69,046
4·626	19·536 306 602	276,441	4·676	20·419 796 729	85,601
4·627	19·553 583 043	292,260	4·677	20·437 882 330	102,169
4·628	19·570 875 303	308,093	4·678	20·455 984 499	118,754
4·629	19·588 183 396	323,940	4·679	20·474 103 253	135,354
4·630	19·605 507 336	17,339,802	4·680	20·492 238 607	18,151,970
4·631	19·622 847 138	17,355,679	4·681	20·510 390 577	18,168,600
4·632	19·640 202 817	371,571	4·682	20·528 559 177	185,246
4·633	19·657 574 388	387,477	4·683	20·546 744 423	201,908
4·634	19·674 961 865	403,398	4·684	20·564 946 331	218,586
4·635	19·692 365 263	419,334	4·685	20·583 164 917	235,278
4·636	19·709 784 597	435,285	4·686	20·601 400 195	251,986
4·637	19·727 219 882	451,250	4·687	20·619 652 181	268,710
4·638	19·744 671 132	467,230	4·688	20·637 920 891	285,449
4·639	19·762 138 362	483,225	4·689	20·656 206 340	302,204
4·640	19·779 621 587	17,499,236	4·690	20·674 508 544	18,318,973
4·641	19·797 120 823	17,515,260	4·691	20·692 827 517	18,335,762
4·642	19·814 636 083	531,300	4·692	20·711 163 279	352,561
4·643	19·832 167 383	547,354	4·693	20·729 515 840	369,379
4·644	19·849 714 737	563,424	4·694	20·747 885 219	386,212
4·645	19·867 278 161	579,509	4·695	20·766 271 431	403,059
4·646	19·884 857 670	595,608	4·696	20·784 674 490	419,924
4·647	19·902 453 278	611,722	4·697	20·803 094 414	436,804
4·648	19·920 065 000	627,851	4·698	20·821 531 218	453,699
4·649	19·937 692 851	643,995	4·699	20·839 984 917	470,610
4·650	19·955 336 846	17,660,154	4·700	20·858 455 527	18,487,536

x	I_0x	Difference	x	I_0x	Difference
4·700	20·858 455 527	18,487,536	4·750	21·803 898 741	19,354,230
4·701	20·876 943 063	18,504,479	4·751	21·823 252 971	19,371,977
4·702	20·895 447 542	521,438	4·752	21·842 624 948	389,742
4·703	20·913 968 980	538,411	4·753	21·862 014 690	407,522
4·704	20·932 507 391	555,401	4·754	21·881 422 212	425,320
4·705	20·951 062 792	572,406	4·755	21·900 847 532	443,133
4·706	20·969 635 198	589,428	4·756	21·920 290 665	460,963
4·707	20·988 224 626	606,465	4·757	21·939 751 628	478,811
4·708	21·006 831 091	623,518	4·758	21·959 230 439	496,674
4·709	21·025 454 609	640,586	4·759	21·978 727 113	514,553
4·710	21·044 095 195	18,657,671	4·760	21·998 241 666	19,532,451
4·711	21·062 752 866	18,674,772	4·761	22·017 774 117	19,550,364
4·712	21·081 427 638	691,888	4·762	22·037 324 481	568,294
4·713	21·100 119 526	709,020	4·763	22·056 892 775	586,240
4·714	21·118 828 546	726,169	4·764	22·076 479 015	604,204
4·715	21·137 554 715	743,332	4·765	22·096 083 219	622,183
4·716	21·156 298 047	760,513	4·766	22·115 705 402	640,181
4·717	21·175 058 560	777,709	4·767	22·135 345 583	658,193
4·718	21·193 836 269	794,921	4·768	22·155 003 776	676,225
4·719	21·212 631 190	812,148	4·769	22·174 680 001	694,270
4·720	21·231 443 338	18,829,393	4·770	22·194 374 271	19,712,335
4·721	21·250 272 731	18,846,653	4·771	22·214 086 606	19,730,415
4·722	21·269 119 384	863,928	4·772	22·233 817 021	748,513
4·723	21·287 983 312	881,221	4·773	22·253 565 534	766,626
4·724	21·306 864 533	898,529	4·774	22·273 332 160	784,758
4·725	21·325 763 062	915,854	4·775	22·293 116 918	802,905
4·726	21·344 678 916	933,193	4·776	22·312 919 823	821,070
4·727	21·363 612 109	950,550	4·777	22·332 740 893	839,252
4·728	21·382 562 659	967,923	4·778	22·352 580 145	857,450
4·729	21·401 530 582	985,311	4·779	22·372 437 595	875,665
4·730	21·420 515 893	19,002,716	4·780	22·392 313 260	19,893,898
4·731	21·439 518 609	19,020,137	4·781	22·412 207 158	19,912,147
4·732	21·458 538 746	37,575	4·782	22·432 119 305	930,413
4·733	21·477 576 321	55,028	4·783	22·452 049 718	948,696
4·734	21·496 631 349	72,497	4·784	22·471 998 414	966,997
4·735	21·515 703 846	89,984	4·785	22·491 965 411	985,314
4·736	21·534 793 830	107,485	4·786	22·511 950 725	20,003,648
4·737	21·553 901 315	125,004	4·787	22·531 954 373	22,000
4·738	21·573 026 319	142,539	4·788	22·551 976 373	40,367
4·739	21·592 168 858	160,089	4·789	22·572 016 740	58,754
4·740	21·611 328 947	19,177,657	4·790	22·592 075 494	20,077,155
4·741	21·630 506 604	19,195,241	4·791	22·612 152 649	20,095,576
4·742	21·649 701 845	212,840	4·792	22·632 248 225	114,012
4·743	21·668 914 685	230,457	4·793	22·652 362 237	132,466
4·744	21·688 145 142	248,089	4·794	22·672 494 703	150,937
4·745	21·707 393 231	265,738	4·795	22·692 645 640	169,425
4·746	21·726 658 969	283,404	4·796	22·712 815 065	187,931
4·747	21·745 942 373	301,086	4·797	22·733 002 996	206,454
4·748	21·765 243 459	318,783	4·798	22·753 209 450	224,993
4·749	21·784 562 242	336,499	4·799	22·773 434 443	243,550
4·750	21·803 898 741	19,354,230	4·800	22·793 677 993	20,262,125

x	I_0x	Difference	x	I_0x	Difference
4·800	22·793 677 993	20,262,125	4·850	23·829 901 540	21,213,203
4·801	22·813 940 118	20,280,716	4·851	23·851 114 743	21,232,679
4·802	22·834 220 834	299,325	4·852	23·872 347 422	252,174
4·803	22·854 520 159	317,951	4·853	23·893 599 596	271,686
4·804	22·874 838 110	336,595	4·854	23·914 871 282	291,217
4·805	22·895 174 705	355,256	4·855	23·936 162 499	310,765
4·806	22·915 529 961	373,934	4·856	23·957 473 264	330,333
4·807	22·935 903 895	392,629	4·857	23·978 803 597	349,917
4·808	22·956 296 524	411,343	4·858	24·000 153 514	369,521
4·809	22·976 707 867	430,073	4·859	24·021 523 035	389,143
4·810	22·997 137 940	20,448,821	4·860	24·042 912 178	21,408,782
4·811	23·017 586 761	20,467,585	4·861	24·064 320 960	21,428,440
4·812	23·038 054 346	486,369	4·862	24·085 749 400	448,117
4·813	23·058 540 715	505,168	4·863	24·107 197 517	467,811
4·814	23·079 045 883	523,986	4·864	24·128 665 328	487,525
4·815	23·099 569 869	542,822	4·865	24·150 152 853	507,256
4·816	23·120 112 691	561,674	4·866	24·171 660 109	527,005
4·817	23·140 674 365	580,544	4·867	24·193 187 114	546,774
4·818	23·161 254 909	599,431	4·868	24·214 733 888	566,560
4·819	23·181 854 340	618,337	4·869	24·236 300 448	586,365
4·820	23·202 472 677	20,637,260	4·870	24·257 886 813	21,606,189
4·821	23·223 109 937	20,656,201	4·871	24·279 493 002	21,626,030
4·822	23·243 766 138	675,158	4·872	24·301 119 032	645,890
4·823	23·264 441 296	694,134	4·873	24·322 764 922	665,769
4·824	23·285 135 430	713,128	4·874	24·344 430 691	685,667
4·825	23·305 848 558	732,138	4·875	24·366 116 358	705,582
4·826	23·326 580 696	751,167	4·876	24·387 821 940	725,516
4·827	23·347 331 863	770,214	4·877	24·409 547 456	745,469
4·828	23·368 102 077	789,277	4·878	24·431 292 925	765,441
4·829	23·388 891 354	808,360	4·879	24·453 058 366	785,431
4·830	23·409 699 714	20,827,459	4·880	24·474 843 797	21,805,439
4·831	23·430 527 173	20,846,576	4·881	24·496 649 236	21,825,466
4·832	23·451 373 749	865,711	4·882	24·518 474 702	845,512
4·833	23·472 239 460	884,865	4·883	24·540 320 214	865,577
4·834	23·493 124 325	904,035	4·884	24·562 185 791	885,660
4·835	23·514 028 360	923,223	4·885	24·584 071 451	905,761
4·836	23·534 951 583	942,431	4·886	24·605 977 212	925,882
4·837	23·555 894 014	961,654	4·887	24·627 903 094	946,022
4·838	23·576 855 668	980,897	4·888	24·649 849 116	966,179
4·839	23·597 836 565	21,000,156	4·889	24·671 815 295	986,356
4·840	23·618 836 721	21,019,435	4·890	24·693 801 651	22,006,552
4·841	23·639 856 156	21,038,730	4·891	24·715 808 203	22,026,766
4·842	23·660 894 886	58,044	4·892	24·737 834 969	46,999
4·843	23·681 952 930	77,376	4·893	24·759 881 968	67,252
4·844	23·703 030 306	96,726	4·894	24·781 949 220	87,522
4·845	23·724 127 032	116,094	4·895	24·804 036 742	107,812
4·846	23·745 243 126	135,480	4·896	24·826 144 554	128,120
4·847	23·766 378 606	154,883	4·897	24·848 272 674	148,448
4·848	23·787 533 489	174,305	4·898	24·870 421 122	168,794
4·849	23·808 707 794	193,746	4·899	24·892 589 916	189,160
4·850	23·829 901 540	21,213,203	4·900	24·914 779 076	22,209,544

x	I_0x	Difference	x	I_0x	Difference
4·900	24·914 779 076	22,209,544	4·950	26·050 626 651	23,253,325
4·901	24·936 988 620	22,229,947	4·951	26·073 879 976	23,274,701
4·902	24·959 218 567	250,369	4·952	26·097 154 677	296,095
4·903	24·981 468 936	270,811	4·953	26·120 450 772	317,510
4·904	25·003 739 747	291,271	4·954	26·143 768 282	338,945
4·905	25·026 031 018	311,750	4·955	26·167 107 227	360,400
4·906	25·048 342 768	332,249	4·956	26·190 467 627	381,874
4·907	25·070 675 017	352,767	4·957	26·213 849 501	403,370
4·908	25·093 027 784	373,303	4·958	26·237 252 871	424,884
4·909	25·115 401 087	393,858	4·959	26·260 677 755	446,418
4·910	25·137 794 945	22,414,433	4·960	26·284 124 173	23,467,974
4·911	25·160 209 378	22,435,028	4·961	26·307 592 147	23,489,549
4·912	25·182 644 406	455,640	4·962	26·331 081 696	511,143
4·913	25·205 100 046	476,273	4·963	26·354 592 839	532,759
4·914	25·227 576 319	496,925	4·964	26·378 125 598	554,394
4·915	25·250 073 244	517,595	4·965	26·401 679 992	576,049
4·916	25·272 590 839	538,285	4·966	26·425 256 041	597,725
4·917	25·295 129 124	558,995	4·967	26·448 853 766	619,421
4·918	25·317 688 119	579,723	4·968	26·472 473 187	641,137
4·919	25·340 267 842	600,471	4·969	26·496 114 324	662,872
4·920	25·362 868 313	22,621,238	4·970	26·519 777 196	23,684,630
4·921	25·385 489 551	22,642,024	4·971	26·543 461 826	23,706.406
4·922	25·408 131 575	662,831	4·972	26·567 168 232	728,203
4·923	25·430 794 406	683,655	4·973	26·590 896 435	750,020
4·924	25·453 478 061	704,501	4·974	26·614 646 455	771,858
4·925	25·476 182 562	725,364	4·975	26·638 418 313	793,716
4·926	25·498 907 926	746,248	4·976	26·662 212 029	815,595
4·927	25·521 654 174	767,150	4·977	26·686 027 624	837,493
4·928	25·544 421 324	788,073	4·978	26·709 865 117	859,412
4·929	25·567 209 397	809,015	4·979	26·733 724 529	881,351
4·930	25·590 018 412	22,829,976	4·980	26·757 605 880	23,903,312
4·931	25·612 848 388	22,850,957	4·981	26·781 509 192	23,925,292
4·932	25·635 699 345	871,957	4·982	26·805 434 484	947,293
4·933	25·658 571 302	892,978	4·983	26·829 381 777	969,314
4·934	25·681 464 280	914,016	4·984	26·853 351 091	991,356
4·935	25·704 378 296	935,076	4·985	26·877 342 447	24,013,418
4·936	25·727 313 372	956,155	4·986	26·901 355 865	35,502
4·937	25·750 269 527	977,253	4·987	26·925 391 367	57,605
4·938	25·773 246 780	998,370	4·988	26·949 448 972	79,729
4·939	25·796 245 150	23,019,509	4·989	26·973 528 701	101,874
4·940	25·819 264 659	23,040,665	4·990	26·997 630 575	24,124,039
4·941	25·842 305 324	23,061,843	4·991	27·021 754 614	24,146,226
4·942	25·865 367 167	83,039	4·992	27·045 900 840	168,432
4·943	25·888 450 206	104,256	4·993	27·070 069 272	190,659
4·944	25·911 554 462	125,492	4·994	27·094 259 931	212,908
4·945	25·934 679 954	146,749	4·995	27·118 472 839	235,176
4·946	25·957 826 703	168,023	4·996	27·142 708 015	257,466
4·947	25·980 994 726	189,320	4·997	27·166 965 481	279,776
4·948	26·004 184 046	210,635	4·998	27·191 245 257	302,108
4·949	26·027 394 681	231,970	4·999	27·215 547 365	324,459
4·950	26·050 626 651	23,253,325	5·000	27·239 871 824	24,346,832

x	I_0x	Difference	x	I_0x	Difference
5·000	27·239 871 824	24,346,832	5·050	28·485 059 067	25,492,459
5·001	27·264 218 656	24,369,225	5·051	28·510 551 526	25,515,920
5·002	27·288 587 881	391,640	5·052	28·536 067 446	539,404
5·003	27·312 979 521	414,075	5·053	28·561 606 850	562,908
5·004	27·337 393 596	436,532	5·054	28·587 169 758	586,436
5·005	27·361 830 128	459,009	5·055	28·612 756 194	609,984
5·006	27·386 289 137	481,507	5·056	28·638 366 178	633,555
5·007	27·410 770 644	504,026	5·057	28·663 999 733	657,147
5·008	27·435 274 670	526,566	5·058	28·689 656 880	680,763
5·009	27·459 801 236	549,127	5·059	28·715 337 643	704,399
5·010	27·484 350 363	24,571,709	5·060	28·741 042 042	25,728,058
5·011	27·508 922 072	24,594,312	5·061	28·766 770 100	25,751,739
5·012	27·533 516 384	616,937	5·062	28·792 521 839	775,441
5·013	27·558 133 321	639,581	5·063	28·818 297 280	799,167
5·014	27·582 772 902	662,248	5·064	28·844 096 447	822,914
5·015	27·607 435 150	684,936	5·065	28·869 919 361	846,683
5·016	27·632 120 086	707,644	5·066	28·895 766 044	870,474
5·017	27·656 827 730	730,374	5·067	28·921 636 518	894,288
5·018	27·681 558 104	753,125	5·068	28·947 530 806	918,124
5·019	27·706 311 229	775,897	5·069	28·973 448 930	941,982
5·020	27·731 087 126	24,798,690	5·070	28·999 390 912	25,965,863
5·021	27·755 885 816	24,821,505	5·071	29·025 356 775	25,989,764
5·022	27·780 707 321	844,341	5·072	29·051 346 539	26,013,690
5·023	27·805 551 662	867,198	5·073	29·077 360 229	37,637
5·024	27·830 418 860	890,077	5·074	29·103 397 866	61,606
5·025	27·855 308 937	912,976	5·075	29·129 459 472	85,598
5·026	27·880 221 913	935,897	5·076	29·155 545 070	109,612
5·027	27·905 157 810	958,840	5·077	29·181 654 682	133,649
5·028	27·930 116 650	981,804	5·078	29·207 788 331	157,708
5·029	27·955 098 454	25,004,789	5·079	29·233 946 039	181,789
5·030	27·980 103 243	25,027,796	5·080	29·260 127 828	26,205,893
5·031	28·005 131 039	25,050,824	5·081	29·286 333 721	26,230,019
5·032	28·030 181 863	73,873	5·082	29·312 563 740	254,168
5·033	28·055 255 736	96,945	5·083	29·338 817 908	278,340
5·034	28·080 352 681	120,037	5·084	29·365 096 248	302,533
5·035	28·105 472 718	143,151	5·085	29·391 398 781	326,750
5·036	28·130 615 869	166,287	5·086	29·417 725 531	350,989
5·037	28·155 782 156	189,444	5·087	29·444 076 520	375,251
5·038	28·180 971 600	212,623	5·088	29·470 451 771	399,534
5·039	28·206 184 223	235,823	5·089	29·496 851 305	423,842
5·040	28·231 420 046	25,259,045	5·090	29·523 275 147	26,448,171
5·041	28·256 679 091	25,282,289	5·091	29·549 723 318	26,472,524
5·042	28·281 961 380	305,554	5·092	29·576 195 842	496,898
5·043	28·307 266 934	328,842	5·093	29·602 692 740	521,296
5·044	28·332 595 776	352,150	5·094	29·629 214 036	545,717
5·045	28·357 947 926	375,480	5·095	29·655 759 753	570,160
5·046	28·383 323 406	398,833	5·096	29·682 329 913	594,626
5·047	28·408 722 239	422,206	5·097	29·708 924 539	619,114
5·048	28·434 144 445	445,602	5·098	29·735 543 653	643,626
5·049	28·459 590 047	469,020	5·099	29·762 187 279	668,161
5·050	28·485 059 067	25,492,459	5·100	29·788 855 440	

Experiments for improving the Construction of Practical Standards for Electrical Measurements.—Report of the Committee, consisting of Professor CAREY FOSTER (*Chairman*), Lord KELVIN, Lord RAYLEIGH, Professors AYRTON, J. PERRY, *and* W. G. ADAMS, Drs. O. J. LODGE, JOHN HOPKINSON, *and* A. MUIRHEAD, Messrs. W. H. PREECE *and* HERBERT TAYLOR, Professor J. D. EVERETT, Professor A. SCHUSTER, Dr. J. A. FLEMING, Professors A. W. RÜCKER, G. F. FITZGERALD, G. CHRYSTAL, *and* J. J. THOMSON, Messrs. R. T. GLAZEBROOK (*Secretary*) *and* W. N. SHAW, Rev. T. C. FITZPATRICK, Dr. J. T. BOTTOMLEY, Professor J. VIRIAMU JONES, Dr. G. JOHNSTONE STONEY, Professor S. P. THOMPSON, Mr. G. FORBES, Mr. J. RENNIE, *and* Mr. E. H. GRIFFITHS.

THE work of testing resistance coils at the Cavendish Laboratory has been continued, and a table of the values of the coils tested is given.

Ohms.

No. of Coil		Resistance of Coil in Ohms	Temperature
Paul, 38 . . .	No. 447	1·00098	11°·9
Paul, 35 . . .	No. 448	100 (1 – ·00179)	11°·8
Paul, 40 . . .	No. 449	1000 (1 – ·00188)	12°·5
Elliott, 227 . . .	No. 450	·99658	12°·4
Paul, 37 . . .	No. 451	·99961	13°·4
Nalder, 5324 . . .	No. 452	·99881	12°·8
Nalder, 5326 . . .	No. 453	·99869	13°·5
Nalder, 4939 . . .	No. 454	·99899	13°·6
Elliott, 323 . . .	No. 455	1·00050	17°·7
Elliott, 324 . . .	No. 456	1·00067	17°·8
Elliott, 325 . . .	No. 457	1·00057	17°·8
Elliott, 326 . . .	No. 458	1·00060	17°·8

The comparison between the set of standards ordered from Germany—referred to in the last report—is not yet completed. The work will be continued during the current year.

At the Ipswich Meeting of the Association the question of a standard thermal unit was referred to the Electrical Standards Committee, and has been under their consideration during the year.

After the Ipswich Meeting Mr. E. H. Griffiths sent the following letter to a number of physicists in various foreign countries, together with a copy of the paper[1] he had communicated to the Association :—

Herewith I forward you a copy of a recent communication to the 'Philosophical Magazine,' in which I have endeavoured to call attention to the unsatisfactory nature of our present system of thermal measurements.

At the Ipswich Meeting of the British Association the consideration of the question of a standard thermal unit was referred to the Electrical Standards Committee.

As a member of that Committee I now approach you with a request that you will communicate to me any suggestions which you may regard as calculated to assist our deliberations on the subject.

I am anxious to lay before the Committee the opinions of the leading authorities of all countries; I trust, therefore, that you will favour me with some expression of your views, particularly as to the nature and magnitude of the thermal unit (if any) that you would recommend for adoption.

Unless you state that I am to regard your reply as 'for Committee only' or 'private,' I shall conclude that you have no objection to its publication.

The importance of arriving (if possible) at some general agreement regarding the thermal unit will, I hope, be accepted as a sufficient excuse for thus troubling you.

Copies of the circular letter, and of the paper[1] on the Thermal Unit, were sent to the following :—

Professor Abbe, Washington, U.S.A.
Professor Ames, Baltimore.
Professor Bartoli, Pavia.
Professor Barus, Providence, R.I.
Professor Benoît, Sèvres.
Professor Berthelot, Paris.
Professor Boltzmann, Vienna.
Professor Callendar, Montreal.
Dr. Chappuis, Bureau International, Sèvres.
Dr. Curie, Paris.
Professor Dieterici, Hanover.
Professor Dorn, Halle.
Professor Du Bois, U.S.A.
Professor Willard Gibbs, Yale, U.S.A.
Dr. Guillaume, Bureau International, Sèvres.
Professor Hall, Harvard, U.S.A.
Professor Himstedt, Freiburg.
Professor Hittorf, Münster.
Professor Joubert, Paris.
Professor Kayser, Bonn.
Professor Kohlrausch, Berlin.
Professor de Kowalski, Freiburg, Switzerland.
Dr. S. P. Langley, Washington, U.S.A.
Professor Landolt, Berlin.
Professor Le Chatelier, School of Mines, Paris.
Professor Lippmann, Paris.
Professor Victor Meyer, Heidelberg.
Professor Nernst, Göttingen.
Professor Nichols, Ithaca, U S.A.
Professor Olszewski, Cracow.
Professor Ostwald, Leipzig.
Professor Overbeck, Tübingen.
Professor Paschen, Hanover.
Professor Planck, Berlin.
Professor Pellat, Paris.
Professor Pernet, Zürich.
Professor Potier, Ecole Polytechnique, Paris.
Professor Quincke, Heidelberg
Professor Remsen, Baltimore, U.S.A.
Professor Rowland, Baltimore, U.S.A.
Professor Runge, Hanover.
Professor Schuller, Budapest.
Professor Stohmann, Leipzig.
Professor J. Thomsen, Copenhagen.
Professor Van 't Hoff, Amsterdam.
Professor Vaschy, Ecole Polytechnique, Paris.
Professor E. Warburg, Berlin.
Professor Wartha, Budapest.
Professor Weber, Zürich.
Professor E. Wiedemann, Erlangen.
Professor G. Wiedemann, Leipzig.
Professor Wüllner, Aachen.

[1] *Phil. Mag.*, November 1895.

Replies were received from the following, and the Committee desire to thank those who so courteously responded to Mr. Griffiths' inquiry for their very valuable assistance.

Professor Ames, Baltimore.
Professor Boltzmann, Vienna.
Professor Callendar, Montreal.
Dr. Chappuis, Bureau International, Sèvres.
Professor Dieterici, Hanover.
Professor Dorn, Halle.
Dr. Guillaume, Bureau International, Sèvres.
Professor Le Chatelier, School of Mines, Paris.
Professor Victor Meyer, Heidelberg.
Professor Nernst, Göttingen.
Professor Nichols, Ithaca, U.S.A.
Professor Olszewski (and Colleagues), Cracow.
Professor Ostwald, Leipzig.
Professor Paschen, Hanover.
Professor Planck, Berlin.
Professor Quincke, Heidelberg.
Professor Remsen, Baltimore, U.S.A.
Professor Rowland, Baltimore, U.S.A.
Professor Runge, Hanover.
Professor Stohmann, Leipzig.
Professor Wüllner, Aachen.

Extracts from such replies as contain definite suggestions bearing on the question of the unit of heat are printed in Appendix I.; the letters have been translated, and those which merely give general approval to some such scheme as that outlined have not been included. No replies were received adverse to the suggestion that an endeavour should be made to secure common agreement in the matter.

The concluding propositions of Mr. Griffiths' paper were substantially as follows:

(I.) To adopt as the theoretical unit of heat a multiple (42×10^6) of the erg.

(II.) To adopt as the practical unit of heat, the heat required to raise 1 gramme of water 1° C. of the nitrogen thermometer at some temperature t° C. as given by that thermometer.

(III.) To adopt provisionally some formula expressing the specific heat of water in terms of the temperature over a range of, say, 10° C.

If the number, 42×10^6 ergs, be adopted for the theoretical unit, then, according to the experiments of Rowland, the theoretical and the practical unit agree, provided that the temperature t° C. be 10° C.

Mr. Griffiths, in the paper already referred to, has made a comparison of the results obtained by Joule, Rowland, Schuster, Miculescu, and himself, for the amount of energy required to raise 1 gramme of water 1° C. at various temperatures. The results differ according as the readings of Joule's mercury thermometer are reduced to the scale of Rowland's air thermometer, or to the scale of the nitrogen thermometer, as has been done by Schuster.

In the first case the mean values are—

At 10° C. $(41{\cdot}971 \pm {\cdot}023) \times 10^6$; and at 15° C. $(41{\cdot}891 \pm {\cdot}023) \times 10^6$;

and in the second—

At 10° C. $(41{\cdot}958 \pm {\cdot}029) \times 10^6$; and at 15° C. $(41{\cdot}875 \pm {\cdot}029) \times 10^6$.

Tables of the values of the specific heat of water between 10° C. and 20° C. have been calculated by Mr. Griffiths, and are given in Appendix II.

The Committee have made an analysis of those replies which contain definite suggestions.

Most of the writers wish to see some multiple of the erg adopted as the theoretical unit, but there are differences of opinion as to the multiple to be chosen.

Thus, Professors Dorn and Wüllner, Dr. Chappuis, and Professor Ames would prefer 42×10^6 ergs. Professor Ostwald, Professor Olszewski and his colleagues, and Professor Callendar suggest 10^7 ergs. Professor Planck and M. Le Chatelier suggest 10^8 ergs, or in the case of the latter, as an alternative, 5×10^7.

Professors Rowland and Nichols consider the ice unit as theoretically best; the latter, however, would be willing to adopt 42×10^6 ergs as the theoretical unit, while Professor Rowland writes: 'From a practical standpoint, however, the unit depending on the specific heat of water is certainly the most convenient. It has been the one mostly used, and its value is well known in terms of energy.'

There is fairly general agreement in the view that as a practical unit the heat required to raise 1 gramme of water 1° C. at some fixed temperature must be taken, but views differ as to the temperature which it is most convenient to choose.

Mr. Griffiths suggested the nitrogen thermometer as the standard of temperature. The French physicists agree in the opinion that the hydrogen thermometer should be adopted, and reasons are given for this in the letters of M. Guillaume and M. Chappuis. The Committee concur in this view.

The Committee are of opinion that Mr. Griffiths' paper, and the replies received by him, show clearly that it is desirable to come to an agreement as to the definition of the unit of heat.

They understand that a Committee of the French Physical Society have the question at present under consideration, and they hope it may be possible for the Electrical Standards Committee of the British Association to co-operate with this Committee and with representatives of other foreign countries in the matter.

The Standards Committee have provisionally approved the following propositions, with the view of opening international discussion of the question. They propose to send the propositions to representative bodies throughout the world, with a letter stating that they have been provisionally approved, inviting further discussion, and asking those bodies to take the steps which seem to them most desirable in order to secure international agreement on the matter.

Proposition I.—For many purposes heat is most conveniently measured in units of energy, and the theoretical C.G.S. unit of heat is 1 erg. The name Joule has been given by the Electrical Standards Committee to 10^7 ergs.

For many practical purposes heat will continue to be measured in terms of the heat required to raise a measured mass of water through a definite range of temperature.

If the mass of water be 1 gramme, and the range of temperature 1° C. of the hydrogen thermometer from 9°·5 C. to 10°·5 C. of the scale of that thermometer, then, according to the best of the existing determinations, the amount of heat required is 4·2 Joules.

It will, therefore, be convenient to fix upon this number of Joules as a secondary unit of heat.

This secondary thermal unit may be called a 'Calorie.'

For the present a second proposition is

Proposition II.—The amount of heat required to raise the temperature of 1 gramme of water 1° C. of the scale of the hydrogen thermometer, at a mean temperature which may be taken as 10° C. of that thermometer, is 4·2 Joules.

If further research should show that the statement in II. is not exact, the definition could be adjusted by a small alteration in the mean temperature at which the rise of 1° takes place. The definition in I. and the number (4·2) of Joules in a Calorie would remain unaltered.

In Appendix II. a table is given showing the capacity for heat of water between 10° C. and 20° C., and in Appendix III. the values of the total heat of water has been calculated by Mr. Shaw from his experiments of Regnault and Rowland.

Professor J. V. Jones has, during the year, calculated the correction to be applied to the value of the international ohm in absolute measure given by him at the Oxford meeting (1894), in consequence of the ellipticity of the standard coil used in his experiments. The required correction is ·00684 per cent., and the corrected value of the international ohm is $\cdot 99983 \times 10^9$ absolute units.

In conclusion the Committee recommend that they be reappointed, with a grant of 5*l.*; that Professor G. Carey Foster be chairman, and Mr. R. T. Glazebrook secretary.

APPENDIX I.

Extracts from Letters received, dealing with the Question of the Unit of Heat.

1.—*From Dr. C. Dieterici, Professor of Physics, Hanover.*

[This reply has, since it was sent to Mr. Griffiths, been printed in full in *Wiedemann's Annalen* for February 1896. It is therefore not thought necessary to print it again here.]

2.—*From Dr. Dorn, Professor of Physics, Halle, December* 27, 1895.

[Translation.]

. . . I quite agree with you that it is very necessary there should be an improvement in the department of calorimetry, and that the first step must be the determination of sharply defined units. I agree with you in the opinion that the new unit ought not to differ in a marked degree from the present, for it would otherwise cause great inconvenience to both physicists and chemists, and there would be no hope of introducing the new unit technically.

I have really no objection to offer to the thermal unit being 42×10^6 ergs (or rather $41{\cdot}89 \times 10^6$ ergs).

3.—*From Dr. W. Ostwald, Professor of Chemistry, Leipzig, February* 12, 1896.

[Translation.]

I entirely agree with your proposal to take some multiple of the erg as unit of heat. Such a step seems to me so undoubtedly necessary that, in my opinion, the question is *when* and not *if* such a change should be carried out. I therefore regard your proposition as a welcome opportunity for going into the neglected question, and I may say that I am determined to recalculate, in the forthcoming third edition of my text-book, the whole of the thermo-chemical data in such a manner as to do my utmost to diminish the difficulties consequent on the transition. I have already (in 1891) expressed my opinion very clearly, and I now send you the memoir referring to it.[1]

I differ from your proposals, however, as regards the magnitude of the unit to be adopted. I believe that only an erg multiplied by some integral power of 10 should be chosen. I formerly proposed a Mega-erg, but have now altered my opinion.

As a practical multiple of the erg, we already possess one in electricity, viz., the Joule $= 10^7$ ergs; and it appears to me to have the great advantage that the practical unit of energy in constant use in the two great departments of electrical and thermal measurements would be identical; therefore I do not think that any other choice could be so advantageous.

4.—*From Dr. F. Paschen, Tit. Professor of Physics, Hanover, November* 24, 1895.

. . . We must have an absolute unit simply related to other absolute units, and that would be your 'Rowland'; but we must also know how to realise this unit. For this purpose the specific heat of water must be fixed for each temperature.

I think, as the different observations on the variability of the specific heat of water differ so greatly, your statement III. (p. 3) is a very preliminary one. . . . I think it would be best to propose that a new determination of the changes in the specific heat of water should be undertaken by some institute that has the necessary apparatus and money.

5.—*From Dr. M. Planck, Professor of Physics, Berlin, November* 25, 1895.

[TRANSLATION.]

If I may venture on giving my opinion on the propositions made by you, I must emphasise, before all things, that I agree with you as to the necessity of having a well-defined universal unit of heat, and I should be very glad if your well-considered plans led to a definite result. As a theorist I would make even more radical demands as to the unit to be defined. The ideal universal unit of heat appears to me to be still more closely related to the definition of the electrical units; consequently I would define:—

I. One 'Rowland' (or 'Meyer,' or 'Kelvin') as that quantity of heat which is equivalent to 10^8 ergs.

II. According to the best measurements hitherto obtained 1 'Rowland' is that quantity of heat which raises 1 gramme of water at 15° C. through 2°·39 C. It would be possible to modify this number in the light of subsequent experiments. We should thus avoid the arbitrary character involved in the choice of such numbers as $41{\cdot}89 \times 10^6$ or 42×10^6.

[1] See *Studien zur Energetik*, p. 577.

At the same time I quite acknowledge that the establishment of this unit will cause a considerable revolution in present thermal calculations which will be difficult to carry out, and it will therefore probably meet with energetic opposition from practical physicists and from technical men. Still, as I have already remarked, I should consider it a great step in advance if even the value of the equivalent of heat were established.

6.—*From Dr. Wüllner, Professor of Physics, Aachen, February* 23, 1896.

[Translation.]

I, also, have finally decided on determining the unit of heat by the work done, inasmuch as I have endeavoured to determine the work which is equivalent to the mean calorie measured by the ice calorimeter.

I hope I made it evident that I am quite aware of the uncertainty of this method of calibration. I thus arrived at the value $4175{\cdot}8 \times 10^4$, or, in whole numbers, 4176×10^4, which, according to Rowland, corresponds to the heat required to raise the unit weight of water through 1° C. at 22° C. of the air thermometer.

I am, however, quite willing, if an agreement can be arrived at, to discard the always uncertain relation to the mean unit of heat, and to accept your proposed unit 42×10^6. The temperature 15°, at which the specific heat of water is then unity, is more convenient. The consequence of such an agreement will be that all thermal measurements in which absolute values are aimed at will be made with the water calorimeter, in which case it appears easier to experiment with temperatures about 15°; also we are in better agreement as to the behaviour of water between 10° C. and 20° C., although, even then, there is not complete certainty. I should, for example, prefer to make the reductions at 15° entirely according to the observations of Rowland, as he has directly measured the equivalent of heat at these temperatures. Finally, as regards the designation of the new unit, I do not approve of giving it the name of a physicist; also the name 'therm' is suitable for English physicists, but not for others.

Why should we not simply preserve the name 'thermal unit'? Or, if a distinctive name is used, then, approximating to the long-used 'calorie,' call the new unit a 'calor.' The definition would then be, 'A calor is the heat value of $41{\cdot}89 \times 10^6$ ergs,' and, until further notice, the calor will be equal to the amount of heat which will raise the unit mass of water at 15° through 1° C.

No especial name has been given to the length of the mercury column which is equivalent to 1 ohm. In no case would I advocate the adoption of a second definition for the practical unit (besides 'Rowland,' 'calor,' or simply 'thermal unit'), as that would lead to confusion.

7.—*From Dr. Boltzmann, Professor of Theoretical Physics, Vienna, November* 26, 1895.

The unit ought to be as simple as possible and capable of accurate determination, as all other qualities are of less importance. It would be simplest to choose the heat which raises the temperature from 10° to 11° C.

In general I am in accord with all you say in your paper. The most important thing is that the same conception should be adopted everywhere, and for this reason I will fully accept the decision of the majority of the Committee.

8.—*From Dr. K. Olszewski, Professor of Chemistry, Cracow, December* 14, 1895.

I have taken the advice of my colleagues in the Cracow University, Professors Witkowski and Natanson, and I beg to submit to your attention, as well as to that of the British Association Electrical Standards Committee, the following suggestions, being the conclusions arrived at conjointly by the above-named gentlemen and myself.

1. It would be advisable, on theoretical grounds, to select a Joule, or 10^7 ergs, as the fundamental theoretical or ideal unit of heat-energy. Hence the following proposal is brought forward :—

> 'That the *theoretical* or *thermo-dynamical*, or, say, *c.g.s. standard thermal unit*, be defined as the heat equivalent of a Joule or of 10^7 ergs, and termed *a thermal Joule*.'

2. That, as a *practical thermal unit*, the quantity of heat required to raise 1 gramme of pure water through 1° of the thermo-dynamical scale at 15° of that scale be temporarily adopted.

3. That, in view of the exceptional importance of the question, steps be taken, by international co-operation or otherwise, leading to the determination of the numerical value of the ratio between the theoretical unit and the practical unit, defined by 15°, as above stated, by some at least of the leading physical and metrological laboratories and institutions of the world, with the highest degree of accuracy nowadays attainable ; and to the extension (if possible) of such determinations over as great a range of temperature as practicable. Added to the highly valuable work already done, such an investigation cannot fail to settle the question of the specific heat of water ; and if this be done, the subject of thermal units will have lost nearly all of its present difficulty.

9.—*From Dr. Chappuis, Bureau International des Poids et Mesures, Sèvres, February* 2, 1896.

[TRANSLATION.]

. . . Your arguments have led me to accept the propositions given by you on pp. 452 and 453.

If, however, I may be allowed to express a wish, it is that the values may be reduced to the normal scale of temperature, *i.e.*, to that of the hydrogen thermometer, and not to the air or nitrogen.

It is true that the difference between these scales is very small, but still it is perfectly measurable. Some experiments of the Bureau International des Poids et Mesures (not yet published) have led me to the conclusion that the thermometric scale of hydrogen is independent of the initial pressure between 0·5 and 2 atmospheres, and that the hydrogen thermometer at constant pressure gives sensibly the same values as the thermometer at constant volume. It is not so with the nitrogen or the air thermometer.

The difference between the nitrogen and hydrogen scales is indicated both in the original memoir ('Trav. et Mém. du Bureau International,' Vol. VI.) in the pamphlet on thermometry of precision by M. Guillaume, as well as in Landolt and Börnstein's physical tables, 2nd edition, p. 93. Also a great number of physicists have adopted the decision of the International Committee of the Poids et Mesures to take, as the normal scale of temperature, that of the hydrogen thermometer at constant volume.

10.—*From Professor Le Chatelier, School of Mines, Paris.*

[TRANSLATION.]

. . . I should like the thermal unit to be a number of ergs chosen arbitrarily; either 10^8 ergs, or, in order to approach more nearly to the present unit, 5×10^7 ergs. Then, as practical unit, I should like two: (1) A unit, of precision analogous to the ohm, which should be the quantity of heat yielded by a given mass of mercury in passing from one state to another, the states being defined by volume or electrical conductivity. (2) The present unit should be the specific heat of water at 15°.

The use of water is indispensable for current researches, but it appears to me very doubtful for researches of precision.

It is supposed that the condition of water and, consequently, its internal energy are completely determined when the pressure and temperature are ascertained. Now, nothing is less probable. Since Ramsay's researches, we know decisively that water is formed of a mixture of molecules at various degrees of association; it is a system in equilibrium. The state of equilibrium of analogous systems is in theory entirely defined when the pressure and temperature are known. But in practice the state of equilibrium is only attained with an extreme slowness, and sometimes it is never reached. The lower the temperature, the more serious are those delays in reaching the state of equilibrium. It is therefore possible that the specific heat of water varies with the temperature, and that it differs according to whether the initial temperature of the experiment has been reached when ascending or descending.

11.—*From Dr. Guillaume, Bureau International des Poids et Mesures, Sèvres, November* 19, 1895.

[TRANSLATION.]

I believe that if the French Committee adopt your proposal as to the fixing of the new unit, they will declare themselves still more decidedly in favour of the name which you have given them, as it has already been proposed here to name 'therm' the equivalent of heat of the erg or of one of its decimal multiples.

I do not think, in return, that we could agree with you as to the scale of the nitrogen thermometer. There appears to be no doubt that the hydrogen thermometer gives a scale extremely like the thermo-dynamic, and that it is, at all events, the most analogous we can have. Sooner or later it will be necessary to adopt the thermo-dynamic scale, and it is well to now approach to it as nearly as possible.

Besides, this scale is one of a certain small number of units on which a legal authority has been conferred. It is now included in the decisions arrived at by the International Committee of Weights and Measures, which a certain number of States have introduced into their legislation.

In itself the thing is actually of little importance; but it becomes more important in proportion as experiments become more exact, and it is best to have as little as possible to change in the end.

12.—*From Professor J. S. Ames, Johns Hopkins University, U.S.A., December* 10, 1895.

. . . I must say your proposal appeals to me in every way. The 10° unit seems to me to be preferable to the 15° one.

13.—*From Professor H. L. Callendar, Professor of Physics, McGill University, Montreal, December* 5, 1895.

I entirely agree that it would be a very great improvement to adopt an absolute unit in place of the present various and uncertain units based upon the peculiar properties of water. I think, however, that it would be better to connect it more simply and directly with the system of electrical units, and to use only names which are already familiar to all engineers, than to attempt to retain a close approximation to the value of any of the old specific heat units, which are essentially arbitrary.

The following are the names of the series of thermal units which I should be inclined to suggest as being already familiar in practice :—

1. The thermal watt-second, or 'Joule,' defined as being equivalent to 10^7 c.g.s. units of work. A rider might be added to the effect that, according to the best determinations, this unit is approximately equal to $\frac{1}{4\cdot2}$ of the gramme degree centigrade at 10° C.

2. The thermal watt-hour, which would be equivalent to 3,600 Joules, and would therefore be of a similar magnitude to the kilogramme degree centigrade, which is so largely used in the thermo-dynamics of the steam-engine. The watt-hour, in fact, would be exactly $\frac{6}{7}$ths of the kilogramme degree centigrade at some temperature in the neighbourhood of 10° C.

3. The thermal kilowatt-hour, or simply kilowatt-hour, which, as the Board of Trade unit of electrical energy, is already so familiar and useful for the commercial measurement of large quantities of energy.

In connection with the latter unit it may be remarked that it would be a great advantage if engineers could be induced to adopt the kilowatt as their unit of mechanical power in place of the horse power. The latter unit differs from the 'cheval-vapeur,' and being based upon the foot-pound has different values in different latitudes. For the order of accuracy generally attainable in steam-engine work, it would, as a rule, be sufficient to take the horse power as being $\frac{3}{4}$ths of the kilowatt power.

For steam-engine work undoubtedly one of the most important units at present in use is the British thermal unit, or pound degree Fahrenheit. It happens that the watt-hour is very nearly equal to 3·400 B.T.U. The reduction of the latter to watt-hours may be very readily effected by multiplying by 0·3 and then reducing the result by 2 per cent.

It would seem, on the whole, not improbable that the simple adoption of all the familiar units of electrical energy, with the prefix 'thermal,' if necessary, as our absolute units of heat, would result in a more general agreement and a greater simplification of expression than any attempt to re-define one of the older units in terms of the absolute system. The latter course might readily lead to confusion, and would necessitate the retention of the constant factor $J = 4{\cdot}2 \times 10^7$ in our equations whenever they involved electrical or mechanical measurements.

To put the question in a brief and concrete form for the consideration of the Committee, I think that the views above expressed might be embodied in some such resolutions as the following :—

1. That the thermal equivalents of the practical units of electrical energy above mentioned may be taken as convenient absolute units of heat.

2. That when used to denote quantities of heat these units may be distinguished, if necessary, by prefixing the word 'thermal.'

3. That the 'thermal watt-second,' which is intended to represent 10^7 c.g.s. units of energy, be also called a 'Joule.'

4. That the heat developed by an electromotive force equal to that of a standard Clark cell at 15° C., when acting through a resistance equal to one standard ohm, may be taken as 1·4340 Joule per second.

5. That (pending the results of further investigations) the quantity of heat required to raise the temperature of one gramme of water through one degree of the centigrade air thermometer in the neighbourhood of 10° C. may be taken as 4·200 Joules.

6. That the thermal watt-hour, which is equal to 3·600 Joules, may be taken as equal to $\frac{6}{7}$ths of the kilogramme degree centigrade at 10° C., or as equal to 3·4 times the pound degree Fahrenheit at 50° F.

7. That for the reduction of observations to the standard temperature of 10° C. or 50° F., the temperature coefficient of the diminution of the specific heat of water may be taken as ·00036 per 1° C., or ·00020 per 1° F., over the range 10° to 20°.

With regard to the last resolution I do not see that anything would be gained in the present state of our knowledge by adopting a more complicated or discontinuous formula of reduction, until we are prepared to extend it to higher ranges of temperature.

The name 'Joule,' as that of the father of the mechanical measurement of heat, would not, I think, be open to objection. At the same time I feel that the choice of a special name for the absolute unit of heat is one comparatively of secondary importance. The really essential points to impress upon the world of science in general, and upon engineers in particular, are, that the specific heat of water is far from constant, and that 772 foot-pounds are not very accurately equivalent to the B.T.U. Also that in measuring quantities of heat by the rise in temperature of a mass of water it is most important to have an accurately verified thermometer, and to state the limits of temperature between which the observations were taken. It would certainly be a great advantage for the reduction and comparison of observations to use always the same standard formulæ, such as those which you suggest; but it would still be necessary in accurate work to state the limits of temperature for subsequent identification, should these formulæ prove on more exact investigation to be not sufficiently approximate.

14.—*From Professor E. L. Nichols, Professor of Physics, Cornell University, Ithaca, U.S.A., January* 12, 1896.

The suggestion of defining the heat units by means of the melting of ice strikes me so favourably that, in spite of the difficulties which have hitherto been found in determining the precise heat of fusion, I am considering the question of the redetermination by new methods with a view of finding whether one can obtain a sufficient degree of accuracy to warrant the adoption of the heat of fusion of water as the basis for thermal measurement.

15.—*From Professor Rowland, Professor of Physics, Johns Hopkins University, Baltimore, U.S.A., December* 15, 1895.

As to the standard for heat measurement, it is to be considered from both a theoretical as well as a practical standpoint.

The ideal theoretical unit would be that quantity of heat necessary to melt one gramme of ice. This is independent of any system of thermometry, and presents to our minds the idea of quantity of heat independent of temperature.

Thus the system of thermometry would have no connection whatever with the heat unit, and the first law of thermodynamics would stand, as it should, entirely independent of the second.

The idea of a quantity of heat at a high temperature being very different from the same quantity at a low temperature would then be easy and simple. Likewise we could treat thermodynamics without any reference to temperature until we came to the second law, which would then introduce temperature and the way of measuring it.

From a practical standpoint, however, the unit depending on the specific heat of water is at present certainly the most convenient. It has been the one mostly used, and its value is well known in terms of energy. Furthermore, the establishment of institutions where *it is said* thermometers can be compared with a standard renders the unit very available in practice. In other words, this unit is a better practical one at present. I am very sorry this is so, because it is a very poor theoretical one indeed.

But as we can write our text-books as we please, I suppose that it is best to accept the most practical unit. This I conceive to be the heat required to raise a gramme of water 1° C. on the hydrogen thermometer at 20° C.

I take 20° because in ordinary thermometry the room is usually about this temperature, and no reduction will be necessary. However, 15° would not be inconvenient, or 10° to 20°.

As I write these words I have a feeling that I may be wrong. Why should we continue to teach in our text-books that heat has anything to do with temperature? It is decidedly wrong, and if I ever write a text-book I shall probably use the ice unit. But if I ever write a scientific paper of an experimental nature I shall probably use the other unit.

APPENDIX II.

The Capacity for Heat of Water from 10° to 20° C. referred to its Capacity at 10° C. as Unity.

—	Rowland	Griffiths	Bartoli and Stracciati	Mean
°				
10	1·0000	*1·0000*	1·0000	1·0000
11	·9995	*·9997*	·9997	·9996
12	·9990	*·9994*	·9994	·9993
13	·9985	*·9991*	·9991	·9989
14	·9980	·9989	·9988	·9986
15	·9974	·9986	·9985	·9982
16	·9969	·9983	·9981	·9978
17	·9964	·9981	·9979	·9975
18	·9959	·9978	·9978	·9972
19	·9954	·9975	·9977	·9969
20	·9950	·9973	·9977	·9967

(Numbers given in italics are obtained by extrapolation.)

Note.—If we assume the validity of the numbers in the last column, then any quantity of heat (Q_t) expressed in terms of the capacity for heat of water at t° C. may be expressed with sufficient accuracy in terms of the thermal unit at 10° C. (Q_{10}) by means of the following formula :—

$$Q_{10} = Q_t \{1 - \cdot 00033\,(t-10)\},$$

where t lies between 10° and 20° C.

Then $Q_{10} \times 4{\cdot}2$ gives the equivalent in Joules.

APPENDIX III.

Recalculation of the Total Heat of Water from the Experiments of Regnault and Rowland. By W. N. Shaw.

Tables of Thermal Data expressed in terms of Joules.

The thermal data depending upon a thermal unit, which are, as a rule, included in tables of physical constants, comprise the following:—

The variation of the specific heat of water with variation of temperature.

Specific heats of various substances, solid, liquid, or gaseous.

Latent heats of fusion.

Latent heats of evaporation.

Heat of chemical action.

Thermal conductivities of various substances.

The tables are mainly compiled by grouping the results obtained by a number of observers. Such results are only, strictly speaking, comparable where the scales of temperature, and the thermal units adopted for the reduction of the observations, are identical. With different observers this is only the case if very rough approximation be allowed; but the experimental data communicated in the description of observations sometimes afford the possibility of putting the results upon a better footing for comparison than that upon which the author's own reductions leave them. It is clear that the auxiliary data which must be used in order to render the results strictly comparable, are in effect precisely those which are necessary to express the author's data in absolute measure, except that for the mere purposes of comparison one datum—the dynamical equivalent at one specified temperature—is not actually required. At the same time the comparison of data is in no way vitiated by the use of some number (for the present a conventional one), in order to convert a result from some definite gramme-degree-unit to Joules.

An examination of the tables of thermal data with a view to expressing the results in Joules furnishes, therefore, a very effective test of the comparability of the results obtained by different observers for the same thermal constants, and, moreover, the difficulties to be met with in making the reduction to Joules give the best indication of the points which must be settled before the results of thermal measurement can be regarded as final. To carry out such an examination completely, using numbers for reduction that can only be regarded as provisional, would be an unnecessary labour, but a few selected instances may help to exhibit some of the uncertainties which might reasonably be expected to disappear if observers once recognised the desirability of expressing all thermal measurements in Joules, or in some accepted equivalent.

As an example, I have computed the total heat of water at various temperatures as determined experimentally. I have used Rowland's numbers for lower temperatures, and have recomputed Regnault's experiments, accepting Table I. (computed from Rowland) as correct.

I think it might be possible to find data enough to recompute some others, *e.g.*, the latent heat of steam at 100°, the specific heat of air at constant pressure, which, by the way, is almost exactly a Joule. The labour is, however, very considerable, and it might be abbreviated (for the Committee) if those who are or have recently been engaged in thermal measurements would supply the Committee with the results of their own observations reduced to Joules and thermometric units.

TABLE I.—*Total Heat of Water at Various Temperatures of the scale of the Hydrogen Thermometer between* 0° *and* 36°, *expressed in Joules* (*Rowland's Experiments*).

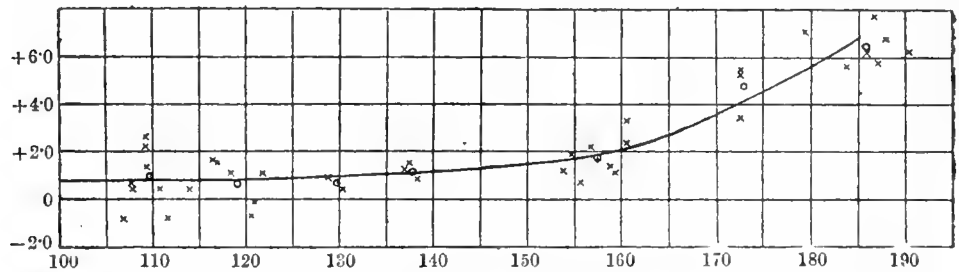
T	Total Heat in Joules between 0° and T°	T	Total Heat in Joules between 0° and T°
°		°	
5	21·044[1]	21	88·144
6	25·254	22	92·321
7	29·462	23	96·496
8	33·668	24	100·671
9	37·871	25	104·844
10	42·072	26	109·017
11	46·271	27	113·188
12	50·468	28	117·359
13	54·663	29	121·530
14	58·856	30	125·700
15	63·046	31	129·871
16	67·234	32	134·042
17	71·420	33	138·214
18	75·604	34	142·386
19	79·786	35	146·558
20	83·966	36	150·731

[1] The total heat between 0° and $4\frac{1}{2}$° is obtained by extrapolation from Rowland's numbers.

The numbers are reduced from the table in the 'Mémoires de l'Institut,' tome xxi. p. 743, by assuming the mean specific heat of water for the calorimetric range of each experiment to be the specific heat of water as given in Rowland's table for the mean calorimetric temperature of the experiment, and adding to the heat thus computed as that given out by one gramme of water in cooling from T° to the final calorimetric temperature, the further amount which, upon an estimation based on Rowland's data, would be given out on cooling to 0°.

Some doubt has been thrown on the accuracy of the data quoted by Regnault in the table referred to. I have adopted Mr. Macfarlane Gray's conclusion that the computations of the mean specific heat are correct, though the data are erroneously printed in Regnault's paper.

The results of the individual experiments are shown in the following table. In order to obtain a mean result a curve of differences (see figure)



Abscissæ.—Air Temperatures (T.)
Ordinates.—Differences (in Joules) between **Total heat from 0° to T° and 4·2 × T.**

between total heat at temperature T and 4·2 × T has been plotted, and the means of observations, collected into seven groups, have been taken and also plotted. These are indicated in the diagram by circular dots, the individual results being shown by crosses.

TABLE II.—*Regnault's Observations for the Total Heat of Water between 0° C. and Various Temperatures (T) of the 'Air Thermometer' above the Boiling-point of Water.*

(Reduced from Regnault's and Rowland's results. Expressed in Joules.)

T	Total Heat from 0° to T°	4·2 × T	Difference	T	Total Heat from 0° to T°	4·2 × T	Difference
	I.				II.		
107·70	451·83	452·34	− ·51	116·60	491·35	489·72	+ 1·63
107·90	453·60	453·18	+ ·42	116·91	492·46	491·02	+ 1·44
107·79	453·36	452·72	+ ·64	118·54	498·76	497·87	+ ·99
109·38	460·69	459·40	+ 1·29	120·39	504·86	505·64	− ·78
109·25	461·44	458·85	+ 2·59	120·84	507·36	507·53	− ·17
109·25	460·94	458·85	+ 2·09	121·86	512·72	511·81	+ ·91
109·25	460 84	458·85	+ 1·99		III.		
110·80	465·76	465·36	+ ·40				
111·51	467·60	468·34	− ·74	128 91	542·30	541·42	+ ·88
113·86	478·56	478·21	+ ·35	130·40	548·07	547·69	+ ·38

TABLE II.—*continued.*

T	Total Heat from 0° to T°	4·2 × T	Difference	T	Total Heat from 0° to T°	4·2 × T	Difference
	IV.				VI.		
137·16	577·27	576·07	+1·20	172·66	728·47	725·17	+3·30
137·27	577·96	576·53	1·43	172·75	730·82	725·55	+5·27
138·27	581·58	580·73	+ ·85	172·71	730·68	725·38	+5·30
				172·66	730·59	725·17	+5·42
	V.				VII.		
153·68	646·44	645·46	+ ·98				
154·80	651·97	650·16	+1·81	179·23	759·70	752·77	+6·93
155·61	654·27	653·56	+ ·71	183·56	776·57	770·95	+5·62
156·82	660·89	658·64	−2·25	186·00	787·34	781·20	+6·14
158·82	668·38	667·04	+1·34	186·65	791·62	783·93	+7·69
159·19	669·64	668·60	+1·04	186·89	790·86	784·95	+5·91
160·34	675·74	673·43	+2·31	187·75	795·35	788·55	+6·80
160·61	677·61	674·56	+3·05	190·36	805·80	799·51	+6·29

A curve based upon these means as accurate would show a minimum ordinate above 100° C. Without any definite experimental reason I have considered this as outside the range of probability, and have drawn a curve corresponding to a gradual increase of specific heat between the limits of the experiments, viz., 107° and 190°, which fairly connects the means. Continuing that curve beyond 107° to 100°, and reading off from it the value of the total heat minus 4·2 × T at intervals of 10° we get the following result :—

TABLE III.—*Total Heat of Water between 0° and T° (Air Thermometer) according to Regnault and Rowland.*

T	Total Heat between 0° and T° in Joules	Excess over 4·2 × T
100°	420·68	·68
110	462·73	·73
120	504·80	·80
130	546·88	·88
140	589·04	1·04
150	631·40	1·40
160	674·02	2·02
170	717·52	3·52
180	761·60	5·60

Whence we obtain—

Mean specific heat of water between 0° and 100° is 4·2068 Joules =1·0016 [1] thermometric units.

Mean specific heat of water between 0° and 180° is 4·2312 Joules =1·0075 [1] thermometric units.

[1] It will be remembered that Regnault gives for these two values 1·0050 and 1 0133 respectively.

Meteorological Observations on Ben Nevis.—Report of the Committee, consisting of Lord McLaren, Professor A. Crum Brown (*Secretary*), Dr. John Murray, Dr. Alexander Buchan, *and* Professor R. Copeland. (*Drawn up by* Dr. Buchan.)

The Committee were appointed, as in former years, for the purpose of co-operating with the Scottish Meteorological Society in making meteorological observations on Ben Nevis.

The hourly eye observations, carried on by night as well as by day, have been made without interruption during the year at the top of Ben Nevis; and the continuous registrations and other observations have been carried on at the Low Level Observatory at Fort William with the same fulness of detail as heretofore.

The Directors of the Observatories tender their best thanks to Messrs. A. Drysdale, M.A., B.Sc., A. Russell, B Sc., G. Ednie, and W. Thomson for the assistance they rendered as volunteer observers during the summer months, thus giving a greater extension than could otherwise have been given to the holiday time of the members of the regular observing staff, which it is in every way so desirable to secure.

Table I. gives for 1895 the monthly mean pressure, mean and extreme temperatures; hours of sunshine; amount of rainfall; number of fair days, and of days when the rainfall exceeded one inch; the mean percentage of cloud; and the mean rain-band at both Observatories; and the mean hourly velocity of the wind in miles at the top of the mountain. The mean barometric pressures at the Low Level Observatory are reduced to 32° and sea level, but those at top of the Ben are reduced to 32° only.

Table I.

1895	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
						Mean Pressure in Inches.							
Ben Nevis Observatory	25·095	25·412	25·031	25·251	25·549	25·526	25·287	25·274	25·525	25·222	25·166	25·038	25·284
Fort William	29·768	30·169	29·617	29·819	30·101	30·042	29·771	29·733	30·012	29·802	29·735	29·652	29·852
Differences	4·673	4·727	4·586	4·565	4·552	4·516	4·484	4·459	4·487	4·580	4·569	4·614	4·568
						Mean Temperatures.							
Ben Nevis Observatory	17·5	18·7	24·7	29·8	36·3	39·9	38·2	41·2	43·3	27·2	38·3	23·0	30·7
Fort William	32·4	30·9	40·6	45·9	52·7	55·4	55·4	56·9	56·6	43·6	42·5	39·6	46·0
Differences	14·9	12·2	15·9	16·1	16·4	15·5	17·2	15·7	13·3	16·4	14·2	16·6	15·3
						Extremes of Temperature, Maxima.							
Ben Nevis Observatory	30·3	38·5	37·9	40·7	54·1	59·8	48·4	50·6	59·9	53·3	40·7	34·1	59·9
Fort William	45·5	48·0	51·9	63·8	73·0	74·4	69·4	70·3	74·4	66·2	56·1	52·8	74·4
Differences	15·2	9·5	14·0	23·1	18·9	14·6	21·0	19·7	14·5	12·9	15·4	18·7	14·5
						Extremes of Temperature, Minima.							
Ben Nevis Observatory	6·0	1·8	8·6	11·6	19·8	24·2	30·0	30·1	30·3	17·4	18·3	13·9	1·8
Fort William	9·0	8·9	26·6	29·9	36·0	35·7	44·3	44·4	41·5	30·7	27·8	25·0	8·9
Differences	3·0	7·1	18·0	18·3	16·2	11·5	14·3	14·3	11·2	13·3	9·5	11·1	7·1

TABLE I.—*continued.*

1895	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
						Rainfall in Inches.							
Ben Nevis Observatory	6·89	3·51	14·32	11·73	3·69	3·97	10·79	12·76	8·95	12·07	13·88	15·41	118·00
Fort William	2·70	1·13	5·55	5·26	2·07	3·04	4·89	9·37	5·52	4·78	8·47	7·65	60·43
Differences	4·19	2·41	8·77	6·47	1·62	0·93	5·90	3·39	3·43	7·29	5·41	7·76	57·57
						Number of Days 1 in. or more fell.							
Ben Nevis Observatory	1	2	5	4	1	1	3	4	2	3	6	4	36
Fort William	0	0	1	0	0	0	0	2	1	0	2	2	8
Differences	1	2	4	4	1	1	3	2	1	3	4	2	28
						Number of Days of no Rain.							
Ben Nevis Observatory	11	19	4	9	17	12	3	3	12	6	9	10	125
Fort William	13	20	8	12	18	18	9	4	12	18	12	10	154
Differences	2	1	4	3	1	6	6	1	0	12	3	0	29
						Mean Rain-band (scale 0–8).							
Ben Nevis Observatory	0·9	0·8	2·0	2·5	2·3	3·2	3·4	4·2	2·7	2·7	1·8	1·4	2·3
Fort William	2·3	1·7	3·3	3·7	3·6	4·2	5·3	5·0	4·4	2·6	3·1	3·6	3·6
Differences	1·6	0·9	1·3	1·2	1·3	1·0	1·9	0·8	1·7	0·1	1·3	1·8	1·3
						Number of Hours of Bright Sunshine.							
Ben Nevis Observatory	29	83	20	82	139	149	24	25	74	41	26	3	695
Fort William	49	101	72	113	197	208	75	58	102	104	45	8	1,132
Differences	20	18	52	31	58	59	51	33	28	63	19	5	437
						Mean Hourly Velocity of Wind in Miles.							
Ben Nevis Observatory	21	18	18	16	16	5	11	12	15	15	19	23	16
						Percentage of Cloud.							
Ben Nevis Observatory	84	60	95	81	75	70	95	94	79	81	80	95	82
Fort William	66	45	81	73	64	65	87	87	69	70	65	81	71
Differences	18	15	14	8	11	5	8	7	10	11	15	14	11

At Fort William the mean temperature of 1895 was 46°·0, being 0°·9 less than the annual mean of previous years. The mean temperature at the top of Ben Nevis, was 30°·7 or 0°·7 less than the mean for the same years. This was the deficiency for the year over a wide district of Scotland surrounding Ben Nevis.

The following shows the departures from the mean temperatures during the great cold of the first two months of the year :—

TABLE II.

—	Mean Temperature.		Departures from Means.	
	Jan.	Feb.	Jan.	Feb.
Fort William Observatory . .	32°·4	30°·9	−6°·1	−7°·6
Ben Nevis Observatory . . .	17·5	18·7	−6·3	−4·7

These very different results for the two months are a good example of the striking weather differences observed at the top and bottom of the mountain respectively, under different types of weather, or under cyclonic or anticyclonic conditions. Thus in January the weather usual to the season prevailed—in other words, it was decidedly cyclonic—and consequently at both Observatories the lowering of the temperature below the average was substantially the same. But in February it was quite otherwise, the weather of this month being eminently anticyclonic. Hence, on account of the higher temperature at the top accompanying the anticyclones, the mean temperature of the month was only 4°·7 under the average, but at Fort William the mean temperature was 7°·6 under the average. This effect of the prevailing anticyclones is also well seen in the difference of the mean temperature at the two Observatories. From the past observations the mean difference in February is 15°·1, whereas in February 1895 the difference was only 12°·2.

Similarly striking contrasts were shown in the weather of the summer months at the two Observatories. The following indicates the departures from the mean temperatures from June to September :—

TABLE III.

—	Mean Temperature.				Departures from Means.			
	June	July	Aug.	Sept.	June	July	Aug.	Sept.
	°	°	°	°	°	°	°	°
Fort William Observ.	55·4	55·4	56·9	56·6	+0·1	−1·4	−0·4	+3·4
Ben Nevis Observ.	39·9	38·2	41·2	43·3	+1·0	−2·1	+1·3	+5·4

Of these four summer months it was in July when anticyclones prevailed least, and it is seen that at the top of the mountain, as compared with Fort William, the mean temperature was relatively the lowest of the months ; notwithstanding, the difference between the mean temperatures of the two Observatories exceeded the average. But in September these conditions were all reversed. In this month the weather was strongly anticyclonic. Consequently, while at Fort William the mean temperature exceeded the average by 3°·4, the excess at the top of the mountain was 5°·4 ; and while the mean difference between the top and bottom of the mountain has been 15°·3, in September 1895 it was only 13°·3.

In September the minimum temperature at the top of the Ben was 30°·3, which is the highest minimum yet recorded for any September; thus further evidencing the anticyclonic influence on the weather at this high elevation in constantly maintaining a relatively higher temperature.

Table IV. shows the deviations from the mean temperatures of the months from their respective averages :—

TABLE IV.

	Fort William.	Top of Ben Nevis.
	°	°
January	−6·1	−6·3
February	−7·6	−4·7
March	0·2	1·0
April	0·5	2·1
May	3·1	3·5
June	0·1	1·0
July	−1·4	−2·1
August	0·4	1·3
September	3·4	5·4
October	−3·1	−4·1
November	−0·1	0·3
December	0·2	—2·0
Year	−0·9	—0·7

The maximum temperature at Fort William was 75°·0 on June 2, and at the top 59°·9 on September 9; where on June 25, 59°·8 was recorded. The minimum temperature was, at Fort William 8°·9 on February 11, and on January 28 9°·0 was recorded; and at the top 1°·8 on February 7. This is the lowest minimum temperature yet recorded at the Fort William Observatory; and the above minimum, 1°·8, at the top of the mountain, is the lowest there, with the exception of the previous year, when temperature fell to 0°·7. The minimum on the top fell below freezing each month.

As regards extremes of temperature, the difference between the maxima was greater in July, when it was 21°·0, and least in February, when it was only 9°·5; and the difference between the minima greatest in April, when it was 18°·3, and least in January, when it was only 3°·0.

The registrations of the sunshine recorder at the top show 695 hours out of a possible 4,470 hours, being 115 hours fewer than in 1894. This equals 16 per cent. of the possible sunshine. The maximum was 149 hours in June, and the minimum 3 hours in December, being, along with January of the previous year, the lowest hitherto recorded in any month, except in December 1893, when there was only 1 hour of sunshine. At Fort William the number for the year was 1,132 hours, or 28 hours fewer than in 1894. The largest number was 208 hours in June, and the least 8 hours in December. As the number of hours of possible sunshine at Fort William Observatory is 3,497 hours, the sunshine of 1895 was 32 per cent. of the possible number of hours.

In Table V. are enumerated for each month the lowest hygrometric observations:—

TABLE V.

—	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Dry Bulb	17°·1	14°·7	24°·6	38°·9	32°·3	46°·0	36°·0	50°·1	46°·3	29°·3	36°·7	22°·0
Wet Bulb	14·0	10·1	22·5	28·4	25·7	34·0	31·1	47·2	35·7	25·8	25·7	20·4
Dew-point	−9·6	−25·8	−2·9	14·7	11·2	20·8	23·8	44·1	24·0	13·7	9·2	9·8
Elastic Force	·027	·011	·038	·085	·071	·112	·128	·289	·129	·081	·065	·067
Relative Humidity (Sat.=100)	29	13	29	36	33	36	60	80	41	50	30	58
Day of Month	20	11	9	17	8	8	5	18	23	17	25	20

Of these lowest monthly humidities the lowest occurred on February 11, when the dew-point fell to −25°·8, the elastic force of vapour to 0·011 inch, and the humidity to 13. On the other hand, in August no low humidities occurred, the lowest in this month being 80, a month which stands out as being characterised by unrelieved high humidities throughout. In this month the hours of sunshine were 25, which is the lowest yet recorded in August, except in 1889, when only 9 hours occurred; and the amount of cloud was very large, being exceeded only by the August of 1889. At the Ben Nevis Observatory the percentage of cloud covering the sky was, on the mean of the year, 82, being 2 per cent. less than the mean of previous years. The variation among the months was unusually large, the lowest being 60 per cent. in February, and the highest 95 per cent. in March, July, and December. At Fort William the annual mean was 71 per cent., the lowest being 45 per cent. in February, and the highest 87 per cent. in July and August. The mean rain-band (scale 0–8) observation at the top was 2·3 for the year, the highest being 4·2 in August, and the lowest 0·8 in February; and at Fort William the annual mean was 3·6, the highest being 5·3 in July, and the lowest 1·7 in February.

The mean hourly velocity of the wind at the top of the Ben was 16 miles for the year, the highest monthly mean for the year being 23 miles for December, and the lowest 5 miles for June. This minimum of 5 miles per hour is the lowest mean monthly velocity yet recorded for any month since the beginning of 1884. For the three summer months, June, July, and August, the mean was at the rate of 11 miles per hour; but in December, January, and February it was 21 miles, or nearly double the summer velocity.

The rainfall for the year at the top of the mountain was 118·00 inches, being 31·87 inches less than in 1894; and the lowest that has yet occurred, excepting the year 1886, when the amount was 107·85 inches. The highest monthly amount was 15·41 inches in December, and the lowest 3·54 inches in February. The above monthly maximum of 15·41 inches is a very low maximum for the top of Ben Nevis. The heaviest daily fall was 3·48 inches on August 29, which is also a rather small maximum daily fall for the year.

On the top rain fell on 250 days, and at Fort William on 211 days, being respectively 10 and 27 days under their averages. The maximum number of days on which rain fell at the top was 28 days in July and the same number in August; and at Fort William, 27 days in August; and the minimum number of days 9 at the top, and 8 at Fort William in February.

During the year the number of days on which an inch of rain was exceeded was 36 at the top and 8 at Fort William.

The mean rain-band (0–8) was 2·3 at the top and 3·6 at Fort William, being nearly the average; the lowest being in January and February, and the highest in July and August.

Auroras are reported to have been observed on the following dates:—February 5, 9, 10, 13, 15, 16, 17, 18, 19, 20, 25; April 13, 14, 15, 16, 17; May 2, 23; September 20, 22, 23, 29, 30; October 16, 17, 26; November 10, 23, 24, 25; December 13, 22.

St. Elmo's Fire was seen on April 23, 24, 25; May 1, 23, 24, 25; June 19, 28; July 2, 23; August 11; October 6; November 13, 14; December 1.

The Zodiacal Light, February 11, 12, 13, 16, 17, 18, 19.

Thunder and lightning was reported on May 9, 23, 24, 25; June 9, 25, 26; July 2, 21; August 6, 11; December 5, 6. Lightning only on February 28; May 9, 23, 25; September 9, 10, 23, 24; October 1; November 10.

At Fort William the mean atmospheric pressure was for the year reduced to 32° and sea-level 29·852 inches, and at the top reduced only to 32°, 25·284 inches, being 0·005 inch above, and 0·012 inch under, the respective averages. The difference for the two heights was thus 4·568 inches, the mean difference being 4·553 inches. At the top the highest pressure was 25·975 inches on May 3, and the lowest 23·889 inches on November 11, the annual range being thus 2·086 inches; and at Fort William the highest was 30·673 inches on February 16, and the lowest 28·601 inches on November 10, the annual range being 2·072 inches.

The differences from the monthly means of the two Observatories greatly exceeded the average differences in January, February, October, and December, which were substantially occasioned by the very low temperature of these months, so that the high-level pressure, when reduced to sea level, closely agrees with the sea level pressure at Fort William.

In September, however, though the mean temperature was 3°·5 and 5°·4 respectively above the averages, the difference between the mean pressure at the two Observatories was 4·487 inches, the September averages of the previous 15 years being 4·450 inches. The characteristic of the weather of the month was eminently anticyclonic, and as the anticyclones extended, in a modified form, downward, considerably below the level of the summit, they carried down with them their characteristically very dry and therefore heavier air, thus increasing the density of the aërial stratum between the top and bottom of the mountain, above what would have been if this stratum had been of the usual humidity. Hence pressure at Fort William was relatively higher, and consequently the difference between pressure at the top and bottom was correspondingly increased.

But during the last three days of the month over Scotland the sky was clear, sunshine strong, humidity high, night temperatures unusually high, and dews heavy, with calms or light winds. The weather of this period has been discussed with some fulness in a paper published in the last issued 'Journal of the Scottish Meteorological Society,' to which reference may be here made. On these days, while at the top temperature was very high and the air clear and very dry, at Fort William, under a sky equally clear and temperature high, the air showed a large humidity, and this state of moisture extended to a height of about 2,000 feet, or nearly halfway to the summit. Thus, then, while the barometer at the top was under an atmosphere wholly anticyclonic, with its accompanying dry dense air, the barometer at Fort William was not so circumstanced. On the other hand, it was under the pressure of such dry dense air, above the height of 2,000 feet only, whereas from this height down to sea level it was under the pressure of air whose humidity was large and pressure therefore much reduced. The result was that the sea-level pressure at Fort William was 0·050 inch lower than it would have been if the dry dense air of the anticyclone had been continued down to Fort William. This is confirmatory of what is to be expected, that the greater density of dry air as shown in our laboratories prevails equally in the free atmosphere.

The discussion of the observations reveals numerous instances of an opposite condition of things, viz., the air at the lower levels remaining comparatively dry, while aloft at higher altitudes it is becoming rapidly moister, the moister air gradually occupying lower levels as a cyclone is advancing. In these cases the lower barometer reads—not the relatively lower, but the relatively higher, of the two. An important result is emerging as the discussion proceeds, since it appears that an indication is hereby given towards a more accurate knowledge than is at present possessed of the intensity of a coming cyclone and of the attendant anticyclone.

In addition to the variability of the distribution with height of the humidity, the distribution of the temperature is also being particularly investigated, especially as regards the light it casts on the interpretation of the causes leading to the variability in the vertical distribution of the pressure. This department of the inquiry is in the hands of Mr. Omond, who read a preliminary paper on the subject at the meeting of the Scottish Meteorological Society in July last.

The large inquiry carried on by Dr. Buchan and Mr. Omond for some years, and reported on to the British Association in preceding Reports, on the influence of fog or cloud and clear weather respectively on the diurnal fluctuations of the barometer has been extended into other regions of the globe, notably into the Arctic regions, particularly over the ocean, the data employed being the observations made by Mohn, during 1876–78, over the Norwegian Sea and the Arctic Ocean, and those by the expedition of the Austrians in Jan Mayen, and ocean in the neighbourhood, in 1882–83. The inquiry will be completed in a few months, and the results will be communicated to the next meeting of the British Association.

For the contribution of the observations necessary to the carrying out of these inquiries the directors of the Ben Nevis Observatories have resolved to establish a temporary station, intermediate in height between the two Observatories, for the purpose of ascertaining with greater precision than has hitherto been possible the extent to which anticyclones descend on the mountain, and more particularly the relations of pressure, temperature, and humidity at the new station as compared with the observations at Fort William and the summit of Ben Nevis. A suitable situation was formally obtained from the tenant on August 14, a complete set of instruments procured, and the building materials conveyed for the enlargement of the present hut to accommodate Mr. Muir, one of the assistant masters of the High School of Edinburgh, who had volunteered his services as observer till the close of September. The height of the hut, where the barometer is placed, is 2,196 feet, or nearly midway in height between the two Observatories; and the thermometer, rain-gauge, and other instruments are placed 30 yards distant above the hut over a grass plot on a slight ridge, which will to a large extent secure that the down-flowing cold-air currents which set in from terrestrial radiation chiefly at night will pass down on each side, thus protecting the thermometers from their disturbing influence.

The Application of Photography to the Elucidation of Meteorological Phenomena.—Sixth Report of the Committee, consisting of Mr. G. J. Symons (*Chairman*), Professor R. Meldola, Mr. J. Hopkinson, *and* Mr. A. W. Clayden (*Secretary*). (*Drawn up by the Secretary.*)

During the past year the attention of your Committee has been almost entirely confined to the determination of cloud altitudes by the photographic method briefly sketched in former reports. As this method differs considerably from those which have been employed elsewhere, and as it has been found to give very satisfactory results, it seems desirable to give a fuller description of the apparatus than appears in the report of two years back, in which it was first indicated.

The observations are carried on upon a level piece of ground close to Exeter, between some workshops and shunting lines belonging to the London and South-Western Railway Company, who have given your Committee an agreement providing for the use of the site on payment of a nominal rent of 1*l.* per annum. This ground is conveniently near the residence of the Secretary to your Committee: it provides an excellent sky view without interference of trees or buildings, and, being the property of the railway company, is under a certain amount of supervision.

The site, moreover, admits of the selection of a base-line lying exactly east and west, a point of some importance for simplifying the reduction of the observations.

The observing stations are at present placed only 200 yards apart. They are connected by a line of wire stretched on small telegraph poles in the ordinary manner. At each end the iron wire is soldered to an india-rubber coated insulated copper wire, which is led down one of the stays of the last pole into the camera-stand, in such a manner as to prevent any rain-water from flowing down this wire into the apparatus contained in the stand.

Each stand is a four-sided cupboard built of thick matchboarding, three sides sloping towards the top, which forms a level table about 18 inches square. The fourth side, which faces north, contains a door which can be locked. The base of the cupboard is about 2 feet 6 inches square, and is supported by four legs about 9 inches above the surface of the ground. Several coats of paint have made these stands so secure against weather that exposure for more than two years has not effected any injury except a slight shrinkage in the top, which is easily repaired. As the cameras and electrical apparatus are contained in these boxes, their construction is important.

The two observing cameras have been specially constructed. Each swings on trunnions between uprights rigidly secured to a flat stand. The camera can thus be directed to any altitude, and can be firmly clamped. In order to make this clamping secure, and at the same time add to the steadiness of the whole, there is fixed to the base board of the swinging camera a flat board whose margin forms a segment of a circle whose centre is the same as that of the trunnions. This passes smoothly between two pieces of wood let into the flat stand, which can be drawn together by a screw, thereby grasping the margin of the circle. The surfaces of contact are faced with leather, in order to prevent any sticking or injury to the polished clamping-board.

Adjustment in azimuth, which need not be done with any great exactness, is effected by rotating the whole apparatus on the levelled top of the camera-box. Each camera is provided with a lens of 18 inches focal length, which is provided with an iris diaphragm, and covers a plate of the size known as whole plate.

The two lenses were carefully compared, both by testing their focal lengths by the ordinary methods, and finally by comparing two views taken simultaneously with the two cameras placed side by side. When it was seen that the two pictures coincided exactly, it was certain that the adjustments were correct, and the focus of each camera was fixed by firmly screwing up the adjusting screws and putting a coat of varnish over them to prevent any possibility of after-slipping. This fine adjustment is rendered possible by making the back part of the camera of the well-known 'bellows' pattern. In order to be sure that no shrinkage of the materials should affect the result, they were made of old, well-seasoned wood, were adjusted and freely exposed to sun and wind, and to the changes of temperature and moisture experienced by keeping them for several months in the camera-boxes. On again testing them by the superposition of two negatives, no change could be detected. The lenses are provided with shutters, which can be simultaneously released by an electro-magnet fixed to the front of the camera. The shutters used at present are of the kind known as the 'chronolux,' which can be adjusted for any exposure from three seconds down to the one-sixtieth ; but in practice it is found that the exposures required are always very brief, and a latitude of exposure from a quarter of a second downwards would be ample. This is with the diaphragm aperture about a quarter of an inch in diameter, and it is evident that variation in this would afford the equivalent of much greater variation in exposure. The shutters also suffer from the fact that the sliding portions are made of ebonite, which is liable to warp in consequence of the high temperatures sometimes produced in the interior of the camera-box when exposed to a hot summer sun. Shutters like those at Kew, or with aluminium sliding parts, would probably be better.

The electrical exposing connections proved to be a great source of trouble. The site is on hard Permian sandstones and breccias, which are very dry, and so hard that it would have been very costly to have made a large hole to be filled with coke. After several trials a satisfactory earth was obtained by leading the terminal to the end of about 50 yards of copper wire, such as is used by bell-hangers, and twisting this to and fro in a trench in the surface of the rock, which was then filled in with soil and turfed over.

The electro-magnets on the cameras, however, required a fairly strong current to make sure that they would act, so the primary current from the discharging key works two relays of similar construction, placed one in each camera-box, which simultaneously close local independent circuits and release the shutters.

Another source of trouble has been the batteries. Those used were of the dry-cell type. But during the past summer they were found to fail several times, the moisture essential to their working being apparently driven off by the excessive heat and drought to which they were exposed. If they could be placed in a more substantial structure, which could be kept cooler, they would doubtless do better. Your Committee propose to replace them by Leclanché cells next year.

The plates used have been those already found to give excellent results for ordinary cloud photography, namely, Mawson and Swan's photo-mechanical plates, or those prepared by the same firm for transparencies.

They are carried in double dark slides of the ordinary pattern, two of which are provided for each camera ; but those belonging to the camera at one end of the base are slightly thicker, and differ in other ways from those used at the other end, so that there is no possibility of mistaking them after exposure, and they cannot be used for the wrong camera.

On the right-hand side of the central part of each camera is a small view-finder, in which a minute image of the view is projected on ground glass, and which is adjusted once for all, so that the view in the finder corresponds with that on the plate.

A loose piece of black velvet for each camera completes the apparatus.

Two observers are required, one for each camera, and in making the observations the Secretary to your Committee has been assisted by Mrs. Clayden, or by his brother, Mr. C. E. Clayden.

Each observer is provided with three small flags—pink, blue, and yellow (to avoid railway colours), by means of which a simple code of signals can be made. For simplicity, let us call the observers A and B, and suppose A directs the observations and B can close the key which will effect the exposure. A watches the sky until a favourable opportunity seems to be approaching. He then puts up the yellow flag and places a dark slide in position, sets the shutter and adjusts the camera, so that the image of the sun is in about the centre of the ground glass of the finder. B does the same with the other camera, and, when ready, puts up the yellow flag at that end, and stands ready to press the exposing key. A then watches for the best moment for exposure, and, when it arrives, holds up the blue flag, on seeing which B presses the key and holds up the other blue flag as a signal that the exposure is complete at that end of the line. The pink flag is used as an indication that something is wrong, and delay is inevitable; but if pink and blue are shown simultaneously, it means that the opportunity for a good observation has passed, and that the dark slide must be closed while waiting for another chance.

As soon as one exposure has been made the dark slide is turned, and preparations are made for a second exposure, leaving the drawing out of the slide until the signal is given. When A gives the signal for exposure he has his watch in his hand, and notes the time at which he hears the click made by the release of the shutter. This time is noted down and checked as soon as possible afterwards by comparing the watch with a trustworthy clock, and, if necessary, correcting the record.

The exposures having been made, the cameras are replaced in their boxes, the relays are examined to see that the armatures have broken the local circuit, and the line wire is disconnected from the key, these precautions being taken to make sure that the batteries may not run down owing to the circuits being unbroken or remade by the operations of spiders or accumulations of earwigs, which find a welcome shelter in the camera-boxes, and which it seems impossible to entirely exclude.

The plates are then taken into the dark room, and before opening the dark slides the shutter of each is pulled out a little way, while the date and time of exposure are written in pencil in the corner of each plate. The subsequent processes do not remove this. They are then developed with pyro and ammonia developer, and for the most useful results a fairly rapid development is best. It should be remembered that prints will not be required, and that, provided all the detail obtainable is on the plate, very great differences of density are permissible. Indeed, when the image of the sun is quite hidden in a black blur, as seen by transmitted light, it can always be found on the glass side of the negative as a white or pale disc. Sometimes it is reversed, and stands out clearly by transmitted light; but this is exceptional with the exposures which have been used.

In order to work out the negatives we have certain facts known. These are the latitude and longitude of the place of observation, the date and time at which the observation was made, and the relative positions of the image of the sun, and the selected point of the cloud in the two negatives. The first step is to determine the altitude and azimuth of the sun, since its image on the plate is the fixed point of reference from which the co-ordinates of the point of cloud in the image will be measured.

From the declination of the sun corrected for variation, and from the known latitude, the meridian zenith distance can be calculated. From the Greenwich time observed, the longitude and the equation of time, the sun's distance from the meridian is obtained.

It should be remembered that the meridian zenith distance need only be determined once for a number of observations made within a few hours of each other, and the correction of time is practically constant for a day. Moreover, it is useless to attempt to do more than ascertain the altitude to the nearest minute of arc.

Now if H be the hour angle, D the reduced declination, and M the meridian zenith distance, log versin H + L cos lat. + L cos D − 20 = log n, where n is a natural number and n + vers M = covers alt.

Again, to find the azimuth, vers sup. (lat. + alt.) − vers polar dist. = m, where m is another natural number, and log m + L sec lat. + L sec alt. − 20 = log vers azim. reckoned from south. Thus, on June 12 (local time 12 hrs. 11 mins.):—

Log versin H = 3·061310
L cos lat. = 9·801356
L cos D = 9·963379

Log n = 2·826045 ∴ n = 670
Vers M = 113258

Covers alt. = 113928

∴ Alt. = 62° 23′

Vers sup. (lat. + alt.) = 607395
Vers N. polar dist. = 606058

m = 1337

Log m = 3·126131
L sec lat. = 10·198644
L sec alt. = 10·333900

3·658675

Vers azim. = 004556

∴ Azim. = 5° 28′ west.

Two lines are then drawn on the negative, one vertical and one horizontal, intersecting in the centre of the sun's image. Two corresponding points in the cloud are selected, and their respective linear distances from the vertical and horizontal lines measured as accurately as possible. In some hazy cases this cannot be done with greater accuracy than about the $\frac{1}{30}$th of an inch; but these are exceptions, and as a rule some small speck or sharp angle of cloud can be found, the position of which may be fixed with certainty to the $\frac{1}{100}$th part of an inch. From these linear distances the angular displacement is easily found, either by direct calculation of the tangents or by reference to a previously constructed scale. By adding or subtracting from the sun's azimuth, as the case may be, the position of the cloud point in azimuth from the two stations is determined, and thence the horizontal distance of the point vertically beneath the cloud from either station.

Similarly the altitude of the cloud point from the same station is obtained from the corresponding plate, and the height above the horizontal plane then computed.

Now if a and b be the angles from the stations A and B respectively, the difference of their sum from 180° gives the angle subtended by the base line at X, the point vertically beneath the cloud. Then the distance AX is given by the equation:

$$\text{Log AX} = \text{L} \sin b - \text{L} \sin \text{AXB} + \log \text{AB}$$

and the height h of the cloud point above X is given by the equation :

$$\text{Log } h = \log \text{AX} + \text{L tan alt.} - 10.$$

Thus in the case given above the angles a and b are 85° 45′ and 92° 53′, whence AXB must be 1° 22′. The altitude in angular measure is 67° 46′.

Then :

$$\begin{array}{ll} \text{L sin } b & = 9{\cdot}99945 \\ \text{L sin AXB} & = 8{\cdot}37749 \\ \hline & 1{\cdot}62195 \\ \text{Log AB} & = 2{\cdot}30103 \\ \text{L tan alt.} & = 10{\cdot}38851 \\ \hline 10 + \log h & = 14{\cdot}31150 \end{array}$$

$$\therefore h = 20{,}488 \text{ yards} = 11{\cdot}64 \text{ miles.}$$

If the angle AXB becomes much smaller than 1° less confidence can be placed in the result, and it is better to calculate from the different altitudes at the two stations, as such minute angles can only occur when the direction is nearly in line with the base.

Now it is seen that in the above calculation the angle AXB is certainly small, but owing to the length of focus adopted an angle of 2′ may be certainly detected, and by taking the mean of three or four measurements there is little risk of error. The height determined above was that of some high cirriform clouds, and is confirmed, not only by other measurements on the same plates, but by other determinations made 35 and 47 minutes later, the three determinations being 11·64, 11·2, and 11·45 miles.

A little later in the same day a still higher layer of cirrus appeared, and two measurements of this at a brief interval of time work out to 16·83 and 17·02 miles.

These are, of course, extreme altitudes, and are quoted in order to show that the results obtained by the method employed are sufficiently accurate even under such circumstances. With lower clouds the displacements of the image relatively to that of the sun are much larger, and the heights obtained are more uniform.

It should be remembered that the base line adopted is only 200 yards long. This is not quite enough for very exact measurements of great heights, nor is it enough for the determination of heights of less magnitude when the clouds under observation are either east or west, that is, in line with the base. But, on the other hand, the effects of perspective are quite sufficiently troublesome with low-level clouds, or when an upper layer is seen through gaps in a lower one, and many negatives have had to be rejected from the impossibility of identifying corresponding points. In some cases the corresponding negatives were so much unlike that it was difficult to believe they could really have been simultaneous exposures. The distance of 200 yards has therefore been chosen as a convenient mean. For low stratus and cumulus 100 yards would be better, and for high cirrus about 400 yards would give more precise results.

The orientation of the base line again simplifies the angular measurements, but for observations in the afternoon later than about 3.30 to 4 P.M. the horizontal projection of the base is reduced to a very trifling amount, and a complete installation should certainly consist of three stations, the third being placed either due north or due south of one of the others, so that either an east and west or a north and south line could be used at pleasure.

The result of the observations made so far is to suggest that the method has certain advantages over others which have been used elsewhere.

1. The long focus gives a large image on which much minute detail can be seen, and affords a large displacement for a small angle and the best opportunity of selecting accurately corresponding points on the two negatives.

2. The image of the sun as a fixed point of reference is completely reliable.

3. The observation of the time is easily made, can be made with exactness, and is the only precise observation required at the time of exposure.

4. There is no possibility of misunderstanding between the two observers.

5. The share of work falling upon the assistant observer is extremely simple.

6. The shortness of base diminishes perspective difficulties and allows the use of a smaller site.

It has, however, one great disadvantage, it cannot be applied to clouds which do not come near enough to the sun to be in the same field of view, nor to clouds which completely hide the sun. This, however, could easily be got over by providing each camera with altitude and azimuth circles, of which the former need only be graduated from the zenith to the horizon, while the latter should be complete. They should be provided with verniers reading to 2′ of arc. Telephonic communication between the two stations would also be a convenience, but its absence has only been felt occasionally when things have gone wrong.

Nearly a hundred pairs of exposures have been made, not counting many experimental observations, but all these have not yet been worked out.

The following table gives the heights so far determined. They are given in yards and miles, the latter being offered for comparison with the Kew results.

Date	Time	Yards	Miles	Cloud
	H. M.			
April 17 . .	12 45 P.M.	3,736	2·13	Broken fragments of cumulus.
„ . .	12 45	3,982	2·26	
May 8 . .	4 10	838	·47	Base of cumulus.
„ . .	4 15	995	·56	Side of cumulus.
„ . .	4 15	1,950	1·10	Top of cumulus.
May 14 . .	10 0 A.M.	6,330	3·59	Cumulo-stratus.
„ . .	10 20	7,575	4·30	Cumulo-stratus.
„ . .	4 10 P.M.	2,592	1·47	Stratus.
„ . .	4 15	2,478	1·40	Stratus.
May 15 . .	1 0	3,358	1·9	Cumulus forming.
„ . .	4 30	1,782	1·01	Cumulus disappearing.
May 19 . .	10 15 A.M.	2,525	1·43	Cumulus forming top.
„ . .	10 20	1,394	·79	Cumulus forming base.
May 22 . .	11 0	7,708	4·38	Stratiform cloud forming.
„ . .	3 0 P.M.	5,847	3·32	Stratiform cloud disappearing.
June 2 . .	3 20	10,288	5·84	Alto-cumulus forming.
„ . .	3 20	12,530	7·12	Mackerel sky, massing into high stratus.
„ . .	3 28	12,772	7·25	

Date	Time	Yards	Miles	Cloud
	H. M.			
June 5 . .	2 35	2,270	1·28	Part of cumulus.
" . .	2 40	3,914	2·22	Upper part of cumulus.
" . .	2 40	7,627	4·38	High cumulo-stratus.
" . .	2 50	5,329	3·02	Top of cumulus.
" . .	3 20	1,790	1·02	Lower part of cumulus.
" . .	3 20	3,827	2·17	Middle of cumulus.
" . .	4 45	7,860	4·46	High cumulo-stratus.
" . .	4 50	2,618	1·49	Side of cumulus.
" . .	5 7	1,303	·74	Fragments of disappearing cumulus.
" . .	5 20	669	·38	
" . .	5 20	1,258	·71	
June 6 . .	1 10	1,340	·75	Fragments of disappearing cumulus.
" . .	1 13	2,051	1·16	
" . .	1 20	1,112	·63	
" . .	1 25	1,895	1·07	
June 10 . .	3 0	6,846	3·89	High stratus.
" . .	3 5	1,358	·77	Points on side of cumulus. The lowest by the base.
" . .	3 5	1,139	·65	
" . .	3 5	1,199	·68	
" . .	3 12	1,112	·63	
June 12 . .	9 25 A.M.	8,378	4·76	Cirro-cumulus.
" . .	9 25	8,216	4·67	Cirro-cumulus.
" . .	9 45	3,470	1·97	Cumulus forming.
" . .	10 5	6,912	3·92	Alto-cumulus.
" . .	10 10	8,838	5·02	Cirro-cumulus cirrifying.
" . .	12 20 P.M.	7,010	3·98	Summit of cumulus.
" . .	12 24 P.M.	14,084	8·00	Cirro-stratus (*a*).
" . .	12 25	20,488	11·64	Cirrus.
" . .	12 25	16,804	9·54	Cirro-stratus (*b*).
" . .	1 0	13,923	7·91	Cirro-stratus (*a*).
" . .	1 0	16,958	9·63	Cirro-stratus (*b*).
" . .	1 0	19,717	11·20	Cirrus.
" . .	1 12	16,110	9·15	Cirro-stratus (*b*).
" . .	1 12	20,164	11·45	Cirrus.
" . .	1 30	29,633	16·83	Upper level cirrus.
" . .	1 32	29,983	17·02	Upper level cirrus.
		Heavy clouds lasted through the afternoon and cleared off about 4.30, after which—		
" . .	5 20	7,673	4·36	Cirro-cumulus.
" . .	5 25	14,024	7·97	Cirrus.
June 23 . .	9 0 A.M.	4,621	2·63	Strato-cumulus.
" . .	9 0	4,997	2·83	Strato-cumulus.
" . .	9 0	5,559	3·16	Alto-cumulus.
" . .	9 3	4,752	2·70	Strato-cumulus.
" . .	9 3	5,535	3·14	Alto-cumulus.
" . .	9 3	7,122	4·04	Cirro-stratus.
" . .	9 30	5,692	3·23	Alto-cumulus.
" . .	9 30	6,280	3·56	Cirro-stratus.
" . .	9 35	6,671	3·79	Cirro-stratus.
" . .	9 35	7,644	4·34	Cirro-cumulus.
June 24 . .	11 56	2,847	1·61	Fragments on side of cumulus.
" . .	12 NOON	2,434	1·38	
" . .	12 NOON	6,300	3·58	Alto-cumulus forming.
" . .	12 10 P.M.	3,010	1·71	Fragment of cumulus.
" . .	12 10	3,177	1·80	Top of cumulus.
" . .	12 15	7,373	4·19	Cirro-cumulus.
" . .	12 15	8,684	4·93	Cirro-stratus.

The above results are put forward at present merely to show the kind of determinations which have been made. Further comment would be premature, but they show that there is a wide field for future investigation opened up in following the changes of level which attend changes in form. The general tendency to rise shown by clouds forming is well marked, and this is also true of the ascent of the general cloud-levels towards the early afternoon. But many more observations are required before such questions can be discussed. The negatives also contain material for some determinations of cloud velocity in a horizontal plane, but time has not allowed of any being made as yet.

Your Committee think, therefore, that the observations should certainly be continued, as they promise to throw considerable light on many questions, and will at least give material for instructive comparison with other determinations made in America and on the Continent.

Your Committee have done little to add to their collection, the time at their disposal having been almost entirely taken up by the cloud measurements.

In conclusion, they would ask for reappointment, with the addition of Mr. H. N. Dickson, and a renewal of the grant of 15*l.*

Seismological Investigation.—First Report of the Committee, consisting of Mr. G. J. SYMONS (*Chairman*), Dr. C. DAVISON *and* Professor J. MILNE (*Secretaries*), Lord KELVIN, Professor W. G. ADAMS, Mr. J. T. BOTTOMLEY, Sir F. J. BRAMWELL, Professor G. H. DARWIN, Mr. HORACE DARWIN, Mr. G. F. DEACON, Professor J. A. EWING, *the late* Professor A. H. GREEN, Professor C. G. KNOTT, Professor G. A. LEBOUR, Professor R. MELDOLA, Professor J. PERRY, Professor J. H. POYNTING, *and* Dr. ISAAC ROBERTS.

CONTENTS.

AT the Ipswich meeting of the Association it was resolved that the two committees which were studying vibrations of the earth's crust, viz., 'The Committee for investigating the Earthquake and Volcanic Phenomena of Japan,' and 'The Committee on Earth Tremors,' should not be re-appointed individually, but that the whole subject should be referred to a new committee (consisting largely of the members of the old committees), which should be called 'The Committee on Seismological Observations.' This Committee now presents its first report, and in doing so desires to record its thanks to the Secretaries of the two old committees for having continued their work as joint Secretaries to the new one. Statements of what they have been doing form the bulk of the present report.

The Committee, however, thinks that it would be well, in this its first report, to state definitely what it hopes to accomplish, and how far it thinks that the British Association should go. It has long been an unwritten rule, that the Association should initiate work, but should not charge itself with its maintenance. That is precisely what your Committee desires. Now that it has been proved that any important earthquake is felt all over the globe, the Committee considers that arrangements should be made for the record and study of these movements. Your Committee believes that such records may prove as important as those of, *e.g.*, terrestrial magnetism, and, just as we have magnetic observatories in various parts of the world, so in its opinion should there be seismological ones. But, before advocating their erection, it is essential that a decision be arrived at as to the form and the degree of sensitiveness of instrument to be recommended.

This, and correspondence connected with the organisation of the system, is the work which the Committee desires to complete. Previous reports, and the appendices to the present one, show how much has been done in this direction, but the Committee wants to do much more. It wishes to place side by side four good patterns of instruments, and to compare and study their records. When this is done it hopes to receive the support of the Association in approaching Government with the view to the establishment of a limited number of instruments identical in sensitiveness, in this country, in India and in the Colonies, and of a small central office, at Kew or elsewhere, for co-ordinating and publishing the results. As far as the Committee can at present judge, the equipment of each station with complete apparatus for continuous photographic record would not exceed 100*l.* For the experimental work of the coming year the Committee have one instrument, and can have the use of another (constructed under a grant to Professor Milne by the Royal Society); it wishes to purchase two others, and will have to build piers, &c., and pay for photographic necessaries and an assistant to run the instruments, which, altogether, would probably cost over 200*l.* Your Committee thinks it desirable that to meet unforeseen items it should have 250*l.*, but without 200*l.* the work cannot go on.

Report by Professor John Milne, *F.R.S.*

I. *Notes on Instruments which will record Earthquakes of Feeble Intensity.*

What we desire to record are preliminary tremors of small amplitude followed by quasi-elastic waves of comparatively large amplitude.

Within a hundred or two hundred miles of an origin, the former of these have periods varying between $\frac{1}{6}$ and $\frac{1}{15}$ of a second. At a great distance, say one quarter of the earth's circumference, these *may* have periods of from 5 to 12 seconds.

The latter near to an origin have periods varying between $\frac{1}{2}$ and 2 seconds, whilst at a great distance this period may be 20 seconds. As an average maximum velocity for the propagation of the preliminary tremors, we shall take 11 km. or about 7 miles per second. The large wave motion is propagated at about $\frac{1}{5}$ of this rate.

It has been found by trial that fifteen or twenty stations can be found on the globe, so that one of these shall be near to the antipodes of shocks originating on the west coast of South America, Japan or the Philippines, or the Western Himalaya, whilst six or seven other stations between one of these origins and its antipodes will lie at distances from each other of between one thousand and two thousand miles.

Because such an arrangement of stations is possible, we may take one thousand miles as being the minimum difference in distance between observing stations relatively to important seismic centres.

With the assumed velocity of propagation of 7 miles per second, the difference in times we expect to note will be about 143 seconds.

Because some stations will be at shorter distances from each other relatively to origins, I shall assume that instruments are required to note differences in time of 100 seconds.

Instruments.

The instruments at our disposal are :—

1. An Italian type like that of Vicentini which I call V.
2. Von Rebeur's Horizontal Pendulum „ „ R.
3. Milne's „ „ „ „ M.
4. Darwin's Bifilar Pendulum „ „ D.

Vicentini.—A pendulum of 100 k. at least 1·50 m. long. Light indices, multiplying motion eighty times relatively to the pendulum as a steady point, write on a moving surface of smoked paper. Two components of motion are recorded.

Von Rebeur.—A light horizontal pendulum weighing 42 grammes and 188 mm. in length, carrying a small mirror. Light from a lamp is reflected from this back through suitable lenses upon a slit in a box containing a drum carrying a bromide film.

Milne.—A horizontal pendulum with a boom 2 ft. 6 in. long, the whole apparatus within a case 4 ft. × 1 ft. 3 in. × 2 ft. The end of the boom is continuously photographed on a bromide film 2 in. wide. Because the lamp is within 6 in. of the paper, the necessary light is small.

Darwin.—A circular mirror with a bifilar suspension, so arranged that a slight tilt causes the mirror to rotate. This is immersed in paraffine. The instrument is exceedingly sensitive to change of level, but not to elastic tremors. The recording apparatus is photographic and very similar to that used by von Rebeur.

Accuracy as time-recorders (important).—The accuracy depends upon the rate at which the recording surface is moved, the method employed to mark time intervals upon its surface, and lastly the fineness or sharpness of definition of the record.

Assuming that on a diagram we can measure within ·25 mm., because

V runs at	5 mm. per minute, therefore we can read to within					3	seconds.
M „	1	„	„	„	„	15	„
R „	$\frac{1}{3}$	„	„	„	„	45	„
D „	$\frac{1}{6}$	„	„	„	„	90	„

By shaking M at known times, and comparing these times with times determined from the developed film, the difference between these is about half the expected error. Because this is probably true for the other instruments, the errors in 100 seconds may be,

V	1·5	seconds or per cent.
M	7·5	„ „
R	22·5	„ „
D	45	„ „

Because time-intervals in V and M do not depend upon the clock driving the record-receiving surface, but are marked by an independent time-keeper, these errors should not exceed a small fraction of a second per hour. R and D do not share this advantage, the time being dependent upon a clock driving a drum or a broad film of bromide paper.

As a time recorder D is like R. Should the rate be made greater, it might involve an increase in light-source. The time intervals might also be marked by an independent clock.

V and M also present the advantage of yielding a diagram, the definition of which is much sharper than R and D. V is slightly better than M.

The M clock, which, however, only drives a film 2 inches wide, is so arranged that it can be instantly altered to drive the paper at a rate of about 6 or 10 in. per day, which, when recording diurnal waves, is sufficiently quick.

Equality in Adjustment (important).—If two or more similar instruments are not adjusted to have equal sensibility, they may commence to indicate with different phases of motion, and much of what is gained in the accuracy of the time scale is lost.

M and equivalent of R can be adjusted to have a close similarity in sensibility, and this is probably true of D.

With V, which writes by the friction of a pointer on a smoked surface, we have no experience, but from experience with its equivalent and a large experience with ordinary seismographs writing upon smoked surfaces, it seems likely that there would be great difficulty in obtaining equal sensibility, especially with instruments which were not side by side.

Even if absolute equality is attainable with a group of instruments, it should be remembered that instruments further from the epicentre will necessarily indicate a later phase of the movement than those close to it.

Sensibility.—All types record long period wave motion.

V gives an *open* diagram for movements, the period of which is not less than five seconds—that is of preliminary tremors at a distance from their origin. R and M show the presence of these, but of D we have no experience.

R and D give diagrams of large amplitude, but V has the best definition.

We do not know which instrument would at a given station commence to move the first. The probable order would be R, M, D, V.

Carts, trains and traffic, unless very near, do not affect any of the instruments.

D and V are probably not affected by 'earth (?) tremors' whilst M and R are affected, but the serious character of these in obliterating effects due to small movements has been greatly reduced.

D and R are most sensible to tilting effects like the diurnal wave, and therefore, unless we reduce their multiplication by reducing the distance between the mirrors and the film, they require a broad recording surface.

D is entirely unaffected by rapid tremors. The movement of the image during the passage of earthquake pulsations is absolutely steady, showing that the rapid vibrations superposed on the long waves (tiltings of the ground) are entirely quenched.

Installation and working.—V requires a strong support, like a solid wall, and vertically a space of 10 or 12 feet.

R and D require, as at present used, at least 12 feet horizontally, and unless we reduce their multiplication, a fairly strong light, and considerable isolation from the effect of loads. Six feet might be ample for R and D. The foundation for D costs 7*l.* or 8*l.*

M requires 4 feet horizontally, a small light, and moderate isolation.

Each instrument will require about ten minutes' time daily, and about one hour each week.

It is possible that the smoking and varnishing of a long roll of paper, as required by V, may be more troublesome than developing the photographic films of M, R, and D. The M film lasts one week. R and D require changing at shorter intervals.

Cost.—V, as made in Italy, *about* 20*l.*, but without timekeeper.
M, as made in England, 45*l.* with timekeeper.
R, as made in Strassburg, *about* 29*l.* without special timekeeper.
D, as made in England, *about* 50*l.* without special timekeeper.

Mr. Milne suggests to the Committee that they should buy the apparatus V and an R. After which V, M, R and D should be set up side by side. Let R and D be reduced in length to about 4 feet, and arranged to record on a surface similar to M. A broad recording surface requires a special clock to drive it, whilst it is expensive and troublesome to handle. When this is done, and experiments have extended over two or three months, we shall then be in a position to speak more definitely about the relative merits of these instruments as earthquake recorders.

II. *Observations with Pendulums T and U in the Isle of Wight*, 1895–96.

The Localities and their Geology.

The position of Shide Hill House, where instrument T is installed, is approximately 50° 41′ 18″ N. Lat., and 1° 17′ 10″ W. Long. It is near to the Shide railway station, at the foot of the western side of Pan Down, which is a portion of the chalk backbone of the Isle of Wight.

Up on the Down the chalk reaches to within a few inches of the surface. At Shide Hill House disintegrated chalk, which may have a thickness of about 6 feet, is met with at a depth of 3 feet. In front of the house, or towards the west, at a distance of about 150 yards at the other side of a small stream, there is a railway. In a N.E. direction, at a distance of

242 yards, there is a chalk quarry, where at certain fixed times blasting takes place.

At the back of the house within a few yards of the buildings in which the instrument is placed there is a lane down which on week days carts heavily laden with gravel pass.

Through the kindness of Mr. A. Harbottle Escourt, Deputy Governor of the island, I was enabled to establish a second instrument (U) within the grounds of Carisbrooke Castle. The foundation is similar to that at Shide, being a brick column built up from the chalk. This stands in a small room, one wall of which is the western wall of the castle. Towards the east it faces the Bowling Green.

This instrument gave its first records about June 22, but it was not in proper working order until the middle of July.

Shide lies at a distance of $1\frac{1}{4}$ mile in a N.N.E. direction from Carisbrooke. Mount Joy, which is 274 feet high, lies between the two places.

At Shide and continuing towards Carisbrooke the chalk ridge, which forms the backbone of the island, strikes E.S.E. to W.N.W., and dips at at a high angle approaching verticality towards the north. The central portion of this anticline has been removed by denudation, whilst its southern, which dips gently, can be seen in the Downs along the south coast.

The steep dip on the northern side of this anticline is a feature common to the folds of the continuation of these rocks. Sudden monoclinal folds are generally recognised as representing movements, which if continued result in faulting, and the home of faults is that of earthquakes.

The faults which are actually visible or inferred from the displacement of beds in the Isle of Wight are only seven or eight in number, and the throw of those, excepting the one supposed to exist a few miles east of Shide at Ashey, is but small (see 'The Geology of the Isle of Wight,' by H. W. Bristow, revised and enlarged by Clement Reid, and Aubrey Strahan, 'Memoirs of the Geological Survey,' 1889).

The structural and the stratigraphical conditions which I have personally observed at Shide and its neighbourhood are as follows. The chalk is so sharply tilted that it is reasonable to suppose that limits of its elasticity have often been exceeded. As a result of the pressure and metamorphic actions accompanying this distortion, the chalk has been so far hardened that when two pieces of it are struck together it has almost the ring of crystalline limestone, the flints if not broken into fragments have been brought together in patches, and have been so far fractured that by the application of light blows they fall in pieces. Siliceous matter has been deposited in veins, whilst slickensided surfaces in various directions apparently indicate that from time to time strain has been relieved by minor yieldings.

At Alverton chalk pit, which lies to the west of Carisbrooke, the chalk dips northwards at about 45°. Parallel to the dip the strike, and in intermediate directions the beds, are traversed by fractures which can be traced over lengths of 20 yards.

That these fractures are not mere cracks but are accompanied by displacement, and therefore have the character of true faults, is shown in one instance by the abrupt termination of a band of flint where it meets one of these lines, in another case, as also at Shide, it is shown by the smashing up of a mass of flint and the trailing out of the fragments of the same along the fractured face in a direction parallel to that of the striations. The last indications of displacement are the striations themselves.

The surfaces of these fractures are yellowish in colour, indicating that they have formed channels for subterranean water, but notwithstanding the solvent action accompanying such percolation the striations remain singularly clear.

The inference from this is that these fractures, which penetrate downwards to unknown depths, are of comparatively recent origin. In an upward direction they can be traced to the lower portion of the disintegrated chalk, but they cannot be traced through this into the overlying gravel and its thin capping of earth.

Had these overlying materials been as resistant to fracture as the hard chalk beneath them, it might be reasonably supposed that these fractures had been produced before the deposition of the overlying materials. In this instance, as in all other instances where deposits of a soft and yielding character overlie strata of a much harder nature, one of the usual arguments respecting the age of faults may fail. Very large earthquakes are occasionally accompanied by dislocation which reaches through the alluvium to the surface, but with the majority of such disturbances, as with the fractures which accompany a subsidence in a mine, the dislocations only extend upwards through rocks which are in a state of strain. It is therefore reasonable to suppose that the disintegrated chalk and its overlying soft materials could only be disturbed by faulting of an unusual character, and even in such instances, by settlement, the percolation of water and surface denudation traces of the same would be speedily obliterated.

In the majority of instances traces of fracturing and even faulting at considerable depths would not be visible near the surface. The faults which have been observed in the chalk of the Isle of Wight anticline and in the overlying tertiaries, up to the Hampstead beds, which have shared its movements, are in all probability the natural records of earthquakes of considerable magnitude.

Although geological evidence indicates that the Isle of Wight fold like those to the north of it was commenced in Miocene times, and was contemporaneous with movements which led to the building of the Italian peninsula and some of the largest mountain ranges in the world, actual earthquakes which have been felt in the Isle of Wight are but few in number. Dr. Groves, of Carisbrooke, who is familiar with the island and its history, has failed to meet with any accounts of such disturbances. Mr. Charles Davison, however, gives me the following list of shakings, which, although they did not originate in Vectis, may have been felt there—1734, November 5; 1750, March 19 and 29; 1755, November 1 (Lisbon); 1811, November 30; 1814, December 6; 1824, December 6; 1834, January 23 and August 27; 1853, April 1; 1884, April 22 (Colchester); 1889, May 29 (Channel Islands). On the opposite coast during the last two hundred years, on the authority of Mr. J. E. Sawyer, it may be concluded that a shock of some violence has on the average been felt once in every ten years. These were particularly noticeable about Chichester.

The reason that earth shakings never appear to have originated in the Isle of Wight, possibly lies in the fact that the strata in which it seems so likely that dislocations should occur is almost entirely composed of materials which are soft and yielding in their character, and therefore adjust themselves to new forms by crushing and gliding rather than by sudden fracturing.

The appearance and structure of the Isle of Wight anticline is that of a district in seismic strain, in which we might expect to find adjustments by intermittent and to some extent semi-viscous yielding. Later on it will be shown that horizontal pendulums founded in this chalk often exhibit sudden displacements, the cause of which is at present unknown. These are much too local in their character to be called earthquakes, and it seems likely that they will prove to be settlements beneath, or very near to, the foundations of the piers on which the instruments are placed.

The Instruments T and U and their Installation.

The instrument and the installation at Shide is designated by the letter T. Other horizontal pendulums of a similar type used in Japan are indicated by the preceding letters of the alphabet.

Instrument T differs from the one shown on p. 85 in the Report for 1895 in the arrangement of the boom, which at its outer end carries a small

FIG. 1.

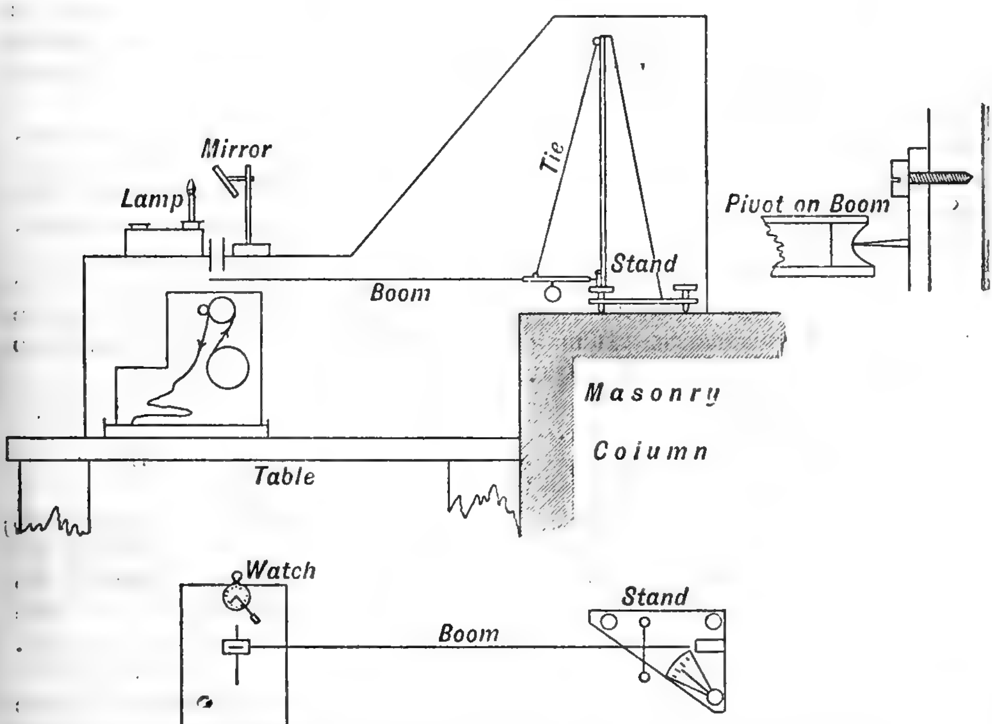


plate with *two* slits, one being large and the other small, the form of the bed plate, the balance weight being pivoted on an arm at right angles to the length of the boom, and the arrangement of a watch, the large hand of which every hour crosses the fixed slit in the box above the moving bromide to eclipse the light and give time intervals (see fig. 1).

Up to March 27, the boom constructed of varnished straw and reed was 2 ft. $5\frac{3}{4}$ in. long and weighed $\frac{3}{8}$ oz. The balance weight weighed $2\frac{1}{8}$ oz. With a period of 17 seconds a deflection at its outer end of 1 mm. corresponded to a tilt of 0″·71.

On April 24 this was replaced by an aluminium boom 3 feet in length, weighing $\frac{1}{2}$ oz. The balance weight weighs 8 oz. With a period of 31 seconds, a deflection of 1 mm. at its outer end corresponds to a tilt of about 0″·2.

The instrument stands upon the cement-covered top of a brick column, which is 1 ft. 6 in. square and 6 feet high. This rises freely in a pit 3 feet deep from a thin bed of concrete covering the surface of the disintegrated chalk. The sides of the column are oriented N S., and E W.

The building in which this is placed is an old stable built with brick, and sheltered by trees on its north, south, and west sides. From October 1895 the southern face of the column was covered with cement, which like the top was on that day coated with paint. The pit in which the column rises is filled with dry straw and hay, whilst for some months the column itself was wrapped round with a double thickness of thick felt.

About the end of June a second instrument which I call U was installed at Carisbrooke Castle. It was made by Mr. R. W. Munro, of Granville Place, King's Cross Road, London, W.C. In nearly all respects, excepting that of better workmanship, it is similar to the one at Shide. It stands on a brick column inside a building, one wall of which is the western wall of the Castle, facing the bowling green. With a period of 8 seconds its sensibility is such that 1 mm. deflection of the boom corresponds to a tilt of about 0″·5.

The cost of working one of these instruments, which includes benzine, bromide paper, used at the rate of 3 feet per day, and developers, is about 2*s.* 6*d.* per week. To wind and compare the watch, mark the bromide papers with a date, and to refill the lamp, which has to be done daily, occupies about 10 minutes. Changing and developing the papers once a week can be done in about 45 minutes. The time occupied to analyse a diagram depends upon its nature and the exactitude required in the necessary measurements. It may be 5 minutes or one hour. The walk to Carisbrooke and back takes about $1\frac{1}{2}$ hour.

Artificial Disturbances.—(Blasting, Train and Cart Effects.)

At a distance of 242 yards on the N.N.W. side of the instrument there is a chalk quarry, at which when the present observations commenced charges of powder of $\frac{1}{2}$ lb. and upwards were fired. Since October 1 the quantities of powder employed are said to have been reduced, and the times of firing the same confined to the half hours between 9 and 9.30 A.M. and 2 and 2.30 P.M.

Although I have several times had the opportunity of watching the instrument within 20 seconds of one of these explosions I never observed that any appreciable motion had been produced.

It may therefore be assumed that the instrument was not seriously affected by these operations. An assurance of this was obtained by comparing the following list of explosions very kindly made by Miss E. A. Evelegh, of Shide House, which is within 50 yards of the quarry and a railway cutting leading to the same, with the records of sudden displacements and swinging of the instrument :—

1895	H. M.	
August 30	7 20 P.M.	Heavy blast.
„ „	7 23 „	Moderate blast.
„ „	7 28 „	„ „
September 29	22 30 „	In the cutting
October 1	20 15 „	„ „
„ 2	19 „	„ „ double blast.
„ 3	22 10 „	„ pit, heavy blast.
„ 4	23 5 „	„ „
„ 4	23 25 „	„ „ 2 or 3 small blasts.
„ 8	19 20 „	„ „ double.
„ 9	21 55 „	„ „
„ 10	0 5 „	„ „
„ 10	18 25 „	„ „
„ 10	19 5 „	„ „
„ 10	23 20 „	„ „
„ 11	5 5 „	Very heavy double blast.
„ 11	21 55 „	In the pit.
„ 12	1 15 „	„
„ 13	20 15 „	„
„ 13	22 15 „	„
„ 14	2 0 „	„
„ 15	3 25 „	„
„ 15	22 0 „	„
„ 16	2 0 „	„
„ 16	20 45 „	„
„ 17	0 5 „	„
„ 17	21 55 „	Very heavy.
„ 18	21 40 „	„

The result of the comparison shows that in most instances no effect can be traced to the explosions. In one or two instances, however, a slight blur from ½ to 1 mm. in width has been the result.

The conclusion therefore is that the swingings recorded, which represent sudden changes in the inclination of the ground, have not been the result of blasting.

A few unusually heavy shots have, however, transmitted elastic vibrations as far as the instrument. These have caused the outer end of the boom to quiver but they have never produced a swing.

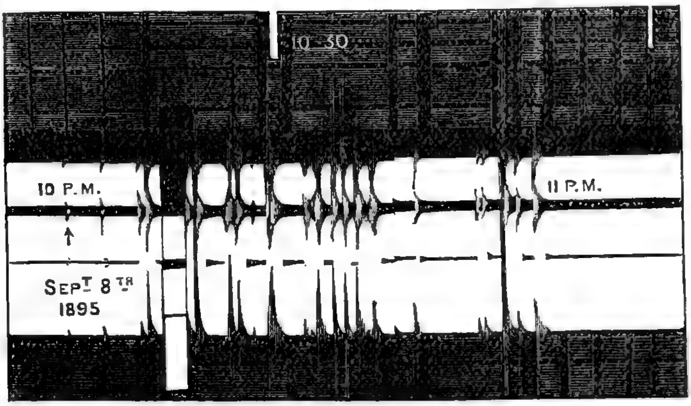
The true amplitude of most of these is in all probability only a fraction of a millimetre and unless carefully looked for would hardly be visible in the photogram.

A heavily laden cart passing at a distance of about 10 yards may produce a somewhat similar effect, but a light train at a distance of 150 yards does not appear to produce any effect.

Sudden Displacements and Earthquakes recorded at Shide.

By sudden displacements I mean movements like those shown in fig. 2. Usually, as here shown, they occur in groups, but now and then they occur singly. A similar appearance can be produced by gently pushing the pier carrying the instrument and then allowing the swinging boom to come to rest. Were they due to settlement in or beneath the pier, I should expect that they would be accompanied by permanent displacements which is seldom the case. A curious feature which now and then shows itself, and can be seen in fig. 2, is a permanent displacement of two or three minutes followed by a sudden return to the normal position. Minute spiders have sometimes found their way inside a case, but it is very doubtful that they should be able to cause the sudden disturbances shown and finally leave the boom in its normal position and free to swing. With records from nineteen installations in Japan I never remember observing movements of this character. Whatever may be the cause of these dis-

FIG. 2.—Displacements on September 10.



placements it is probably very local in its operation, and therefore they cannot be regarded as earthquakes.

The duration of a displacement is evidently the length of time it takes a pendulum which has been slightly deflected to come to rest. With a light boom this is about $1\frac{1}{2}$ minute but with a heavy boom it may be 5 minutes. A group of disturbances may extend over 20 or 30 minutes. One group of 40 occupies 3 or 4 hours.

An earthquake originating at a distance has the appearance of fig. 3, which is probably the Shide record of the commencement of shocks which shook Cyprus on June 29, 1896.

Between August 19, 1895, and March 27, 1896, or during 202 working days, 485 sudden displacements and earthquakes were recorded.

In the following list the records referring to sudden displacements are those which succeed each other at short intervals, and are marked 'sudden' or 'strong.' Those which are followed by the remark 'slight' or 'moderate' may be due to actual earthquakes, the origins of which in some instances have been at great distances.

Records (August to November) marked **A** approximately correspond in time to disturbances noted by Professor Agamennone in the 'Bulletin Météorologique et Seismique de l'Observateur Impérial de Constantinople.' **T** refers to records published by Professor Pietro Tacchini (for September and November) in the 'Bollettino della Società Sismologica Italiana.' **G** refers to records received from Professor Gerland at Strassburg, and **K** to those from Professor Kortazzi at Nicolaiew.

These references, it will be observed, are very incomplete, and are only made up to the end of March 1896. In a subsequent report it is hoped that these will be completed, whilst the list itself will be extended up to date, and include the observations made at Carisbrooke.

The corrections are given in minutes and seconds, and are to be added or subtracted as indicated. From August 19 to October 27 the times after correction may have an error of ± 1 minute, but from the latter date onwards the errors should not exceed ± 5 seconds.

The uncorrected times are given in hours and decimals of the same—Greenwich mean time. Noon = 24 or 0 hours.

Under the column 'Remarks' the duration of disturbances is given in minutes and seconds.

Tremor storms and pulsations are *not* included in this catalogue.

Date	Correction		Time	Remarks
1895	M.	S.	H.	
August 19	+2	0	9·983 A	1m. 27s., sudden.
			15·883	„ „
„ 20	+2	0	7·783	„ „
			9·383	„ „
			Two displacements	The first is permanent to E. and the second partly back to W.
			9·516	1m. 27s., sudden.
			9·900	„ „
			9·933	2m. 10s., „
			11·233 A	„ „
			11·383	0m. 43s. „
			11·516 A	2m. 54s. „
			12·383 A	1m. 27s. „
			12·816	0m. 43s. „
„ 28	.	.	11·5 to 12·5. Altogether nine strong displacements	From 1 to 2 m., sudden.
			14·5 to 15·0. Five strong shocks A	„ „
„ 30	.	.	0·5 to 4·0. There were three or four small displacements	
			9·560	About 1m. 30s.
			9·830	„ „
			9·880	„ „
			11·300	Slight
			16·220	Strong, 15m. earlier, two slight disturbances.
			16·463	Slight.
September 1	.	.	8·050 A	Moderate.
			11·214	19m.
			11·786	Slight.
			11·860	„
			21–24 A	Very slight disturbances. These may be blasts.
„ 2	+0	37	1·30–5·30	Very slight disturbances. These may be blasts.
			9·645 A	Slight.
			11·930, the first of seven heavy displacements A	Total duration 53m., but after the second there is an interval of no motion of 17m.
			21 to 24	Slight, as if by blasting.
„ 3	.	.	19·643	Heavy, 3m.
			20·643	Moderate, 1·5m.
„ 4	.	.	2·000	Slight.
			14·380 A	„
			14·643	Strong.
			14·880	Slight.

TABLE I.—*continued.*

Date	Correction	Time	Remarks
1895	M. S.	H.	
		17·600, the first of five strong displacements	These are separate, but are included in 16m.; the third is strongest.
		18·000, the first of four displacements	The first is heavy. Total duration 18m.
		23–24	Blasting ?
September 5 .	. .	0·2	Blasting.
		9·690	Moderate.
		12·240, the first of two displacements	" Total duration 3m.
		12·790	Moderate.
		12·857	"
		13·071	Strong.
		13·213	Moderate.
		13·500 (about)	Three very slight shocks.
		13·738	Strong.
		14 (about)	Two very slight shocks.
		15·095	Strong.
		15·548	"
		20·357	Moderate.
" 6 .	. .	9·000 (about)	"
		21–24	Blasting.
" 7 .	. .	10·762–13·000. There were fifteen large displacements	
		14·047	Moderate.
		11·095, first of five displacements	Total duration 20m., each one separate.
" 8 .	. .	6·857	Displacement of 1·5m. and return.
		7·357	Displacement of 3m. and return.
		8·798, first of forty-two displacements which ended 12·014	Twenty-eight of these are large; there may have been more in the series, but at midnight the bromide film ended. Record ceases until September 18.
" 19–24	. .	One or two slight sudden displacements but no shocks	
" 25 .	. .	8·340 A	Moderate.
		8·454	"
		10·928 A	Slight.
		13·400	"
		23·5 to about 24·0 A	Six slight shocks amongst tremors.
" 26 .	. .	4·691, followed by two others	Moderate.
		5·600 A	"
		8·5	Strong.
		9·143	Slight.
		9·262	"
		11·341	"
" 27 .	− 3 13	4·739	"
		5·5 (about), three shocks T	The second large.

TABLE I.—*continued.*

Date	Correction	Time	Remarks
1895	M. S.	H.	
		7·120	Slight.
		7·430	
		7·5 to 8·5, six shocks	All moderate.
		9 5 (about)	Moderate.
		9·452	Two slight shocks.
		9·660	Moderate.
		14·320	"
September 30 .	− 4 01	6 (about)	Two shocks, interval 1m.
		6·45 "	" " "
		6·5 "	" " "
		7 "	One shock.
		8 "	"
		9·853, the first of thirteen	Total duration 28m.; the last are feebler and separated more widely than the first.
		21·80 (about) A	Moderate.
		22 "	Slight.
October 1 .	− 4 20	11·643, the first of five	Moderate, duration of series 1 hr. 5m.
" 2 .	− 5 07	9·5–10·5 T	Four or five shocks.
" 3 .	− 0 07	6·0, the first of seventeen displacements	Duration 1hr. 10m. The first commenced gently. The heavy ones are slight displacements.
		8·5 (about)	Slight.
" 4 .	+ 3 58	6·4, the first of three displacements	Duration 8·5m.
" 5 .	+ 4 46	10·0 (about)	Moderate.
" 6 .	+ 2 47	12·5, the first of six displacements T	These occur in an interval of two hours.
" 8 .	+ 3 31	10·140, the first of six shocks A	The first commences gently, duration 30m.
" 9 .	+ 3 0	10·3 (about)	Slight.
" 11 .	+11 7	5·09	Displacement.
		9·762	Strong, duration 3m.
		10·215	Moderate.
		22·333, the first of two shocks A	These are slight, and look like earthquakes from a distance.
" 13 .	+ 9 41	9·0 (about)	Strong.
" 15 .	+ 6 18	21 "	"
" 16 .	+ 4 3	4·25 " T	Moderate.
		5·5 "	Two shocks.
" 18 .	− 0 47	8·75, first of three shocks	
		15·0 (about) A	Slight.
" 19 .	− 2 51	0 to 3, there are seventeen slight disturbances T	These have the character of disturbances from a distance.
		8·25 (about)	Moderate.
		22·30 " V.T.G.K.	Strong displacement in the midst of tremors.
" 21 .	. .	6·25 T	Strong.
" 22 to 30	. .	. . . . .	Lining case with felt. Heavy tremors often eclipse possible shocks.
" 30 to Nov. 4	. .	No shocks	

TABLE I.—*continued.*

Date	Correction	Time	Remarks
1895	M. S.	H.	
November 5 .	. .	8·5 (about)	Strong.
		9·6	Moderate.
		22 (about)	Slight disturbance.
„ 7 .	+ 1 30	9·93, the first of six **A**	Duration 55m. The first two are small, and the third is strong.
		16·8 (about)	Slight.
		20·5 „	Three slight.
		21·75 „ the first of three	All slight.
„ 12 .	– 1 0	7·45 (about)	Shock?
„ 13 .	– 1 0	8·302, slight but followed by forty-four displacements **A**	Total duration, 3hr. 8m. The third shock or group of shocks has a duration of 6m.
		22·25 (about)	Moderate.
„ 14 .	– 1 0	0·6 „	Slight.
		2·6 „	„
		4 „	A slight displacement.
		8·5 „	Four shocks, duration 10m.
		22·3 „	Six shocks, duration about 12m.
„ 15 .	– 1 2	0·640, the first of six displacements	Duration 26m. the fourth is a group lasting 6m.
		3·6, the first of thirteen	Duration 1hr. 30m., the first shocks heavy, and those at the end slight.
		6 (about)	Two slight.
		6·5, three	Heavy.
„ 16 .	– 1 5	3·9 (about) **A**	Slight blur.
		20·0 „	Three?
„ 19 .	– 1 6	6·2 „	Displacement.
„ 21 .	– 1 5	11·270, the first of three displacements **A** No more until Dec. 1	Duration 30m. All are displacements to the W. The return swing of the last takes 7m.
December 1 .	– 1 6	11·0 (about)	Slight, W. displacement.
„ 2 .	– 1 7	10·0 „	„ „ „
„ 5 .	– 0 44	11·5, the first of nine displacements	Duration $2\frac{1}{2}$h.
„ 9 .	– 0 42	0·25 (about)	Strong.
		2·0 „	Slight.
		3·25 „	Vibrations.
„ 10 .	. .	11·7 „	Slight displacement to W.
		0·42	
		14·7–15·0 (about)	Slight displacement to E. and then W. There are several of these up to 24h.
„ 11 .	– 0 40	3·25 (about)	Slight displacement E.
„ 14 .	– 0 30	19·0 „	Slight.
„ 15 .	– 0 11	0·7 „	„
„ 22 .	. .	22·45 „	Moderate.
„ 25 .	+ 0 41	19·0	Strong.
		19·634	„
„ 26 .	+ 0 36	13·28 (about) **A**	Moderate.
		13·32 „	„
		19·15 „	Double shock.
		20·25 „	Moderate.

TABLE I.—*continued.*

Date	Correction	Time	Remarks
1895	M. S.	H.	
December 27 .	+ 0 31	3·50, 4·50, 4·45, 5·5, 7·5, 7·10, 7·12, 7·35, 7·38, 7·55, 8·0, 10·45, 15 50, 19·0, 20·45, 21·15	Approximate time of sixteen distinct displacements, the one at 10·45 commences gently.
„ 28 & 29	. .	. . . .	No records. Dec. 29 to Jan. 18 no shocks.
1896			
January 17 .	+ 0 33	22·45 (about)	Two vibrations.
„ 19 .	+ 0 36	1·0 „	Slight „
„ 22 .	+ 0 46	6·317	Strong.
		9·701, the first of five displacements	Duration 30m. The third is a displacement to E., and the fifth to the W.
„ 24 .	+ 0 55	3·350, the first of seven small displacements	Duration 20m.
„ 25 .	+ 0 59	22·50 (about)	Vibrations.
February 5 .	+ 1 16	2·5 „	Slight displacement.
		2·8 „	„ „
		3·140	Decided shock.
„ 6 .	+ 1 22	0·707	Slight.
		4·190	„
„ 8 .	+ 1 32	1·952	Decided shock.
„ 12 .	+ 1 33	2·0 (about)	Vibrations.
„ 21 .	+ 1 58	15·561	Strong.
		17·0 (about)	Three, the two second strong.
„ 24 .	+ 1 55	5·25 „	Slight tremor.
„ 28 .	+ 1 23	15·805, the first of four	Duration 30m.
		20·25 (about)	Slight.
		22 „ four displacements	Duration 8m.
March 1 . .	+ 2 10	9·0 (about)	Slight.
„ 15 . .	+ 2 0	4·000	Shock commences; max. 4m. later.
„ 16 . .	+ 2 0	5·548	First of three very slight shocks.
„ 22 . .	+ 2 53	1·191	First of two very slight shocks.
		2·309	First of five small shocks. Up to Mar. 27, when circumstances compelled me to cease recording, there were no more shocks.

After comparing 'sudden' disturbances and decided 'shocks' noted in July 1896 with similar records obtained at Carisbrooke, it is seen that these do not coincide in time. Therefore these movements, which appear to be so frequent in the winter, are extremely local in their action, and cannot be regarded as earthquakes. What they mean is at present unknown, and it will not be until two instruments have been installed near to each other that we can speak more definitely regarding their cause.

Because the lists given by Dr. Agamennone, which include, with the earthquakes of Turkey and Asia Minor, those of Italy and other European countries, are very full, we naturally expect to meet with approximate coincidences in time between some of these shocks and those recorded at Shide. As examples of these coincidences, the shock of August 19 at 9·983h. and that of August 20 at 12·383h. may be taken. These two shocks followed heavy disturbances which took place in Asia Minor by intervals of about 28m. 32s. and 32m. 32s. Taking the distance between the Isle of Wight and the western part of Asia Minor at $\frac{1}{15}$th of the earth's circumference and the velocity of a surface-wave at 2km. per second, these intervals of time should have been 23m. or 24m. The discrepancy of from 4m. to 8m. between what is observed and what would be expected might be explained on the assumption that the times noted in Asia Minor seem to be but roughly approximate. Several facts, however, indicate that many of the disturbances noted in the Isle of Wight, although they may agree in time with those catalogued by Agamennone, are not identical with the same.

The Isle of Wight *displacements* commence suddenly and succeed each other at widening intervals of time, both of which characters are suggestive of shocks having a local origin. Farther than this, although certain of them may have taken place at an interval of time roughly proportional to the distance of an origin when there has been a heavy disturbance, there are many in the same series where this proportionality does not exist. For example, although it has been shown that two out of the thirteen shocks of August 19 and 20 might be identical with shocks of those dates in Asia Minor, other shocks amongst the remaining eleven follow those in Asia Minor at intervals exceeding one hour, whilst some *precede* them. The important feature in the European and Isle of Wight records is the approximate coincidence in time of groups of shocks. On August 12 and 20 there were a succession of violent disturbances in Asia Minor, and on the same dates we find a marked set of disturbances in the folded and faulted strata of the Isle of Wight. For the same places the same phenomenon is repeated on November 13 and 14. In the Isle of Wight, on the former date, between 8.30 and 11.30 P.M., forty-four sudden tiltings were recorded, whilst in Asia Minor, between 9.30 on the 13th until the night of the 14th, there were violent shakings. Observations of this character suggest the idea that either unfelt earth-waves radiating from centre of violent activity disturb strata in a critical condition in distant places, or that the relief of strain in one portion of the globe cause readjustment in distant localities. Large earthquakes, like that of 1755, have apparently caused secondary earthquakes, whilst seismological chronology tells us that there have been periods when earthquakes have been more frequent throughout the world than at others.

Copies of this list have been sent to several of the principal observatories in Europe, where there is apparatus which might record similar disturbances. Up to date only three replies have been received, which are as follows :—

Dr. Eschenhagen, Potsdam.

1895. *Nov.* 9.—Schwingungen des Magnets von Lloyd's Wage (Magnet liegt Ost-West) nach den photographischen Curven ermittelt :—

	H.	M.	
Beginn	1	24.6	Mittl. Zeit Potsdam
Maximum	1	27.0	
Ende . . .	1	27.8	

Amplitude sehr klein, c^a $\frac{1}{2}$ Bogenminute

Andeutungen von Schwingungen sind noch um:

1 31.0
1 34.4

1896. *Jan.* 9.—3 Stösse an Lloyd's Wage beobachtet:—

		H.	M.	
(1)	Anfang	3	1.1	P.M. M. Z. Potsd.
	Maxim.		1.8	
	Ende		2.9	
	Amplitude		1	Bogenminute
(2)	Anfang	3	5.8	
	Maxim.		6.9	
	Ende		8.9	
	Amplitude		0.8	Bogenminute
(3)	Anfang	3	11.0	
	Maxim.		12.6	
	Ende		13.9	
	Amplitude		0.5	Bogenminute

1896. *März* 4.—Mehrere Stösse bei allen drei Komponenten beobachtet:—

—	I. Declination	(Bifilarmagnet) II. Horiz. Comp.	III. Wage
	H. M.	H. M.	H. M.
(1) Anfang . .	5 44.8 A.M.	5 36.2	5 42.9
Maxim. . .	46.2	Schwache Bewegung	Schwache
Ende . .	47.7	5 43.7	Bewegung
Amplitude .	cª .1′		—
(2) Anfang . .	5 48.3	—	5 45.3
Maxim. . .	49.9	Gleichmässige Schwingungen	46.3
Ende . .	51.7	5 50.9	48.0
Amplitude .	cª 1.0′	0.5′–1.0′	0.5′
(3) Anfang . .	5 55.1	5 54.7	5 48.5
Maxim. . .	5 58.3	Schwache	—
Ende . .	6 2.0	Bewegung	—
Amplitude .	cª .1′	—	—

Alle Zeitangaben sind nach mittlerer Zeit Potsdam gemacht (0h. 52m. 15.4s. Zeitdifferenz gegen Greenwich). Dieselben sind auf $\frac{1}{4}$–$\frac{1}{2}$ m. sicher. Die hier vorliegenden Beobachtungen zeigen leider keine Coincidenz mit den dortigen.

Potsdam, 1896, Juni 23.

On November 2 and January 9 shocks were not recorded at Shide, whilst on March 4, at the hours specified, the instrument was dismantled, and a felt lining removed from the case.

Professor G. Agamennone, Constantinople.

C'est avec grand plaisir que j'ai reçu la liste des secousses sismiques que vous avez enregistrées à Shide du 17 août 1895 jusqu'au 27 mars 1896.

Je n'ai pas manqué de les confronter avec celles que j'ai déjà publiées ou que je publierai sous peu dans le 'Bulletin Météorologique et Sismique' de Constantinople, bulletin que je m'honore de vous envoyer et que, je l'espère, vous devez régulièrement recevoir.

D'après ce qu'il résulte de cette comparaison je n'ai pu y trouver aucune relation qui soit bien sûre, un intervalle de temps remarquable se trouvant toujours entre les commotions sismiques d'Orient et les perturbations indiquées par vos instruments, eu égard, bien entendu, aux diverses longitudes.

Une différence moindre se montre seulement pour la secousse du 19 août 1895, laquelle fut indiquée dans votre observatoire à 10^h 1^m du matin, tandis que $\frac{1}{4}$ d'heure plus tard un désastreux tremblement de terre ravagea la ville d'Aïdin et ses alentours en Asie Mineure.

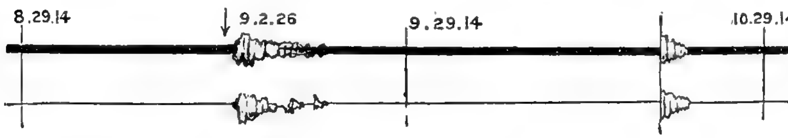
Je porte, enfin, à votre connaissance que le 29 juin passé, vers 11^{h} ½ du soir (t. m. Constantinople ?) une forte secousse sismique à eu lieu sur la côte de la Syrie et s'est fait ressentir aussi avec une grande intensité à Larnaca (Chypre).

6 juillet 1896.

As Professor Agamennone remarks, my record for October 19 precedes the Aïdin Disaster by about 15 minutes, but it follows the fourth and heaviest shock felt at Bouladan, at about 9h. 44m. 6s. G.M.T.

The Cyprus shock of June 29 was recorded at Shide (see fig. 3).

FIG 3.—June 29, 1896. Cyprus.



Dr. Adolfo Cancani writes that the Shide records do not correspond to those at Rocca di Papa.

Earthquakes recorded in Europe, followed by disturbances at Shide, Aug. 19–Nov. 30, 1895.

Date	Locality	Character of Shocks	G.M.T. at Locality	G.M.T. at Shide	Diff. in G.M.T.	Character at Shide
1895			H. M. S.	H. M. S.		
Aug. 1	Bouladan .	Heavy	9 44 6	10 1 0	17 min.	Sudden
„ 20	Patras .	—	10 33 36	11 16 0	42 „	„
„ 20	Aïdin .	Heavy	12 4 6	12 25 0	21 „	„
„ 28	Zante .	Slight	14 14 6	14 30 0	16 „	Strong
Sept. 1	Messina .	—	8 0 0 (about)	8 2 0	2 „ (about)	Moderate
„ 1	Laibach .	—	10 8 0 (about)	11 1 0	53 min. (about)	„
—	Laibach .	Strong	9 12 6	9 38 0	26 min.	Slight
—	Zante .	Light	13 4 6	14 23 0	59 „	„
„ 25	Zante .	—	7 47 6 (and at night)	8 20 0	33 „	Moderate
„ 26	Zante .	Feeble	5 11 6	5 36 0	25 „	„
„ 27	Spoleto .	—	4 9 6	4 43 0	34 „	Slight
Oct. 6	Florence .	—	11 22 34	12 30 0	7 „	—
„ 8	Laibach .	—	night	10 8 0	—	First of 6 commence gently
—	Zante .	Strong	11 4 6	10 24 7	20 „	Light
„ 16	Giano dell' Umbra .	—	3 50 0	4 19 3	29 „	Moderate

Out of these fifteen shocks, if we make an allowance of a few minutes in the accuracy of the times in the fourth column, then there are twelve of them recorded at Shide at about the times we should expect them to have reached that place. Two of the first three shocks which were 'sudden' at Shide took place when we might expect earth-waves to have reached that place from localities where there had been heavy disturbances.

Notes on Special Earthquakes.[1]

October 19, 21*h.* 30*m.* *G.M.T.*, 1895 (*Strassburg*).—The following note is derived from a sketch of the photographic trace sent to me by Dr. Gerland, of Strassburg. This sketch shows the movements which took place in a von Rebeur-Paschwitz pendulum on the morning of October 20.

About 10 A.M. (S.M.T.) there were preliminary tremors, lasting about five minutes. These were followed by strong movements, reaching thirty or more millimetres, which continued until about 11.30, during which time the pendulum was displaced by four steps towards the south. From this time the movement died out, but slight movements are observable until after 1.30 P.M. The duration of the disturbance was therefore at least 3½ hours.

Padua.—Observations made with the pendulum apparatus and multiplying indices of Professor G. Vicentini:—

	H.	M.	S.
Commencement	10	29	44
End	11	55	45
Duration	1	26	0

These times are probably mean European time.

Nicolaiew (Professor Kortazzi).—Observation with a horizontal pendulum :—

	H.	M.	S.
Commencement N.M.T.	21	30	0

Shide, Isle of Wight (Milne's Pendulum).—Unfortunately this disturbance occurred in the midst of a tremor storm. Its commencement and end are therefore lost.

Strong movements occurred at 22h. 24m., 22h. 27m. and 22h. 32m. G.M.T.

Reducing the observations to Greenwich mean time we obtain :—

	Commencement			Maximum			
	H.	M.	S.	H.	M.	S.	
Strassburg	21	28	55	22	28	55	about
Padua	21	29	44	21	43	44	„
Nicolaiew	21	29	51				
Shide	unknown			22	30	0	„

These records show that three types of instrument have each been sufficiently sensitive to record the same disturbance.

September 4, 5, 7 *and* 8.—It will be observed that on these days, from which it must be noted September 6 is omitted, when there was practically no movements, that shocks were very frequent. Dr. Gerland of Strassburg writes me that on these days there were many small shocks, and a tendency for the pendulum to move towards the south.

June 15, 1893.—On the above date Professor Vicentini, at Padua, recorded disturbances, commencing at 10.45 A.M. G.M.T., which reached a maximum at about 11h. 14m. P.M., ending about one hour later.

At Shide a disturbance commenced at 10.30 A.M. G.M.T., but as the instrument was dismantled at 11.30 the record is incomplete.

If we allow forty-five minutes for a disturbance to travel from Japan to Europe, and nine hours as the difference in time between Greenwich and Tokio, then in Japan mean time the earthquakes and sea-waves, which

[1] See Appendix.

resulted in the loss of about 30,000 lives, took place on June 15 at about 8.30 P.M. Until July 11, when we learned that the destruction had taken place on June 15, the impression received from telegrams was that it occurred on June 17. We now know that the information derived from seismographs was correct, whilst that published as telegrams in our daily papers involved an error of two days.

June 29 to July 4, 1896.—At about 11 P.M. on June 29 there was a violent shock in Cyprus, which was followed by a series of others.

An alarming shock was felt at 8.25 A.M. on July 3, and others at noon, 12.38 P.M., 2.52 P.M., and 3.22 P.M.

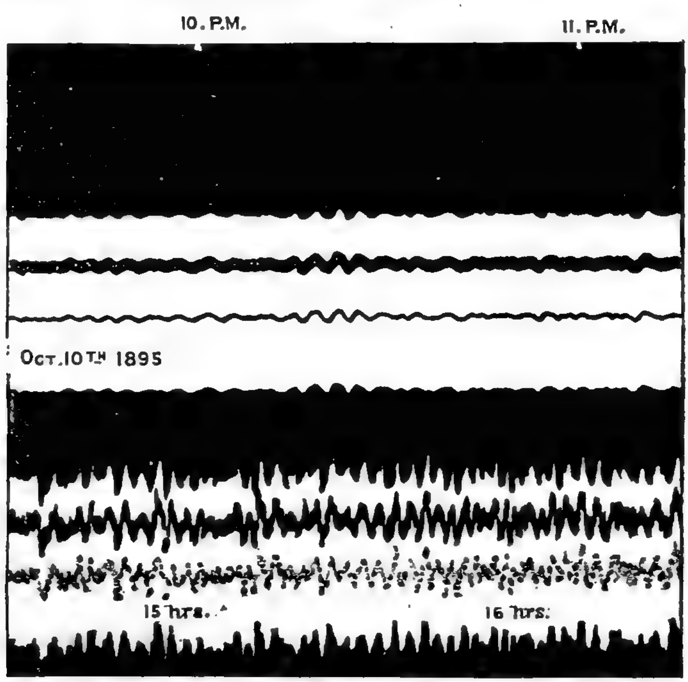
On these days many small shocks were recorded at Shide. Assuming a difference in time between Cyprus and Greenwich of 2h. 12m., the above times and dates in G.M.T. are as follows, and are placed side by side with the observations made at Shide.

	Cyprus H.	M.	S.		Shide H.	M.	S.	
June 29 . .	8	48	0	severe	9	02	26	continuing to 9 24 45
July 2 . .	18	13	0	„	18	51	29	
„ 2 . .	21	48	0	moderate	not recorded			
„ 2 . .	22	26	0	„	„	„		
„ 3 . .	0	40	0	„	„	„		
„ 3 . .	1	10	0	„	„	„		

Tremors and Pulsations.

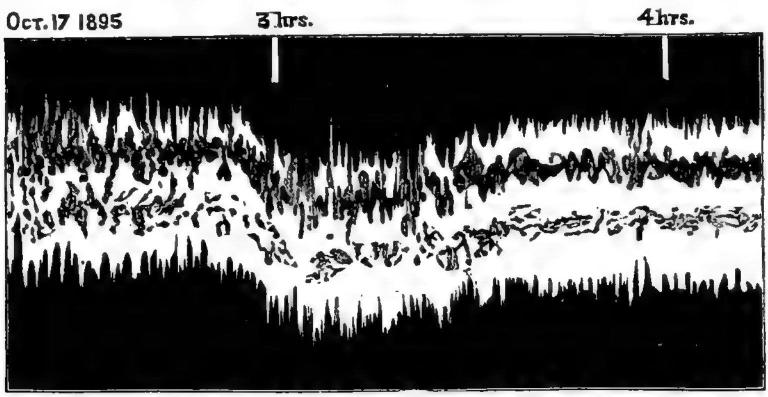
In the following table the more or less continuous, regular, and irregular swingings or repeated tiltings which have been observed are

FIG. 4.—Commencement and Growth of a Tremor Storm.



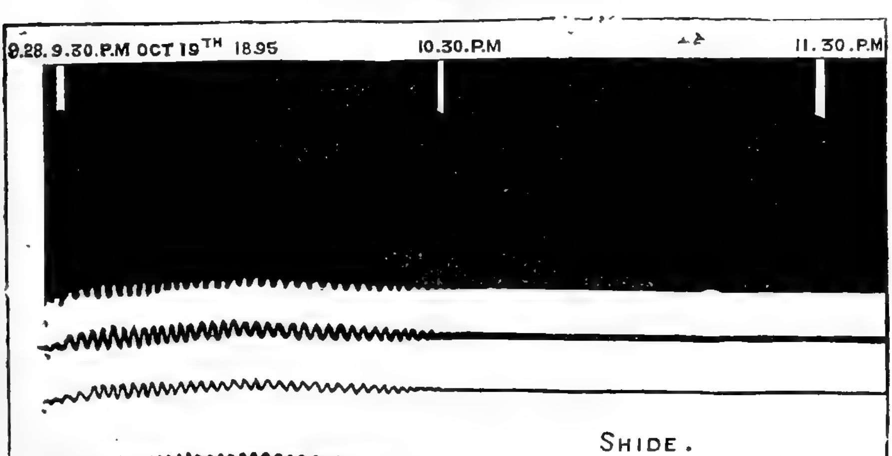
arranged chronologically. The numbers in brackets indicate the range of motion expressed in millimetres. The first entry for August 18 means that between 18 and 19 hours the pendulum was swinging through a range of half a millimetre. On August 23 the motion was continuous for the whole twenty-four hours, and the extent of motion was 10 millimetres. On days that are omitted, unless there are remarks to the contrary, the pendulum was at rest. Although the natural period of

FIG. 5.—Tremor Storm and Deflection.



the pendulum was 17 seconds, it will be noticed that sometimes its period exceeded 5 minutes, while periods of 1½ minute are common. Irregular and comparatively rapid swingings of the instrument are called tremors. Some of these are apparently due to the establishment of air currents within the case of the instruments, while others seem to have their origin in actual movements of the supporting pier.

FIG. 6.—Pulsations at Shide.



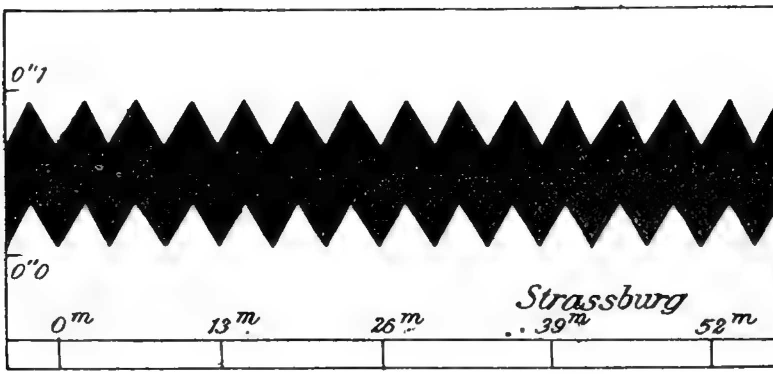
Pulsations are slow movements which are regular in the period and amplitude on the photogram, having an appearance like that produced by a tuning fork recording its vibrations on a moving smoked surface. These pulsations are referred to as such, or as waves. Often they are distinct from tremors, but at other times they lead up to tremor storms, and in such cases it becomes difficult to distinguish between pulsations and tremors.

Fig. 4 shows the commencement of a tremor storm at 10 P.M. on October 10, with long period irregular waves. At 15 and 16 hours it will be noticed that there has been a great increase in amplitude.

Fig. 5 shows a portion of a heavy tremor storm with a rapid tilt on October 17.

Figs. 6 and 7 show pulsations at Shide, commencing on October 19,

FIG. 7.—Pulsations at Strassburg (Paschwitz), enlarged ten times.



at 9.30 P.M., and pulsations at Strassburg magnified 10 times. The latter are reproduced from the work of von Rebeur-Paschwitz because they are identical with records often obtained in Japan.

TABLE II.

Date	—	Remarks
	1895.	
August		
18	18 to 19 (·5), 21 to 24	—
19	0 to 4 (1)	—
20	0 to 3 (·5)	—
23	0 to 24 (10)	Windy. Trays of $CaCl_2$ put in the case. When this was taken out the heavy tremors ceased. This was done three times.
24	0 to 24 (10)	
25	Heavy tremors	
26	”	
27	”	
28	”	
29	”	
30	17 to 20 (1)	—
Sept.		
2	5 to 8 (2)	—
4	16 to 20, max. 18 (3)	—
8 to 19	—	No records.
25	23 to 24 (·5)	Heavy rain and thunder.
28	2 to 4 (1)	—
28	20 to 23 (4)	—
29	18 to 22 (3)	Period 4m. 18s.
October		
1	19 to 24, max. 22 (5)	—
2	0 to 3.30	Tremors die out.
2	3 to 8.30, slight	Very windy on the 3rd, and no tremors.
2	9.30 to 24, max. 17 (6)	—
4	10.30 to 23, max. 16 (5)	Periods 3m. 20s. to 4m.
6	12.30 to 18.30	All tremors for the preceding week have long periods.

TABLE II.—*continued.*

Date	—	Remarks
October		
7	Slight	—
8	,, 7 to 18	Rain at night.
8	18 to 24, max. 23 (10)	Period 3m.
9	0 to 5 slight, and slight all day	—
9	19 to 23 (5)	—
10	8 to 24, max. 18 (8), at 10 (2) with 2m. period	Period is shorter. 1·5m. at end of storm.
11	6 to 24, very slight	—
13	14 to 21, max. 18 (5)	Period reaches 5·4 m.
14	18 to 19, slight	—
15	21 to 24, ,,	—
16	1 to 7 (3)	Sudden increase from 2 mm. to 7 mm. in tremors after opening case at 7.45 P.M.
16	7 to 24, max. 18 to 21 (15)	Period 1m 25s. to 2m. 50s.
17	0 to 6	Tremors die down.
17	9 to 24, max. 12 to 20 (6)	Period at 9h. about 2m. 50s., but decreases at end of storm. Cold at night.
18	0 to 24, slight	Max. of 2·5mm. after opening case at 21. Dies out as regular pulsations of ·5mm. and period 1m. 25s.
19	4 to 5, two groups of 10 waves each (1)	These are good examples of pulsations. The latter has 34 waves. Period 1m. 24s. to 2m. 7s. Max. range 2mm.
19	8 to 10, 34 waves per hour	
19	13 to 24, max. 21 (5)	—
20	0 to 3	Die out.
20	4 to 5, two groups of 9 waves each	—
20	10 to 24, max. 20 (5)	Commence as pulsations.
21	0 to 8	Slight.
21	4 to 6, groups of slight regular waves	—
21	8 to 24, 20 (5)	Increase after opening case at 20.
22	0 to 11	Reach 15mm. when the pendulum is deflected and they stop suddenly.
22	12 to 20 (2)	
22	20 to 24 (15)	These large tremors commence after opening box.
23–24	Heavy tremors (10 to 15)	No $CaCl_2$ in box.
24	—	Box painted inside, and face and top of column covered with cement.
27	Heavy tremors (10 to 15)	These continue even with doors of case open.
30	,, ,,	
30	—	Completely covered inside of case with thick felt and tremors cease.
Nov.		
2	11 to 22 (1)	—
5	22 (·5)	—
8	22 to 24, slight	9h., door slightly opened; closed it at 7h. on the 11th. On the 10th it was very stormy all day and no tremors.
9	0 to 9, ,,	
9	1 to 2, irregular and slow	Period 5·6m.
9	10 to 22 (1)	—
11	5 to 24, max. 14 to 24 (5)	Become marked after closing door at 7 P.M. Period 2·8m., but this is shorter at end of storm.
12	0 to 6	Storm dies out.
12	6 to 7	A calm day.

TABLE II.—*continued.*

Date	—	Remarks
Nov.		
12	7 to 24, max. 13 to 19 (5)	Period often 2·8m.
13	0 to 3, slight	2.30, pulsations 6 waves, each ·5mm. The column was felted and box filled round with straw.
13	3 to 24	Now and then very slight irregularities.
14	10 to 14	" " "
14	14 to 24, max. 18 to 20 (3)	Period 1·4m. Breeze, cloud, rain.
16	16 to 24, max. 19 to 21 (2)	Period of irregular waves reaches 5·6m. High wind in morning and no tremors.
17	0 to 5, slight	Dull, showers, calm.
17	5 to 24, max. 9 to 14 (4)	Irregular waves reach 4·2m. At 23.30 a very heavy storm commences suddenly. Frosty.
18	0 to 2.30 (5)	Period 2·8m. and fairly regular.
18	2.30 to 24	Dying out slowly.
19 to 21	No tremors	Gauze put over door.
22	16 to 24, max. 22 to 24 (3)	Period 1·4m. Calm.
23	0 to 24, max. 12 to 24 (3 to 4)	Period 1·4m. Fine.
24	0 to 8	Tremors die out. N. wind.
24	8 to 24, slight	Dull. Strong wind at night.
24	0 to 16, very slight	—
24	16 to 24 (1)	—
26	0 to 16, very slight	Dull, calm.
27	0 to 14, no tremors	Rain.
27 to 30	Up to 16 hours no tremors	On 29th took gauze off.
27 to 30	16 to 4 (1)	—
Dec.		
1	9 to 24, max. 18 to 22 (2 to 3)	Fog in morning.
2	0 to 3, slight	Fine.
3 to 5	No tremors except 23 to 24, slight	Dull and damp. Strong wind on the 4th and 5th.
6	0 to 24, from 3 violent	High wind at night.
7	0 to 24 (10), violent	Fine, windy.
8	0 to 24 (10), violent; die out from 19 hours, but increase slightly after opening door	Calm.
9	No tremors	Dull.
10	10 to 24, slight	Fog, calm.
11	22 to 24, "	" "
12	1 to 3, "	Heavy S. gale from 10 A.M.
12	3 to 10, "	—
12	10 to 24, max. 18 to 20 (5)	—
13	0 to 24, max. 9 to 22 (4)	Moderate N. wind.
14	No tremors	Fog, calm.
15	8 to 24, max. 18 (2)	Opening door at 21 increased the tremor. Dull, no wind.
16	0 to 8 (3 or 4)	At 8.45 door was closed and tremors are greatly reduced.
16	8 to 24 (1 or 2)	Rain.
17	0 to 24 (1)	Dull, fine.
18	0 to 24 (1)	Slight increase of tremors at night. Dull, drizzle.
19	0 to 24 (4 or 5)	Started by opening the door. Dull and calm.
20	4 to 24, max. 18 to 24 (2)	Calm, tremors reduced from 3 to almost zero by putting in wind guard.
	0 to 24 (2)	Period 2·8m. Fog, calm.
	0 to 24, no tremors	Fine, breeze.

TABLE II.—*continued.*

Date	—	Remarks
Dec.		
23	No tremors	Dull, S. wind.
24	23 to 24, slight	Rain, S.E. wind.
25	0 to 24 (2)	Period 2·8. Little snow.
26	0 to 8, slight	Drizzle.
26	8 to 24, no tremors	Dull, calm.
27	14 to 17, slight	,, ,,
28	No tremors	Dull, rain.
29	,,	Clock sent to be cleaned.
	1896.	
Jan.		
4	0 to 24 (·5), max. 18 to 20 (1)	Period 2·8m. Calm.
5	0 to 24 (·5 to 1), max. 15 to 24 (1·5)	Period regular, about 2·8m. Fog, calm.
6	0 to 24 (1)	Regular character.
7	0 to 24 (1)	,, ,,
8	18 to 24 (1)	,, ,,
9	0 to 24 (1)	,, ,,
10	0 to 18 (·5)	,, ,,
		From 5th to 10th no wind.
11	No tremors	Dull, calm.
12	,,	,, ,,
13	,,	Fine.
14	,,	Dull, calm.
15	,,	S.W. wind, sun, cloud.
16	,,	Dull, windy at night.
17	,,	Fine, calm.
18	,,	Dull, calm.
19	0 to 9, no tremors	,, ,,
19	9 to 24 (10), max. 13 to 24	Calm, drizzle.
20	0 to 24 (3)	Period 1·25m. to 2m. Fine, hard frost.
21	0 to 9 (2)	Dull, damp, calm.
21	9 to 10, no tremors	—
21	10 to 24 (1)	Regular.
22	8 to 22 (·5)	Dull, calm.
23	Occasionally very slight and regular	Calm, fog.
24	No tremors	Calm, but wind rising at night.
25	0 to 24, no tremors	S.W. wind all last night. Rain.
26	No tremors	Dull, calm.
27	,,	Drizzle.
28	0 to 5, no tremors	Fine. Frost at night.
28	5 to 24, max. all night (10)	—
29	0 to 24, max. at night (5)	Frosty, calm.
30	0 to 24 (3)	White frost, calm.
31	0 to 10 (1)	Dull, calm.
31	10 to 24 (2)	—
Feb.		
1	0 to 10, slight	Dull, calm.
1	10 to 24 (1)	—
2	0 to 6, slight	Calm, fine.
2	6 to 24, max. 10 to 16 (3)	—
3	0 to 17, no tremors	S.W. breeze, dull.
3	17 to 23, slight	—
4	0 to 11, no tremors	Dull, calm.
4	11 to 22 (1), max. 16 to 21	—
4	22 to 24, no tremors	—
5	0 to 24, no tremors	Dull, calm.
6	,, ,,	Wind in early morning, calm.

TABLE II.—*continued.*

Date	—	Remarks
Feb.		
7	0 to 13, no tremors	Dull, damp. At night S.W. breeze.
7	13 to 21, max. 19 (2)	—
8	0 to 24, no tremors	S.W. breeze, fine. At night heavy wind.
9	0 to 22, no tremors	Drizzle, calm.
9	22 to 24, slight	—
10	0 to 22, no tremors	Fog, calm.
10	22 to 23, small pulsations (·5)	Period 2·8m. to 5·6m.
11	0 to 10, no tremors	Fine, calm.
11	10 to 12, pulsations (1), which lead to tremors	Period 4·2m.
11	12 to 24, slow tremors (2)	—
12	Slight tremors at night	Fine, calm.
13	0 to 19, no tremors	Fog, calm.
13	19 to 24, tremors or pulsations (1)	—
14	0 to 16, no tremors	Dull, calm.
14	16 to 24, slow tremors, max. 22 to 23, (2)	—
15	0 to 18, no tremors	Fine, calm.
15	18 to 24, slow tremors (2)	—
16	0 to 6, slow tremors (2)	Period 2·8m. to 4·2m.; stop by opening door at 6·33, but in 1½ hour recommence.
16	6 to 7.30, no tremors	—
16	7.30 to 24, max. 19 (2)	Dull, damp.
17	0 to 2 (2)	Calm, dull, cold.
17	2 to 4, no tremors	—
17	4 to 24, max. 17 to 24 (2)	Period 1·4m. to 1·2m.
18	0 to 3 die out	Fog, calm.
18	3 to 24, no tremors	—
19	0 to 24, no tremors	Calm, sunshine, cloud.
20	0 to 24, no tremors, but a trace of tremors at 22	Dull, sea breeze.
21	0 to 24, no tremors, but a trace 21 to 24	Bright sunshine.
22	0 to 6, no tremors	Dull.
22	0 to 24 (increase up to 5)	Period at first 4·2m.
23	0 to 3, die out	Fine, frosty last night.
23	3 to 5, no tremors	—
23	5 to 24 (increase up to 3)	Period 1·4m. to 2·8m. Frosty at night.
24	0 to 1, die out	—
24	1 to 6, no tremors	—
24	6 to 24, max. 18 to 20 (2)	—
25	0 to 4, die out	Frosty last night.
25	4 to 5, no tremors	—
25	5 to 24, max. 17 to 24 (3)	—
26	0 to 8, die out	Cold, frosty, calm.
26	9 to 24, slight, max. 20 to 21 (1)	Slight pulsations in groups of 3 to 8 at intervals of 30 minutes.
27	0 to 24, no tremors	Fine, calm.
28	,, ,,	Fine, stormy, N.W. wind.
29	,, ,,	Dull, S. wind.
Mar.		
1	0 to 13, no tremors	Dull, S. wind.
1	13 to 24, slight	—
2	0 to 24, no tremors	Fine.
3	No record	Removed felt lining from box.

TABLE II.—*continued.*

Date	—	Remarks
Mar.		
4	0 to 24, max. 16 (1)	Stormy.
5	0 to 3, slight	Fine, breezy.
5	3 to 21, no tremors	—
5	21 to 24, slight	After opening door.
6	0 to 2, slight	Dull, S. wind.
6	3 to 24, no temors	—
7	0 to 24, no temors	Rain, calm.
8	,, ,,	Dull, W. wind.
9	0 to 14, no tremors	Dull, S.W. breeze.
9	14 to 24, max. 19 and 20 (5)	Heavy dew at night.
10	0 to 1, die out	Fine, calm.
10	1 to 8, no tremors	—
11	No tremors	Calm, dull.
12	7 to 24, max. 22 (5)	Drizzle.
13	0 to 4, die out	Calm.
13	4 to 12, no tremors	—
13	12 to 21, slight	—
14	0 to 13, no tremors	Calm, fog.
14	13 to 23, max. 22 (5)	—
14	23 and 24, no tremors	Hoar frost in morning.
15	0 to 24, no tremors	Calm, dull. From noon high wind.
16	0 to 16, no tremors	High wind.
16	16 to 21, slight and slow	—
16	21 to 24, no tremors	—
17	0 to 24, no tremors	Calm, drizzle.
18	0 to 3, no tremors	Rain, N. wind.
18	3 to 24, max. 18 to 23 (5)	Decrease by opening door. Heavy dew and frost.
19	0 to 1, die out	Calm, fine.
19	1 to 8, no tremors	—
19	23, slight	—
20	0 to 24, no tremors	High wind, rain.
21	0 to 24, no tremors	Rain, S. wind.
22	0 to 17, no tremors	Dull, calm.
22	17 to 21, slight, slow	—
22	21 to 24, no tremors	—
23	0 to 16, no tremors	Calm, fog.
23	16 to 22, slow max. 18–19 (2 or 3)	—
23	22 to 24, no tremors	—
24	0 to 17, no tremors	Calm, fog.
24	18 to 21, slow max. 18 to 19	Record like 23rd.
25	No record except 20 to 24, when tremors are 2 mm.	Calm, dull.
26	0 to 5, die out	Rain, breeze, high wind.
26	5 to 14, no tremors	—
26	14 to 24, max. 19 (3)	—
27	0 to 4, die out	Fine, N.W. breeze.
27	4 to 10, no tremors	—
27	10 t 24 max. 17 to 19 (3)	—

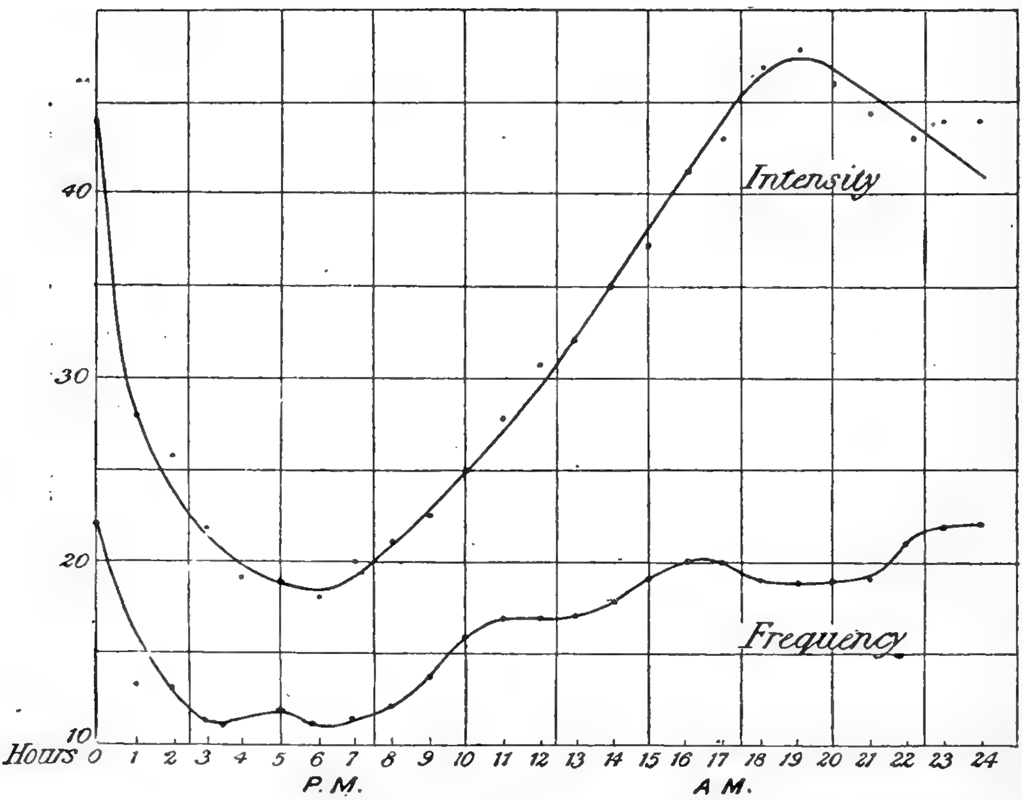
Relationship of Tremors to the Hours of Day and Night.

A general inspection of the preceding table leads to the conclusion that tremors have been more frequent and more intense during the night than during the day, and that they are especially marked during the early morning. To render this relationship more clear, tables have been made in which tremors for successive days have been placed under columns representing 24 hours, 12 hours being midnight. These tremors had values assigned to them equal in millimetres to the range of motion they exhibited on the photograms. By adding these columns up vertically a value was obtained for the period considered for each hour of the day and night. This value has been considered as proportional to the intensity of motion exhibited at various hours. By simply adding up the number of entries a set of numbers were obtained which may be regarded as proportional to the tremor frequency.

These two sets of numbers obtained for the months of November and December 1895, when plotted on squared paper, give the curves shown in fig. 8.

From these curves we see that for the period considered tremors have been least intense and least frequent between 3 P.M. and 7 P.M., but from

FIG. 8.—Tremors November and December 1895.



the latter hour there is a rapid increase in both these quantities. The intensity falls off rapidly from about 6 or 7 A.M., whilst the frequency commences to diminish about five hours later.

From these observations it would seem that the cause of tremors may possibly be found in operations which grow in intensity during the night. and which become gradually enfeebled during the day.

Tremors and Air Currents.

Inasmuch as the atmosphere may be calm, and the air inside an observatory may always be apparently quiescent, and yet an instrument not necessarily a horizontal pendulum, but an ordinary pendulum, a balance, and perhaps even a magnetometer, shows considerable motion within its case, the question arises whether there be not air currents existing within the cases which cover such instruments. With comparatively heavy horizontal pendulums in well ventilated cases in Japan tremors were always small and of rare occurrence, but with light pendulums in similar cases tremors of a pronounced character nearly always occurred between midnight and about six in the morning. With the *light* pendulum at Shide, beneath a fairly tight case, I found tremors, whether the inside of this was lined with thick felt, and the supporting pier covered with the same material, which kept the surroundings of the instrument at a fairly uniform temperature, or whether such coverings were removed. Covering those portions of the column which were inside the case with cement, and painting the surface of the same, did not destroy the intruders. Another experiment was to replace the large doors of the case with fine gauze, thus giving the instrument considerable ventilation ; but, as will be seen from the records (November 21–30), no great improvement was effected. By means of a very fine column of smoke from the spark at the end of a thin joss-stick, joints in the covering cases were tested for draughts. The column of smoke was also placed before a small hole usually closed by a cork, to see if there was any tendency in the air to enter or come out from the case, but no indication of the same was obtained.

One very marked observation was that a strong tremor storm would suddenly cease, or be at least greatly altered in its intensity, by opening the door of the case for one or two minutes.[1]

Although a sudden change of this last description has occurred without opening the doors, we have in this observation an indication that by some means or other, which do not seem to be effects due to differences in temperature in different parts of a case, air-currents are from time to time established within a case, the mechanical working of which can be more or less destroyed by simply opening the door of the case.

One cause of such currents may be due to the different rates at which aqueous vapour is absorbed or given off at different points within the covering, and if these are steady they may set up a steady set of long period displacements in a light pendulum.

By introducing a tray of calcium chloride inside the case, violent movements have resulted, which only ceased after the desiccating agent was removed.

These facts, coupled with the fact that tremors were apparently greatly reduced by surrounding the boom with a trough or wind-guard on three of its sides, lead to the conclusion that air-currents are from time to time generated within casings such as I have employed, which result in movements which are with difficulty separable from those which are attributed to motion of the supporting pier.

The fact that tremors occur when there is a slight fall in temperature outside the case, whilst the fall inside the same would be comparatively small, suggests the idea that at such times, although they have failed detection, there may be streams of air passing through the joints of the coverings. The unlikelihood of this is, however, referred to in the next section.

[1] In some instances, however, the opening of the door seems to have brought a tremor storm into existence.

Tremors in relation to Barometric Pressure, the Hygrometric State of the Atmosphere, Temperature, Frost, Dew, Wind, and Rain.

From November 18, 1895, a self-recording barometer, thermometer, and hygrometer of the Richard types were established at Shide. The two latter instruments usually stood upon the case covering the horizontal pendulum, but for one or two weeks they were placed inside the covering. The tremors have been written, with their magnitudes, on the diagrams showing changes in temperature. Although these changes, which are indicated in degrees Fahrenheit, have been within a period of twelve or twenty-four hours small, it must be remembered that the corresponding changes which have sometimes taken place outside the building may have been comparatively large. The following notes, in which T, B, and H respectively mean temperature, barometer, and hygrometer, are based upon an inspection of these records :—

1895.

Nov. 18–25 . . Tremors occur with falls of T, 55°–49°. B rising, 29·7–30·05 in., and H slightly fluctuating, 40·5–40·7.

Nov. 25–Dec. 2. Slight tremors, with falling T, which sometimes occurs during the day. B down to 29·4, and no tremors.

Dec. 2–9 . . . T falls 56°–40°, and strong tremors of 10 mm. B rising. H steady.

Dec. 16 . . . T at 48°, and tremors with falling T even during the day. B rising.

Dec. 16–23 . . T falls 48°–43°, and tremors. B rising.

Dec. 23–30 . . T falls to 43°, and tremors. B rising.

1896.

Jan. 6–13 . . T falls 50°–45°, but tremors are very slight. B very high.

Jan. 13–20 . . T falls 51°–45°, and heavy tremors of 10 mm.; but there are falls 50°–48° and no tremors. B 30·4. H steady.

Jan. 20–27 . . T 45° and fairly steady, with slight tremors, which, as usual, cease when it rises.

Jan. 27–Feb. 3. T falls 52°–43°, and heavy tremors. So long as it remains at 43° tremors are slight, but with the slightest fall, even to 42°, they recommence.

Feb. 3–10 . . T falls very slightly during the early morning on the 4th and 7th, and there are slight tremors. Whilst T is steady, even if it is low, there are no tremors; also no tremors when rising. B high. H fluctuates, but not at the time of the tremors.

Feb. 10–17 . . Slight tremors, with slight falls of T. B high. There are tremors with three falls of H.

Feb. 17–24 . . Tremors with three falls of T, commencing at 48°. A rapid fall of T on the 22nd was accompanied with heavy tremors. B high. H shows decided fluctuations, but at the times of no tremors.

Feb. 24–Mar. 2. T falls from 45°–40°, and tremors. B high. H has fluctuations, but these occur with or without tremors.

Mar. 2–9 . . . Tremors with T at 48°. A large B wave, 28·7–30·0, but no tremors. H fluctuating.

Mar. 9–16 . . T falls, 58°–53° and 53°–45°, and tremors. B high. H steady.

Mar. 16–23 . . T falls, 54°–52° and 54°–49°, and tremors. B moving steadily down and up, 29·5 to 30·0. H shows three waves, but not with tremors.

Mar. 23–30 . . Six cases of tremors with slight falls of T, and the lower T the greater the tremors. H very irregular. The tremors are most when the air is dryest. B shows several moderately rapid changes, and the tremors chiefly occur with the falls.

The conclusions which may be derived from these notes are :—

1. There does not appear to be any relationship between the indications of the hygrometer and tremors. When the door of the observing room was often left open during the day, at such times the hygrometer

would indicate considerable changes, which are the times at which tremors are least frequent.

2. Tremors have occurred when the barometer has been high, low, rising or falling. These observations, however, do not throw any light upon the connection which may exist between the appearance of tremors and the state of the barometric gradient.

3. Tremors nearly always appear when the temperature is falling, and therefore are frequent at night. When the temperature is steady or rising, tremors have been but seldom observed.

The observation that tremors accompany a falling thermometer receives strong confirmation that they have been markedly large on frosty nights, and that these sometimes have continued whilst the morning sun has been thawing the frozen surface of the ground. Such coincidences occurred on January 20, 28, 29, 30, 31, February 22, 23, 24, 25, March 14 and 18.

The only exceptions to this rule appear on November 25, January 14 and 15, on which occasions the fall in temperature was from 50° to 49° and 48°, which, it may be remarked, are only small changes.

From January 20 to 22 tremors were pronounced, whilst the temperature was steady at about 45°. Although there was this approximately constant temperature in the room, and a temperature yet more constant within the case, on the night of the 20th there was a hard frost, and possibly frost on the other nights. For each of these days it may therefore be assumed that between the day and night, outside the building, the change in temperature was great. The large differences in temperature between the outside and inside of the building no doubt resulted in the establishment of air-currents through a broken pane of glass and other air passages, but, as these do not appear to have disturbed the inside temperature, such air-currents must have been small. Rather, therefore, than looking to such currents as being the cause of the movements of the pendulum, it seems more reasonable to suppose them due to expansions and contractions which were taking place in the ground outside.

Tremors have also occurred on nights which have been accompanied with heavy dew, as, for example, on March 9. This may possibly mean that when large quantities of aqueous vapour are escaping from the ground, as evidenced by copious condensation on its chilled surface, contractions or expansions may be taking place in the same.

My note-book also shows, as it has repeatedly shown in previous years, that tremors have been marked or entirely absent with heavy winds from different directions and at the time of calms.

A long drought followed by heavy rain has been followed by slight tremors.

The conclusions that are arrived at respecting the cause of tremors are yet wanting in certitude.

It is probable that naturally produced elastic tremors with a high frequency have an existence in localities remote from earthquake centres, but this has not yet been demonstrated. The only records bearing upon such an investigation are a few taken at Shide. These are referred to when describing the Perry Tromometer.

The long-continued movements which are so often observed with *light* horizontal pendulums are probably due to the same causes which produce movements in ordinary pendulums, delicate balances, and, as the Rev. W. Sidgreaves tells us, in suspended magnets beneath *air-tight* covers at Kew and Stonyhurst.

As the result of many observations, I venture to suggest that the causes of the so-called 'earth tremors' are twofold :—

1. Air-currents within the cases. Such currents are produced by a cold current of air impinging upon the outside of covers like glass or thin metal, but they are not likely to be produced if the covering is made of thick wood lined with thick felt. They may be produced by an inflow or outflow of air through ill-fitting joints, but what is more likely, as experiment has shown, by a difference in the rate at which moisture is condensed, absorbed, or given off at different points within a cover.

2. By movements in the superficial soil outside the building in which the instrument is installed. These movements take place in soil whilst it is freezing or thawing, and after a heavy shower on dry ground. They may also be produced at the time when there are rapid but small changes in barometric pressure over an area the different portions of which vary in their elasticity and resilience.

Although these suggestions partially destroy the value of many records of 'earth' tremors, they nevertheless leave us confronted with phenomena which it is the interest of all who have to work with instruments having delicate suspensions to understand more clearly, especially, perhaps, the reason that their frequency is so marked at particular hours and seasons.

Diurnal Wave and Wandering of the Pendulum.

On May 24, 1896, a drum moving a bromide film at a rate of about 75 mm. in twenty-four hours was placed beneath pendulum T, and records were taken until June 15. The sensibility of the instrument was such that 1 mm. deflection indicated a tilt of 0″·56.

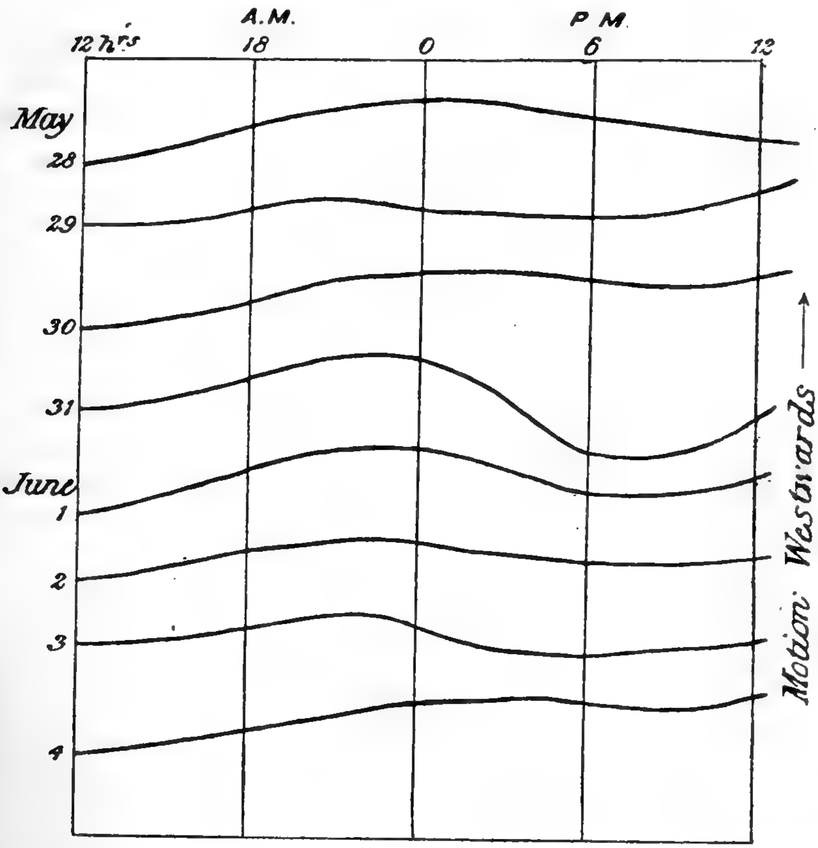
The records yield the following results :—

Date	Farthest East	Farthest West	Range of motion	Difference in Temperature	Remarks
	H.	H.	″	F	
May 24	8	18	1·12	5°	Rain last night
,, 25				5	Wave slight. Fine, cloudy, N. wind
,, 26				3	,, ,, Dull, S. wind
,, 27		24	1·12	7	Fine, E. wind
,, 28	8	24	3·92	6	Fine, N.W. wind
,, 29		3		7	Fair
	12	21	1·12		
,, 30	8	24	2·80	3	Dull, S.W. wind
,, 31	8	22	4·48	4	Fine, E. wind
June 1	8	22	3·36	8	Fine
,, 2		3		7	
	7	19–24	1·68		
,, 3	6	18–24	2·24	5	Fine
,, 4	6–7	24	1·68	6	Fine
,, 5	6–7	22	2·24	3	Dull, W. wind
,, 6	6–7	22		5	Wave slight. Fine rain, W. wind
,, 7		24		2	,, ,, Rain
,, 8				4	,, practically straight. Fine
,, 9				4	,, ,, ,, Dull, S. wind
,, 10				2	,, ,, ,, Drizzle
,, 11				3	,, ,, ,, ,,
,, 12		22		5	Fine
,, 13		22		7	Dull

The differences in temperature which are in degrees Fahrenheit are those recorded in the instrument room between about 8 A.M. and 2 P.M.

Fig. 9 shows tracings from the photograms of diurnal waves observed at Shide. The range of motion has varied between 1″ and 5″. Usually the Western motion ceased about 10 A.M., from which hour the pendulum moved eastwards until about 7 or 8 P.M. The motion from 10 A.M. or noon is therefore similar to that which would accompany a decrease in the steepness of the open bare down on the eastern side of the pendulum, or a rising of the tree and grass covered valley on its western side. The fact that the movements were usually pronounced on bright fine days, and but

FIG. 9.—Diurnal Wave at Shide.



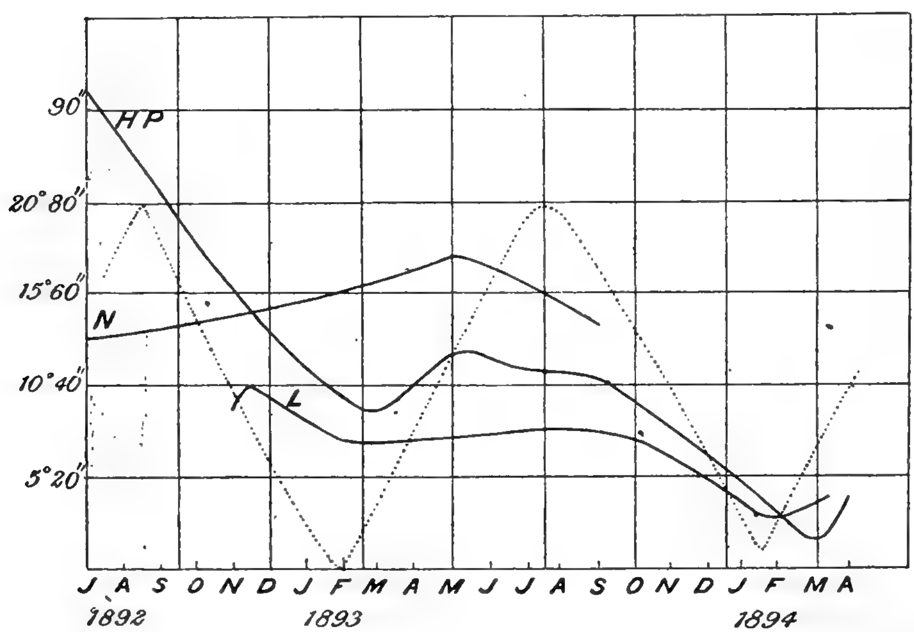
feeble or absent when it was dull or wet, suggests the idea that the observed movements may have been the result of the removal by evaporation of different loads from the two sides of the station. The amplitude of the daily wave is far from being proportional to the daily range of temperature observed near to the instrument.

From May 24 to June 7 the pendulum gradually moved westwards, and during this time the maximum temperature gradually rose from 60° to 70°, that is to say, the direction of motion has been the same as that which takes place whilst the temperature is rising during the day. The creeping of the pendulum between the above two dates is in such a direction that it might be attributed to the removal of a larger load from the hill side of the instrument than from the valley side.

Between June 6 and 7 the maximum temperature fell to 65°, from which it rose to 68° on the 11th. During this time, however, the pendulum crept eastwards, or in the opposite direction to that in which, under similar conditions, it had been previously moving. From June 11 to 13 the temperature rose from 65° to 72°, whilst the pendulum remained stationary.

What these observations show for a period of only twenty-one days is true for longer periods, as observed in Japan, and generally agrees with the observations made at Strassburg, described by the late Dr. E. von Rebeur-Paschwitz. At this latter place, for a period of nineteen months, the character of the curve of wandering is similar to that for a curve of temperature; but when we observe, as this author points out, that the minimum of temperature is reached from $1\frac{1}{2}$ to 2 months *before* a minimum in the curve, showing the displacement in the pendulum, whilst its maximum is reached about four months *later*, the relationship between the two becomes obscured. This and other results obtained at Strassburg are shown in fig. 10, reduced from the observations of von Rebeur.

FIG. 10.



In this diagram the temperature curve taken in the cellar where the pendulum was installed is shown in dots. H P is the horizontal pendulum curve, L a curve from level observations, and N a Nadir curve. An increase in reading indicates a movement towards the north. Although, these three sets of observations were made with instruments near to each other, the difference of the Nadir curve from the other two is very striking. The amounts of change are also noticeable, the horizontal pendulum having been tilted towards the south through 87″, and if we take it from the commencement of the observations in April, 1892, this is increased to 143″.

III. *Changes in the Vertical observed in Tokio, September* 19, 1894, *to March* 1, 1896.

Pendulum L.—On September 19, 1894, pendulum L, which has a boom about 5 feet in length, was installed beneath a wooden case on the concrete floor of a cellar in the N.W. corner of the College of Engineering at the Imperial University of Japan, in Tokio. When set up it had a period of about twenty-eight seconds, and 1 mm. deflection at the end of the boom which is in the meridian corresponds to an angular tilt of about 0″·5. The doubt expressed regarding the value of the readings of this instrument arises from the fact that the notes relating to its calibration were lost by fire. When the readings increase in value the pendulum is swinging towards the west, which means that the ground may have been raised upon its eastern side. The diurnal motions of this instrument were small, not exceeding 1 or 2 mm. For several days readings taken about 9 A.M. have been identical, after which there would be noted a displacement of 1 or more mm. For the first nine months these apparently sudden displacements were towards the east. This was followed by three months of westerly motion, and then three months more of displacements towards the east. For the remaining three months, although the general direction of motion is westwards, it has been somewhat erratic in character.

The readings given in the following table are in millimetres, and the date for any reading is the day on which there was a change from the reading which precedes it.

Date	Deflection	Date	Deflection
1894, September	100 to 101	1895, August 1	79
October 1	95	„ 7	80
„ 9	96	„ 11	81
„ 18	95	„ 23	82
„ 24	96	September 8	81
„ 31	95	„ 10	80
November 24	102	„ 15	79
„ 27	100	„ 25	75
„ 30	97	October 14	73
December 3	95	„ 17	74
„ 20	97	„ 19	70
1895, January 20	89	„ 20	66
February 18	88	„ 23	64
March 10	86	„ 26	63
„ 25	85	November 1	60
April 3	84	„ 24	59
„ 30	83	December 8	64
May 6	76	„ 16	63
„ 8	75	„ 24	64
June 11	68	1896, January 10	61
„ 19	69	„ 19	60
July 5	70	„ 27	71
„ 10	73	February 9	67
„ 14	74	„ 13	69
„ 18	76	„ 16	70
„ 27	78	„ 23	68
		„ 29	66

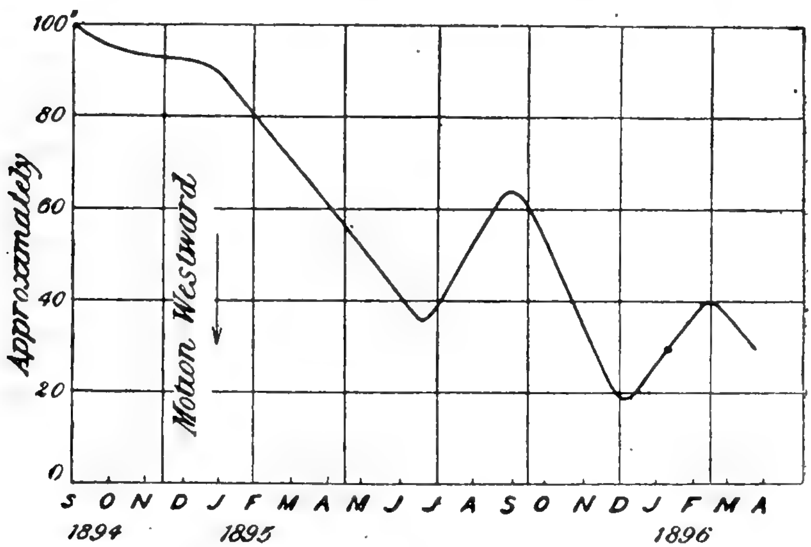
A fact of some importance connected with these displacements is that very many of them took place at the time of earthquakes which were sensible, and most of these small jumps were in the general direction in which the pendulum was suffering displacement. My late colleague, Mr. C. D. West, who from time to time has sent me these readings which are taken by one of the college servants, tells me that the displacement of January 26–27, 1896, cannot be accounted for, but the readings generally follow the seasonal changes in temperature—a conclusion which is at least true for 1895. Fig. 11.

With the assumed values for the readings the approximate changes in the vertical have been as follows :—

	″		
September, 1894, to June 11, 1895 . .	16·0	East side	sinking
June 11, 1895, to August 23, 1895 . .	7·0	,,	rising
August 23, 1895, to November 24, 1895 .	11·0	,,	sinking
November 24, 1895, to January 27, 1896 .	6·0	,,	rising
January 27, 1896, to February 29, 1896 .	2·5	,,	sinking
Total change during whole period . .	17·0	,,	sinking

This long-continued creeping in one direction is common to observations made by Plantamour and others who have made like investigations.

FIG. 11.—Change in Level observed in Tokio.



IV. *Experiments with a Horizontal Pendulum at the Oxford University Observatory*, 1896, *May* 5. *Drawn up by* Professor H. H. TURNER.

1. During the morning Professor Milne set up his horizontal pendulum, which is similar to the one at Shide, on the slate slab in the Students' Observatory. The level of the transit circle was set up on the same slab near the H.P., and watched throughout by Captain E. H. Hills, R.E. This slab rested on a hollow foundation of bricks about 10 inches in height, which in turn rested upon a bed of concrete a few inches in thickness, and common to the whole building. Beneath the concrete there is a natural bed of gravel a few inches in thickness. Because the horizontal pendulum, which pointed from E. to W., stood on the slab near to its edge, it was to be expected that a load on the south side at a distance of, say, 3 feet would produce a greater effect than the same load would produce when moved to the north side, where it would be distant 7 or 8 feet.

The value of one division of the level may be taken=1″·0.

The changes of level N. and S. were observed.

2. The crowd collected at 12.15–12.20 : 76 men in all. Four companies of 18 each (with commanders=19) were formed by Mr. G. C. Bourne. These were halted with front rank 90 feet from observatory. (Pos. I.)

Then marched up, two rear companies taken over fence and brought up inside : front rank 5 feet from N. side of building=10 feet from slab. (Pos. II.)

Then retired to 90 feet. (Pos. III.)

Then marched up again 'closer' ; the two front companies came close up to building ; front rank thus about 5 feet from slab : other ranks say 7, 9, and 11 feet from slab. (Pos. IV.)

Then away again. (Pos. V.)

Then marched up *in open order*, viz. : Each man two arm's lengths away : say at 5 feet apart. Front rank still close to hut, *i.e.* 5 feet from slab ; 2nd rank, 10 feet ; 3rd, 15 feet ; 4th, 20, &c., to 8th, at 40 feet from slab. (Pos. VI.)

Then away again. (Pos. VII.)

Then in more open order, say 10 feet apart :
Front rank 10 feet away : . . .
2nd „ 20 „ . . . .
3rd „ 30 „ . . . .
8th „ 80 „ . . . .
} (Pos. VIII.)

Then away. (Pos. IX.)

Then *on the south side* : In close order, front rank 5 feet away, next $6\frac{1}{2}$ say, &c. (Pos. X.)

Then away=Pos. XI.

A few experiments were made inside the observatory with loads of one or three men standing on the board floor within 3 or 7 feet of the instruments.

The results obtained were as follows :—

Result of Loads outside the Observatory.

Time	Position	Approximate Distance from Slab: Front Rank	Approximate Distance from Slab: Rear Rank	Order	Side N. or S.	Horizontal Pendulum	Level (Mean of 2 ends)	Taking the difference between any reading and the readings before and after mean: Effect H.P.	Effect Level	Mean of 2
		FT.	FT.				″		″	″
12.20	O.	—	—	—	—	—	15·20			
12.25	O.	—	—	—	—	49·5	15·60			
12.27 to 12.28	I.	90	102	close	N.	49·5	16·00	″		
12.29 to 12.31	II.	10	22	„	N.	50·5	15·70	+1·25=+0·42	+0·25	+0·34
12.32 to 12.34	III.	90	102	„	N.	49·0	15·90			
12.35 to 12.37	IV.	5	22	„	N.	50·0	15·10	+1·50=+0·50	+0·73	+0·62
12.38 to 12.40	V.	90	102	„	N.	48·0	15·75			
12.41 to 12.43	VI.	5	40	open	N.	48·0 afterwards	15·35	0·00=0·00	+0·32	+0·16
12.44 to 12.46	VII.	90	102	„	N.	47·0	15·60			
12.47 to 12.48	VIII.	10	80	very open	N.	47·0	15·15	+0·50=0·17	0·00	+0·08
12.49 to 12.50	IX.	90	102	„	N. & S.	46·0 afterwards 45·25	14·50			
12.54 to 12.55	X.	5	15	close	S.	44·25	15·65	−1·13=−0·38	−0·65	−0·52
12.56 to 12.57	XI.	90	102	„	S.	45·5	15·50			

For load approaching on N. side readings of H.P. increase.—Level decrease.
„ „ S. „ „ decrease.—Level increase.
One division of the horizontal pendulum=0″. 33.

3. Experiments *inside* the hut, within 3 feet S. side and 7 feet N. side of the instrument.

Effect of 240 lb. Zero 59.

On North side,	Reading	60·5.	Effect	$1·5=0''·49$
„ South „	„	54·5.	„	$4·5=1''·48$
„ North „	„	60·5.	„	$1·5=0''·49$

Effect of 570 lb. Zero 59.

On South side,	Reading	50.	Effect	$9=2''·97$
„ North „	„	66.	„	$7=2''·31$

4. Experiment with load outside the hut within 5 feet on S. side and 5 feet on N. side.

Effect of 570 lb. Zero 56.

On South side,	Reading	55.	Effect	$1=0''·33$
„ North „	„	55.	„	$0=0$

This last reading is unsatisfactory. Five minutes later it became 55·5, but if the north side load showed an effect it ought to have exceeded 56.

In the afternoon a few experiments were made in the main building of the Observatory. The horizontal pendulum was placed on the top of a massive pier whilst two boys and a man (almost 350 lb.) stationed themselves in the basement of the building, first on the east side and then on the west side of the same. The difference in readings given by the two positions was approximately $0''·16$.

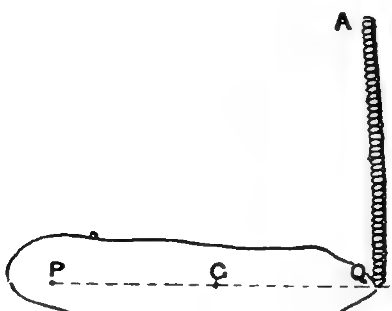
V. *The Perry Tromometer.* *By* Professor JOHN PERRY, *F.R.S.*

What is interesting about the apparatus is this, that any periodic motion of the supports is faithfully indicated by the pointer if its frequency is several times the natural frequency of vibration when its supports are at rest.

One body supported on a pivot with three Ayrton-Perry springs will record the vertical and two horizontal motions.

A body P G Q is free to move about an axis P at right angles to the paper. G is its centre of gravity. An Ayrton-Perry spring is applied

FIG. 12.



vertically at Q from the point A. Weight of body is W. Vertical force at P is P, force at Q is Q. Let P and A get a vertical displacement x_1 downward, and let Q be displaced x downward. Let $Q=Q_0+c(x-x_1)$ where c represents the constant of the spring. Then forming the equations of motion we find, neglecting friction

$$x+n^2x=ex_1+n^2x_1 \quad . \quad . \quad . \quad . \quad (1)$$

Where $\frac{c(a+b)^2}{M(k^2+a^2)}$ is called n^2 so that n divided by 2π is the frequency of the natural vibration of Q.

$$\frac{k^2-ab}{k^2+a^2} \text{ is called } e.$$

The distance PG is called a, and GQ is b, M is the mass of the body and k its radius of gyration about G.

Assuming that friction will destroy the natural vibrations at Q, but neglecting the easily expressed friction term of (1), the forced vibration is easy to find. If an observer moves with P and A, he observes, not x, but $x-x_1$. Let $y=x-x_1$. Then if $x_1=h \sin qt$,

$$y=-h\frac{a(a+b)}{k^2+a^2}\frac{q^2}{q^2-n^2}\sin qt.$$

Now if we arrange that n is, say, less than one-fifth of q [that is, that the natural frequency of Q is less than one-fifth of the frequency of A and P] we may say that the motion y which is observed is a faithful imitation of any periodic motion of P and A; or, letting $a+b$ or PQ be called l and $k^2+a^2=k_1^2$, the square of the radius of gyration about P, $y=-\frac{al}{k_1^2}x_1$.

A magnifying pointer on the spring enables this motion to be observed.

It is obvious that the motion may be in a horizontal plane instead of a vertical.

Note. *By* Professor John Milne.

A form of Perry Tromometer as experimented with at Shide consists of a horizontal beam free to oscillate upon a knife edge. This beam is heavily loaded by two unequal masses which to obtain a balance are placed at different distances from the knife edge. Attached to one of these masses and running vertically upwards is a light A.P. spring, the top end of which is held by a fixed support. To show the movements of the spring which coils or uncoils with vertical vibratory motion, a very light pointer, or a small mirror from which a beam of light is reflected, is attached to the same. One photogram representing a period of twenty-four hours has been obtained by this instrument at Shide. This shows that during nearly the whole of the day the mirror is in motion, and the fact that this motion is due to passing carts, carriages at a distance of several hundred yards, and trains at a distance of about a mile speedily led to the conclusion that an instrument so extremely sensitive to rapid elastic motion could not be used at Shide. One interesting observation was that, at the time of the funeral of Prince Henry of Battenberg, when minute guns were being fired on ship-board at a distance of about five miles, each sound wave was accompanied by the sudden displacement of the spot of light through a distance of about one foot. It did not seem that vibrations came from their origin through the ground to disturb the instrument, but as sound waves through the air, which shook the building and the foundation on which the instrument rested.

If an instrument of this description could be installed at a locality where we can assure ourselves that its movements could only be due to natural causes, it seems likely that we should add to our records of the movements of the earth's crust forms of vibration which horizontal pendulums and seismographs are incapable of recording.

VI. *Earthquake Frequency.* (*Extract from a letter written by* Dr. C. G. Knott.)

In my paper on Earthquake Frequency ('Trans. Seis. Soc. Japan,' vol. ix. 1884), in which, probably for the first time, a sound mathematical treatment of periodicity was insisted upon, various possible causes of periodicity in earthquake frequency were considered. Next to the solar annual and diurnal periods, the most important are the lunar monthly, fortnightly, and daily periods. From lack of completeness of information at that time, it was impossible to search for these. But the great eight years' list of 8,331 Japanese earthquakes, prepared recently by Professor Milne, seemed eminently suitable for harmonic treatment. Other necessary work has prevented me getting the investigation carried out so quickly as I had wished, but enough has been done to show the probable results in certain directions.

The idea is that the tidal stresses due to the moon influence the periodicity. The lunar day gives a periodic tidal stress of comparatively short period; the *anomalistic* month (from apogee to apogee) and the *nodical* month (from ascending node to ascending node), give periodic tidal stresses of long period.

Tabulating the earthquakes according to the number of days each has happened after apogee, or after ascending node, we get two statistical tables of monthly means, one nearly 100 months. The anomalistic month is longer than the nodical month by almost exactly one-third of a day—in the hundred months, therefore, one will have gained upon the other by thirty days, or fully one month. The curves obtained, when created by harmonic analysis, give monthly, fortnightly, and weekly periods; but the fortnightly is more marked in the nodical curve than in the anomalistic.

In discussing the daily lunar period, we must take account of the *districts* in which the earthquakes occur, for only in this way can we compare their times of occurrence with the time of meridian passage, or the time of high water. In the case of the Tokio and Yokohama district, there is evidence of a half daily period; but the investigation is still far from complete.

VII. *Instruments used in Italy.* *By* Dr. C. Davison.

In the following pages a description is given of a few of the principal instruments used in Italy for the registration of pulsations proceeding from more or less distant origins.

Many of the instruments erected in that country are long vertical pendulums, the movements of which are magnified and registered in different ways. The length is made as great as circumstances will allow, so that for rapid vibrations the bob may be practically a steady point, and the bob is made as heavy as possible, so as to lessen the friction introduced by the mechanical registration. Those who have used these pendulums claim that they possess the following advantages over the horizontal pendulum and other instruments designed for photographic registration.

1. They are much less expensive to work; the cost of the paper on

which the records are made being only about a franc or a franc and a half a month.

2. Any person can superintend and adjust them easily.

3. They are not subject to the displacement of the zero-line.

4. Owing to the great velocity which can be given to the paper, the epoch of the different phases of the movement can be determined with great accuracy.

5. They allow all the minute details of the movement to be studied.

It is obvious that these, especially the two last, are great advantages. On the other hand, the long pendulums are subject to several objections as compared with the horizontal and bifilar pendulums.

1. Owing to their great length (Professor Riccò's seismometrograph at Catania is 26 metres long), they are difficult to install, and indeed require a building almost specially constructed for the purpose.

2. They are much less delicate than the horizontal and bifilar pendulums.

3. The latter are also adapted for other purposes—*e.g.*, investigating the bending of the ground by barometric and tidal loading—and this will facilitate their adoption at astronomical observatories, where, from the ease with which the exact time can be ascertained, it is most desirable that they should be established.

The instruments I propose to describe are: (1) Professor G. Vicentini's microseismograph; (2) Dr. G. Agamennone's seismometrograph, (3) Dr. A. Cancani's seismometrograph, and (4) Professor G. Grablovitz's geodynamic levels. It will be seen that the first of these is more or less free from the above-named objections.

Professor G. Vicentini's Microseismograph.—An account of this instrument and the results which have so far been obtained with it is given in the following papers:

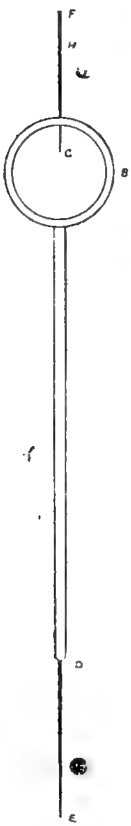
1. G. Vicentini: Osservazioni e proposte sullo studio dei movimenti microsismici: 'Atti della R. Accad. dei Fisiocritici' (Siena), vol. v. 1894.
2. G. Vicentini: Osservazioni sismiche (two papers): *Ibid.*
3. G. Vicentini: Movimenti sismici registrati dal microsismografo nella prima metà del luglio 1894: *Ibid.*
4. M. Cinelli: Sulle registrazioni del microsismografo Vicentini avute a Siena del 15 luglio al 31 ottobre 1894: *Ibid.*
5. G. Vicentini: Microsismografo a registrazione continua: Cenno sui movimenti sismici dei giorni 14 e 15 aprile 1895: 'Bull. della Soc. Veneto-Trentina di Scienze Naturali' (Padova), vol. vi. 1895, pp. 5–12.
6. G. Vicentini: Microsismografo a registrazione continua: 'Boll. della Soc. Sismol. Ital.,' vol. i. 1895, pp. 66–72.
7. G. Vicentini: Intorno ad alcuni fatti risultanti da osservazioni microsismiche: 'Atti e Mem. della R. Accad di Scienze, &c., in Padova,' vol. xii. 1896, pp. 89–97.
8. G. Vicentini and G. Pacher: Considerazioni sugli apparecchi sismici registratori e modificazione del microsismografo a due componenti: 'Atti del R. Ist. Veneto di Scienze,' &c., vol. vii. 1896, pp. 385–399.
9. G. Vicentini: Fenomeni sismici osservati a Padova dal febbraio al settembre 1895 col microsismografo a due componenti: 'Atti della Soc. Veneto-Trentina di Scienze Naturali' (Padova), vol. iii. 1896, pp. 3–63.

Some further details with regard to the construction of the instrument are taken from two letters written by Professor Vicentini to Professor Milne.

Professor Vicentini was led to design this instrument owing, he says, to the difficulty of obtaining good photographic registration, the inconvenience of working in the dark, and of using an apparatus which does not give its record until the sensitive paper is developed, and to the great expense of the photographic paper, the chemical reagents, and the source of light.

His first experiments were made with an ordinary tromometer, about 1·50 metre long, and with a bob 50 kg. in weight. The support of the pendulum was fixed in a wall of the University buildings of Siena, overlooking a much frequented road, on the third floor, and about 20 metres above the ground. A short straw, terminating in a fine steel wire, was attached to the bottom of the bob, and the movements of the point of the wire were observed by means of a totally-reflecting prism and microscope provided with a micrometer. A tromometer of this kind does not give at any instant the true state of vibration of the ground, its movements being affected by previous disturbances. But if the pendulum be obliged to perform a very little work, such as the movement of the light vertical lever described below (fig. 13), the bob is rendered much more insensible to the rapid vibrations of the point of suspension. Substituting this lever for the straw referred to above, the movements of the lower end were observed with the microscope. The superiority of this arrangement is very evident. When a carriage, for instance, approaches from a distance, the point of the lever at first vibrates parallel to the wall, then in a plane more and more inclined to it, until, when the carriage is just opposite the building, the vibrations are performed normally to the wall and are synchronous with the trampling of the horses. When the vibration of the ground ceases, the movement of the lever ceases contemporaneously. Thus, by the application of this vertical lever, the bob of the pendulum is transformed almost into a steady mass, and its steadiness during movements of the ground is further promoted by the addition of the two horizontal levers which give the component movements in two directions at right angles to one another.

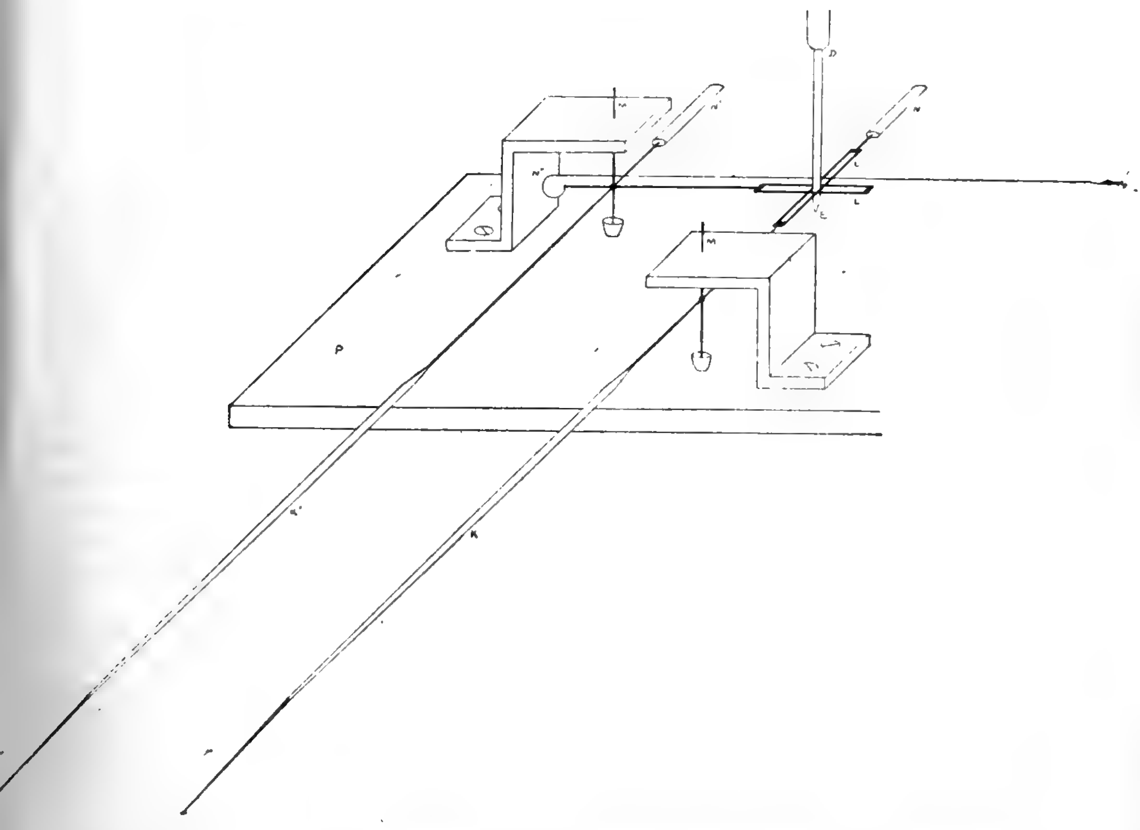
FIG. 13.



In the complete microseismograph erected in the University of Siena, the bob of the pendulum weighs 50 kg., and is supported by three chains, united at their upper ends in a brass cap, to which is attached an iron wire about 2 mm. in diameter. This is fastened to a screw in a strong iron bracket driven into the wall. The length of the pendulum is about 1·50 metre. By means of the screw the bob can be raised or lowered. Immediately below the latter are fixed two iron bars to support it, and prevent damage to the registering apparatus in case the suspending wire or chains should break. The bob is also surrounded by an iron ring carrying three screws, whose office is to prevent excessive displacements of the pendulum. When the pendulum is connected with the recording levers it performs complete oscillations in 2·4 seconds.

Fig. 13 shows the vertical amplifying lever referred to above. It consists of a thin tube of aluminium A, soldered at its upper end to a ring B of the same metal. To its lower end is fixed a sewing-needle, DE, whose cylindrical part has a diameter of 0·6 mm. The ring B is traversed at its highest point by a second needle, FG, exactly similar to the first. Its point, G, penetrating a short way inside the ring, rests in a small glass cup carried by a support fixed to the wall. The position of the cup can be adjusted by screws, both horizontally and vertically. The base of the bob is slightly conical, and in its centre a hole is made, covered by a sheet of brass, in which a small hole with bevelled edges is made which clasps the needle, FG, at the point H. By means of the adjusting screws fitted to the glass cup, the points G and E of the needles are placed as nearly as possible in a vertical line below the centre of gravity of the bob. So long as the bob remains steady the point H is the fulcrum of the lever, and the movements of the wall are magnified at the end E in the ratio

FIG. 14.



EH to GH. The total weight of this lever is 2·2 grammes ; its length is 144 mm., and the ratio EH to GH is equal to 16. The friction at both the points G and H is extremely small.

The movements of the lower end of the vertical lever are magnified by two light horizontal levers (fig. 14), which give the components of its motion in directions at right angles to one another. It should be mentioned that this figure is not drawn exactly to scale, and illustrates the slightly different arrangement in a new microseismograph recently erected at Padua.

One of the levers, K, is rectilinear, and the other, K′, bent at right angles. In the Siena instrument they are made of thin aluminium plate, terminating, at the ends L and L′, in two very thin burnished steel needles, parallel to one another, and separated by a distance equal to the thickness of the needle, DE, of the vertical lever. The vertical axis, M, consists of a fine steel needle, the lower point of which rests in the conical cavity of a small glass cup fixed to the plate, P. The axis, M′, is exactly similar, but the lower end rests in a glass cup, whose height above the plate, P, can be adjusted by a screw. The levers are provided with counterpoises, N, N′, N″. The needle, DE, of the vertical lever passes through the slits, L, L′, and thus any displacement of the end, E, is decomposed by the horizontal levers into two components at right angles to one another.

At the free ends of the aluminium arms of the levers, fibres of glass are fixed at right angles to them with melted wax. In the apparatus afterwards erected at Padua (to which fig. 14 refers), these glass fibres are replaced by broad but thin strips of glass, the terminal parts being drawn out as fibres.

In the horizontal levers the length of the long arm is about five times that of the short arm; the movements of the wall supporting the apparatus are therefore magnified about eighty times.

The smoked paper on which the records are made is a continuous strip, and is driven by a drum which revolves by clockwork. The drum is placed so that the pens rest on its highest horizontal generator, and the fibres are made of such thickness and length that, with the slight friction to be overcome, they do not bend. To diminish their friction they are fused at the tip; the smooth surface of a very small sphere of glass thus slides on the smoked paper. To equalise the friction of the two pens, that of the pen K is first regulated by raising or lowering the support on which the plate P rests by means of the levelling screws with which it is provided. The contact of the other pen is then adjusted by moving the glass cup on which the axis M′ rests. The clock which drives the drum may be of any kind, but, in order to measure the time, a chronograph is connected with a good pendulum clock which closes an electric circuit, and thus causes a stroke to be made on the paper every minute. At each hour a double mark is made.

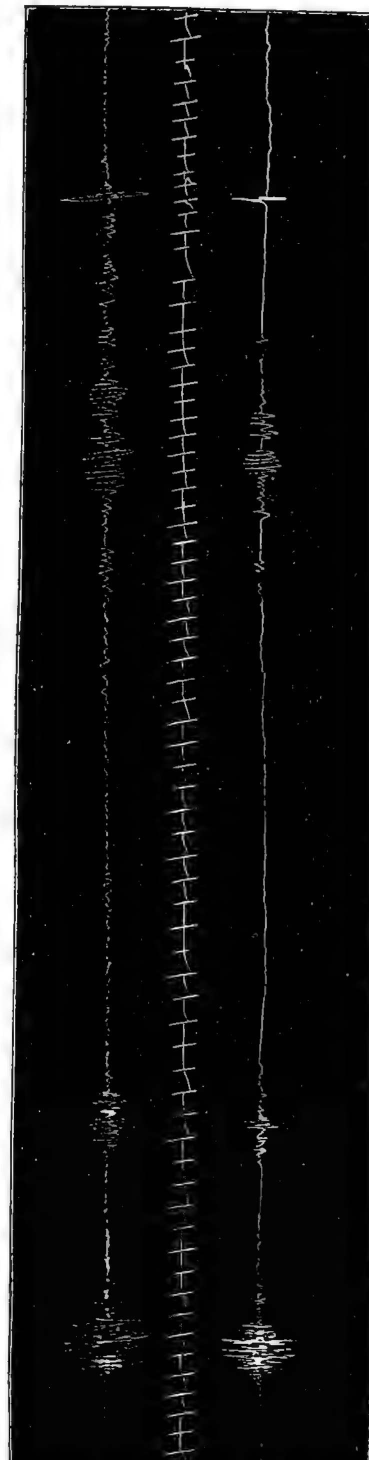
The strip of paper is unrolled at the rate of about 2 mm. a minute. The pens leave on the paper a fine but very clear trace. When heavy carts pass by the University buildings the lines are simply widened, the lampblack being completely carried away. In the case of earthquake movements, however, the separate oscillations are clearly perceptible, though the more rapid ones are only to be seen with the aid of a lens. Fig. 15 reproduces the diagram obtained at Siena of the Japanese earthquake of March 22, 1894. The toothed line in the middle shows the strokes which mark consecutive minutes. This figure may be compared with the record of the same earthquake obtained by means of the horizontal pendulum at Nicolaiew.[1]

Beside the microseismograph above described, Professor Vicentini has recently erected a new instrument at Padua, designed, not for obtaining the times of the different phases of a disturbance, but for determining with greater exactness the direction in which the movement takes place. The mass of the new pendulum is 100 kg., and its length 3·36 metres. It contains a vertical amplifying lever, like the first instrument, but for the horizontal levers a small pantagraph was substituted at Dr. Pacher's suggestion. This is made of aluminium tubes, weighs about eight deci-

[1] See *Brit. Assoc. Rep.*, 1894, p. 156.

grammes, and magnifies five times the displacements of the lower end of the vertical lever. The rate of the smoked paper is increased to about 15 mm. a minute, a velocity which enables the pendular oscillations to be distinctly traced.

Fig. 15.



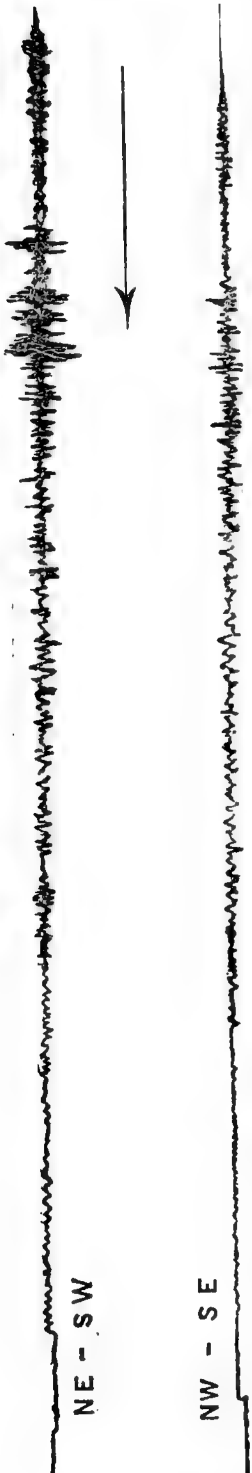
Dr. G. Agamennone's Seismometrograph.—The latest form of this instrument is described in a paper, 'Sopra un nuovo tipo di sismometrografo' ('Boll. Soc. Sismol. Ital.,' vol. i. 1895, pp. 160–168). It was installed at Rome about two years ago in the tower of the Collegio Romano. Owing to the difficulty of reproducing the illustration of this pendulum, several of the details of construction are necessarily omitted in the following account :—

The bob of the pendulum consists of six discs of lead, weighing altogether nearly 200 kg. This heavy mass is suspended by an iron rod 7 or 8 mm. in diameter and 16 metres in length, but to make the pendulum more sensitive the upper end of the rod is prolonged as a steel wire 2 or 3 mm. in diameter, and 50 or 60 cm. long. At the lower end the rod terminates in a smooth cylinder of steel of about the same thickness, passing through slits made in the short arms of two horizontal levers. These levers, which turn with very little friction, are mounted on a strong frame provided with screws for securing the verticality of the axes about which the levers rotate. The longer arms of the levers are about 35 cm. in length, being about twelve times as long as the short arms. They are triangular in form, and are made of very thin brass tubes. The levers are bent, so that while the short arms are at right angles to one another, pens at the ends of the long arms record the components of the movement on the same strip of moving paper. The pens are supplied with ink of different colours to avoid confusion of the records if the pens should happen to cross one another. In order to prevent the pens leaving the strip of paper, the movements of the pendulum are limited by four screws. A strong box is placed immediately below the heavy mass to save the instrument from further damage in case the steel wire should break.

The strip of paper on which the pens record the movements of the pendulum is driven by a cylinder about

8 cm. in diameter, and rotating about a horizontal axis. The part of the paper on which the record is being made lies on a rectangular platform immediately above the driving cylinder. Two pens fixed to the platform record the time every half-hour on the edges of the strip of paper. As a rule the cylinder rotates once in an hour, so that the paper is driven at the rate of about 30 cm. an hour. But when a shock occurs the velocity of the cylinder is immediately increased, so that for three revolutions it revolves once a minute, thus unrolling the paper at the rate of about 5 cm. a minute.

FIG. 16.



The increased velocity is produced by means of a roller, started by an electrical seismoscope. This consists in the longer arms of the levers being continued backwards to a length about fifteen times as great as that of the short arms. Beside, and very near the further ends, are two small vertical rods, which turn at their lower ends about a horizontal axis. A very slight movement of the levers closes an electric circuit, and at the same instant sets in motion the roller which gives the increased velocity, moves a collar which at once withdraws the vertical rods, so that they do not impede the oscillations of the multiplying levers, and also starts a clock previously pointing to xii. The latter clock thus gives the time at which the increased velocity began.

The increased velocity continues, as already mentioned, for three minutes. At the end of this time the two vertical rods return to their original position. But if the pendulum is still in motion, electrical contact is immediately remade, the rods are again withdrawn, and the increased velocity re-established, so that with instantaneous interruptions this lasts until the movement is so slight that it ceases to start the seismoscope.

Fig. 16 reproduces a diagram furnished by this seismometrograph on the occasion of the Caspian Sea earthquake of July 8, 1895.

Dr. A. Cancani's Seismometrograph.—The chief difference in principle between this instrument and the preceding consists in the omission of the arrangements for increasing the velocity at the time of a disturbance. Seismometrographs of this pattern have been in use for some time in the the geodynamic observatory of Rocca di Papa near Rome. Two apparatus of larger dimensions have recently been constructed, one for Rocca di Papa and the other for the observatory at Catania. These are described in a paper, 'Nuovo modello di sismometrografo a registrazione continua' ('Boll. Soc. Sismol. Ital.,' vol. ii. 1896, pp. 62–65).

In the Rocca di Papa seismometrograph, the pendulum is 15 metres long and 200 kg. in mass. The weight is suspended by a steel wire

4·5 mm. in diameter. Near its lower end, the wire passes through slits in the short arms of two horizontal levers. The long arms of the levers are made of two very light brass tubes which, soldered to a small metal plate, form a very elongated isosceles triangle in a horizontal plane. The short arms are inclined at 45° to the long arms in opposite directions, so that, while the former are at right angles to one another, the latter are parallel. The weight of each lever is 25 grammes; the length of the long arm is 40 cm., and its ratio to that of the short arm is at present 10 to 1; but this ratio can, if desired, be increased to 20 to 1. At the free end of the long arm is a small V-shaped frame, which carries a light pen furnished with a counterpoise, similar to those used in the meteorological instruments constructed by MM. Richard of Paris. The levers are arranged so that they are perfectly free throughout their whole range, passing one over the other without striking.

The instrument at Catania differs only in details. The pendulum is 26 metres long and 300 kg. in mass, and the horizontal levers are made of thin aluminium plate.

In both apparatus, the strip of paper on which the registration is made is 14 cm. in breath, and is driven by a brass cylinder 60 cm. in circumference, which rotates once an hour. A strip of paper, which costs one franc, lasts for about seven days, and can be used at least four times, twice on each side, so that the daily cost is less than four centimes. Paper is also wrapped round the driving cylinder to prevent the loss of any part of the diagram, in case the moving strip should come to an end unexpectedly.

For ten seconds at the beginning of every hour, the traces are interrupted, the levers being raised from the paper by means of a system of levers connected electrically with a chronometer. The experience of five years with another instrument shows that this is the best of the methods which have been devised for marking the time. The subsequent movement of the levers does not seem to be in the least affected by their removal, and the missing part of the diagram is so small that it can be reconstructed with ease.

The diagrams corresponding to distant earthquakes which are obtained with this seismometrograph are too large to be conveniently reproduced. The velocity of the paper being so great (60 cm. an hour),[1] the diagrams are exceedingly clear, showing the individual undulations so distinctly that all the elements of the motion and the epochs of the different phases can be determined with great precision.

Professor G. Grablovitz's Geodynamic Levels.—For many of the details given below I am indebted to the kindness of Professor Grablovitz. The levels are installed in the R. Osservatorio Geodinamico of Casamicciola, in the island of Ischia, one being directed north and south, and the other east and west.

The account of these levels is contained in the following papers:—

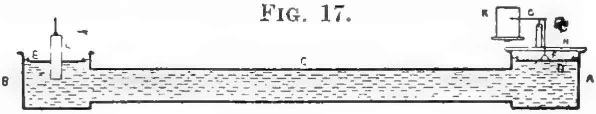
1. 'Livelli geodinamici a registrazione continua:' 'Boll. Soc. Sismol. Ital.,' vol. i. 1895, pp. 39–43.
2. 'Nuovi metodi per indagini geodinamiche:' *Ibid.* vol. ii. 1896, pp. 41–61.

[1] The reasons which have led Dr. Cancani to regard this as the most suitable velocity for the study of pulsations from a distant earthquake are given in a valuable paper, 'Sugli strumenti più adatti allo studio delle grandi ondulazioni provenienti da centri sismici lontani' (*Rend. delle R. Accad. dei Lincei*, vol. iii. 1894, pp. 551–555).

Each level is 2·50 metres long, and consists of two vessels A, B (fig. 17) 30 cm. in diameter and 25 cm. high, communicating with one another by means of a tube C, 15 cm. in diameter. The level is filled with water, and, to prevent evaporation, floats, D, E, consisting of zinc dishes 28 cm. in diameter with a rim 3 cm. high, are placed in the vessels at each end, and these again are surrounded with a stratum of oil. In the centre of the float D there rests a weight F of 100 grammes, connected by a wire with the end of the short arm of the amplifying lever G, the fulcrum of the lever being fixed to a plate H resting on top of the vessel A. The arms of the levers are 3 mm. and 15 cm. in length, so that the movements of the float are magnified fifty times. The longer arms of the levers were at first furnished with pens filled with ink, but for these were afterwards substituted points writing on smoked paper, which give much clearer diagrams. The paper is wrapped round a cylinder K, rotating on a vertical axis once in 53 minutes, and drives the paper under the pen at the rate of $5\frac{1}{2}$ mm. a minute. The levers of the two levels are arranged with their pens on the same vertical line, and about 6 cm. from one another.

In order that the records may not be superposed after a complete revolution is made, a cylinder L, 4 cm. in diameter, is lowered from a drum, driven by another clock, into the vessel B. As it becomes immersed in the water the registering float D is slowly and gradually raised, and the pen in consequence traces a continuous spiral on the paper. As the

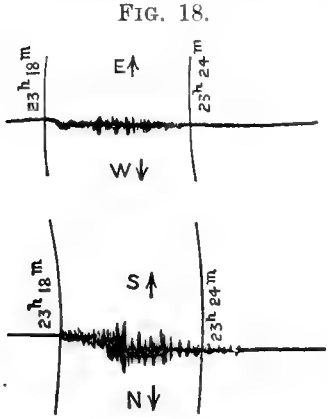
FIG. 17.



cylinder rotates once in 53 minutes the diagram for each component consists of twenty-seven lines, the distance between consecutive lines being about a millimetre. To determine the time of any displacement of the float, a trace is impressed when the paper is put on and taken off, as well as at some intermediate time about equidistant from the ends of the 24 hours. Or, if desired, an automatic hourly trace could be made by electric connection with a chronometer.

The lines of the spiral are parallel and equidistant. Except when the instrument requires sensitising, the registration proceeds without jumps, showing that it is sensible to very small changes of level. Professor Grablovitz informs me that he has not been able to determine the smallest tilt which the levels can detect, but a displacement of the writing-point of half a millimetre, corresponding to a tilt of the ground of 2″ can generally be read with certainty.

FIG. 18.



The levels do not seem to be affected by the tremors of passing carts, &c., but they are sensible to certain seismic movements. They will not register slow movements taking place in a horizontal direction, for in such cases the water receives no displacement relatively to the tubes. Nor do they seem capable of recording the long-period pulsations of very distant earthquakes. For instance, on June 15 of the present year the horizontal pendulums at

Casamicciola revealed oscillations of 10″, due probably to the earthquake which caused the great sea-waves in Japan ; but, at the same time, the levels were not affected, though the corresponding traces on their records would have been 2·5 mm. in length.

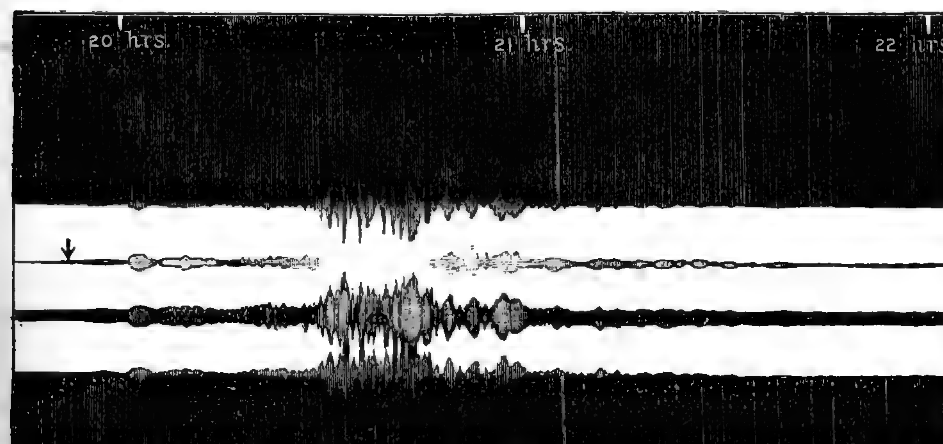
The most marked diagram so far obtained is that which was due to the severe earthquake in Carniola on April 14, 1895 (see fig. 18, in which the scale is half that of the original diagram). The curve in this case was, however, obtained before the employment of smoked paper, so that it is not so clear as that of a similar earthquake at the present time would be.

APPENDIX.

Notes on Special Earthquakes. *By* Professor J. Milne.

About 11.30 P.M. on August 26, 1896, a diagram was obtained which may represent an earthquake that occurred in Iceland on that date. It shows three maxima. A much more remarkable record, however, is one commencing as a series of minute tremors at about 8.23 A.M. on August 31.

Fig. 19.—Japan Earthquake; Carisbrooke Castle Record.



It is shown on the photogram from Shide, and also from that at Carisbrooke Castle (fig. 19), and the times of marked phases of motion in G.M.T. are as follows :—

—	Carisbrooke Castle	Shide
	H. M. S.	H. M. S.
1. Exceedingly minute tremors, August 30 .	20 23 6	Too faint to be visible.
2. First decided tremors	20 31 46	20 31 42
3. Heavy motion commences	20 57 6	20 56 49
4. First maximum (about)	21 4 26	21 1 0
5. The maximum	21 14 26	Not calculated.
6. Heavy motion	21 19 46	,, ,,
7. ,, ,, ...	21 23 6	21 24 43
8. ,, ,, ...	21 27 46	Not calculated.
9. End of tremors	23 16 20	22 59 36
Duration of disturbance	2 53 20	—
Duration of preliminary tremors . .	0 34 0	—

The reason that phase No. 1 is not shown at Shide—and it can only be seen in the Carisbrooke record with the help of a strong magnifying-glass —is apparently due to the fact that the Shide lamp gives a light which is smaller and therefore feebler than that at Carisbrooke. The photograms from the latter station have therefore a definition sharper than those from Shide. Carisbrooke records are also freer from 'tremors' than those at Shide.

Phases 2 and 3 respectively differ by 4 and 17 seconds; but inasmuch as the Carisbrooke time was regulated by comparisons with an ordinary watch, it is remarkable that these well-defined periods are so closely coincident.

The difference in duration at the two stations is also probably due to difference in definition of the photograms.

I do not know where this shock originated, but because the daily papers tell us that there was a severe earthquake in Japan on August 31, and because the preliminary tremors have outraced the principal motion by 34 minutes—which indicates an origin at a distance of about 6,000 miles—the inference is that the above records refer to an exceedingly violent adjustment of crumpling strata, probably in Japan. If this inference is correct, then in that country, in its own time, a violent earthquake took place on August 31 at a few minutes past 5 P.M.

Electrolysis and Electro-Chemistry.—Report of the Committee, consisting of Mr. W. N. SHAW (*Chairman*), Rev. T. C. FITZPATRICK, W. C. D. WHETHAM (*Secretary*).

THE parts of the original scheme for a report on the present state of electrolysis and electro-chemistry which remain to be dealt with are as follows:—

III. (*d*) Electro-chemical thermo-dynamics.
(*e*) Electric endosmose.
(*f*) The theory of ionic migration and ionic velocities.
(*g*) Relations between numerical values of the electrical and other physical properties of electrolytes.
IV. A discussion of experimental methods and apparatus.
V. Electro-chemical phenomena not usually included as 'electrolytic.'
VI. Some miscellaneous electrolytic phenomena.

The Committee divided the work of Sections III. and IV. among its members. Electro-chemical thermo-dynamics and electric endosmose were assigned to Mr. Shaw, the theory of migration and ionic velocities to Mr. Whetham, and the discussion of apparatus and methods to Mr. Fitzpatrick.

Mr. Whetham has completed the account of the theory of migration, &c., and Mr. Fitzpatrick has dealt with the methods of measuring electrical resistance of electrolytes. With regard to the section upon the numerical relations of electrical conductivity with other properties of electrolytes the Committee are of opinion that very valuable results would be obtained by carrying out measurements of the several properties upon identical solutions with special precautions to protect the experiments against the effects of small impurities. They have learnt that Mr. E. H. Griffiths intends, in the course of the coming year, to make a series of observations on the freezing-points of solutions, and it is thought that the opportunity of making electrical measurements upon *the same* solutions should not be allowed to pass. Mr. Whetham will undertake the electrical portion of the work, and it is proposed to apply for a grant of 50*l.* towards the cost of the special apparatus necessary for it.

It is also proposed to print forthwith, and circulate among those most likely to be interested, revised proofs of the portions which have been completed, but not to include them in the published Report for this year. It is intended to publish them in the Report for 1897, with the remainder of the work that the Committee are able to put before the Association.

The Committee therefore ask for reappointment, with the addition of the name of Mr. E. H. Griffiths, and with a grant of 50*l*.

Comparison and Reduction of Magnetic Observations.—Report of the Committee, consisting of Professor W. G. ADAMS (*Chairman*), Dr. C. CHREE (*Secretary*), Lord KELVIN, Professor G. H. DARWIN, Professor G. CHRYSTAL, Professor A. SCHUSTER, Captain E. W. CREAK, The ASTRONOMER ROYAL, Mr. WILLIAM ELLIS, *and* Professor A. W. RÜCKER. (*Drawn up by the Secretary.*)

CONTENTS.

Non-cyclic Effects at Kew Observatory during the selected 'Quiet' Days of the Six Years, 1890–1895. *By* C. CHREE, *Sc.D.*

Introductory Remarks: 'Non-cyclic' Effect.

§ 1. AN analysis of the results from the Kew declination and horizontal force magnetographs during the selected 'quiet' days of the five years, 1890 to 1894, was submitted last year to the Committee and adopted as its report for 1895. The corresponding inclination and vertical force results had also been pretty fully worked up, but I held them over pending an inquiry into the sufficiency of the temperature correction. Some considerable time may elapse before these results can be utilised to full advantage. It has thus seemed inexpedient to defer dealing with one set of phenomena whose general character is unaffected by any uncertainty as to the temperature correction, and whose existence seems to render desirable a reconsideration of the whole system of 'quiet' day observations. The phenomena in question bear on what I termed last year the *non-cyclic* effect.

Supposing H_0 and H_{24} to denote mean values of the horizontal force at the first and second midnights of a selected series of days, then $H_{24}-H_0$ was defined as the non-cyclic effect or variation of horizontal force; and a similar definition applies in the case of any other element.

Non-cyclic Effects during Six Years, 1890–1895.

§ 2. It is proposed to give here complete data as to the non-cyclic effects in the selected 'quiet' days at Kew during the last six years. To some extent this incorporates results given last year, but it seemed desirable to show side by side the results for all the elements throughout the same series of years.

There are five selected 'quiet' days a month, and so a total of 360 in the seventy-two months of the six years considered. In November and December 1890, however, the vertical force magnetograph was out of action, which reduces by ten the number of days available in the case of the vertical force and inclination.

In the following table, I., the six Januarys, six Februarys, &c., of the six years have been combined together, so as to show the values of the cyclic effects at different seasons of the year. The figures under the heading 'Individual Months' show in how many of the six Januarys, &c., the effect was an increase of the element in question, was nil, or a decrease. At the foot of the table appear the mean non-cyclic effects per 'quiet' day throughout the six years, and the totals of the several columns under the headings 'Individual Months.'

TABLE I.—*Non-cyclic Effect from Six Years, 1890–1895 (Mean per 'Quiet' Day).*

Month	Declination				Horizontal Force				Vertical Force				Inclination			
	Effect	Individual Months			(Effect) × 10^6	Individual Months			(Effect) × 10^6	Individual Months			Effect	Individual Months		
		+	0	−		+	0	−		+	0	−		+	0	−
January .	+0′·63	6			+50	5		1	−52			6	−0′·47	1		5
February .	+ ·33	4		2	+57	5	1		+ 5	3		3	− ·35	1		5
March .	+ ·18	3		3	+28	5	1		+13	2	2	2	− ·17	1	1	4
April .	+ ·12	3	1	2	+20	4	1	1	−22	2		4	− ·20	1	1	4
May . .	+ ·07	3		3	+38	5	1		−12	3		3	− ·27	2		4
June . .	− ·17	3		3	+22	4	1	1	−28	1		5	− ·22	1	1	4
July . .	− ·23	3		3	+27	4	2		−13	1		5	− ·22		2	4
August .	− ·30	1	1	4	+37	5		1	− 8	3		3	− ·27		1	5
September	+ ·12	3		3	+38	6			+30	3	1	2	− ·18	1		5
October .	+ ·03	2	1	3	+50	6			+ 5	3		3	− ·28	1		5
November	+ ·18	3	1	2	+53	6			−12	2		3	− ·40			5
December.	− ·10	1	2	3	+15	5		1	− 6	2		3	− ·12		2	3
Annual mean .	+0′·072	—			+36·4	—			−8·3	—			−0′·263	—		
Totals of months.	—	35	6	31	—	60	7	5	—	25	3	42	—	9	8	53

In the case of the declination + signifies a deflection to the west. The true secular variation at present is towards the east. The components of force are measured in C.G.S. units.

Table II. gives the mean results for the several quarters of the year as deduced from Table I., while Table III. gives the annual means for the individual years.

TABLE II.—*Mean Non-cyclic Effect per 'Quiet' Day for each Quarter of the Year.*

—	Declination				(Horizontal Force) × 10^6				(Vertical Force) × 10^6				Inclination			
Quarters	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Effect .	+0′·38	+·01	−·14	+·04	+45	+27	+34	+39	−11	−21	+3	−4	−0′·33	−·23	−·22	−·28

TABLE III.—*Mean Non-cyclic Effect per 'Quiet' Day for each Year.*

Year	Declination	(Horizontal Force) × 10^6	(Vertical Force) × 10^6	Inclination
1890	−0′·36	+23	+15[1]	−0′·10[1]
1891	+ ·29	+23	−12	− ·18
1892	+ ·14	+53	−20	− ·41
1893	+ ·26	+40	−26	− ·35
1894	+ ·15	+33	+12	− ·18
1895	− ·05	+44	−15	− ·33

Relation of Non-cyclic Effects to Annual Changes.

§ 3. To see the full significance of these data regard must be had to the magnitudes of the annual changes of the several elements. Table IV. gives these for the period considered, along with the number of average 'quiet' days, which, according to Table I., would have sufficed to produce changes numerically equal to the annual changes observed.

TABLE IV.

—	Declination	Horizontal Force	Vertical Force	Inclination
Mean annual change, 1890–95 .	−6′·8	21×10^{-5}	-19×10^{-5}	−1′·9
Number of 'quiet' days producing equal change . .	95[2]	6	23	7½

The figures relating to the horizontal force and inclination are so significant that comment in their case seems unnecessary.

As regards the declination and vertical force in individual months, notably January, the non-cyclic effects have been as large and consistent as with the other two elements, but in general this has been far from the case. As Table III. shows, in two years out of the six both declination and vertical force have exhibited a mean non-cyclic effect opposite in sign to that supplied by the six years as a whole.

In considering such a phenomenon one ought of course to remember that it is contrary to probability that any sixty arbitrarily selected days—the number on which an annual mean is based—will produce a diurnal variation truly cyclic after allowance is made for the normal annual change; and thus part of the irregularity exhibited by Table III. may reasonably be attributed to pure chance. When, however, one looks at the uniformity of sign in the non-cyclic effects in the horizontal force and inclination exhibited in Table I., and remembers that the monthly means in that table are based on only thirty days, one must, I think, conclude that the variability of sign in the declination[3] and vertical force[4] results, at least in Table III., has probably a true physical basis.

[1] In 1890 the means of vertical force and inclination are based on the results of only ten months, in one of which (March) an abnormally large positive non-cyclic effect was recorded in vertical force.

[2] In the case of declination, and it alone, the non-cyclic effect is opposite in sign to the secular variation.

[3] In 1890 a *positive* non-cyclic effect appeared in only one month (January); in 1891 a *negative* effect in only one month (November).

[4] In both 1890 and 1894, however, a slight majority of individual months exhibited a *negative* non-cyclic effect as usual.

Mean Annual Values from 'Quiet' and Unrestricted Days.

§ 4. Table IV. is merely a plain statement of facts; but if too exclusively considered it might unquestionably convey an exaggerated idea of the defects attaching to the ordinary use made of 'quiet' days at the present time. At Kew Observatory they are employed to get out the mean diurnal inequality for summer and winter and the whole year, as well as the mean annual values of the several elements.

As regards the mean annual value of an element, the quantity 'mean value from "quiet" days less mean value from all days' may be irregularly positive and negative, or like the non-cyclic effect in the element it may be normally of one sign. It would certainly be desirable to know which of the alternatives is true. The meaning to be attached to the secular variation deduced from two consecutive years or from a short series of years would be much more uncertain if the former alternative represented the facts than if the latter did.

In the Greenwich 'Magnetical and Meteorological Observations' tables are published showing the diurnal variations both in 'quiet' and unrestricted days, but not apparently direct information as to the difference between the absolute values of means deduced from the 'quiet' and from unrestricted days.

At St. Petersburg, and then at Pawlowsk, it has, however, long been customary for Dr. Wild to select a series of normal 'quiet' days whose results are dealt with alongside of those from unrestricted days. The principle of selection guiding the choice at Pawlowsk and Greenwich has probably been slightly different, but there is at least a strong presumption that the differences between the annual means from unrestricted days and from the Astronomer Royal's 'quiet' days will prove to be of the same character as the corresponding differences observed in the case of Wild's 'quiet' days.

§ 5. The annual means for all the elements at St. Petersburg, from both 'quiet' and unrestricted days, for some twelve to sixteen years preceding 1885 are given in a paper by Dr. Müller in the 'Repertorium für Meteorologie,' Bd. XII. No. 8. In the case of every element, according to Müller's tables 20 to 23, the sign of the quantity '"quiet" day mean less unrestricted day mean' was uniformly, or practically uniformly, of one sign; and the secular variations deduced from the 'quiet' and unrestricted day results, even for consecutive years, showed a remarkably good agreement. The following summary of the mean results deducible from Müller's tables is extracted from a recent paper by Leyst[1]:—

Wild's Normal Days—all Days (Annual Means).

Declination west . .	$+\ 0'{\cdot}25$.
Inclination	$-\ 0'{\cdot}23$.
Vertical component .	$-10^{-6}\times 8$ C.G.S. units.
Horizontal component .	$+10^{-6}\times 35$,,

Tables of the monthly and yearly means for Wild's 'quiet' days and for unrestricted days at Pawlowsk continue to be given in the 'Ann. des Phys. Central-Observatoriums.' The results from the last two volumes are as follows:—

[1] *Rep. für Met.* Bd. XVII. St. Petersburg, 1894, No. 1, p. 109.

Wild's Normal Days—all Days (Annual Means).

Year	Declination	Horizontal Force	Vertical Force
1893	+0′·3	$+10^{-6}\times 40$	$-10^{-6}\times 30$
1894	+0′·6	$+10^{-6}\times 60$	$-10^{-6}\times 10$

There would thus appear to be no essential change in the phenomena since the period to which Müller's paper refers.

§ 6. Wild's 'quiet' days numbered only twenty-five in 1893 and thirty-three[1] in 1894, as against the Astronomer Royal's sixty a year; thus the results from the latter are likely to exhibit even less irregularity in their departures from the results of unrestricted days than the former. Mere surmises such as the preceding are vastly inferior to the actual numerical facts. Before deciding on the labour necessary to obtain the facts one has first, however, to estimate their probable value. One factor in this consideration which the practical man can fairly urge is that accuracy in *absolute* value to anything like 1×10^{-5}, in the case even of the horizontal force, is an ideal we can hardly claim to have reached in this country.

Relation of Non-cyclic Effects to Diurnal Ranges.

§ 7. An idea of the amount of uncertainty which the non-cyclic effect may introduce into the mean diurnal inequalities for summer, winter, and the whole year may be derived from Table V. It gives the ranges of the elements, uncorrected for non-cyclic effect, as published annually in the Kew 'Report,' along with particulars as to the ratios borne by the mean non-cyclic effects to the corresponding ranges.

TABLE V.—*Ranges of Elements from Annual Kew Reports.*

—	Declination			(Horizontal Force) $\times 10^5$			(Vertical Force) $\times 10^5$			Inclination		
	Year	Winter	Summer	Year	Winter	Summer	Year	Winter	Summer	Year	Winter	Summer
1890	6′·9	5′·1	8′·7	21	14	30	—	—	—	′ —	′ —	′ —
1891	8·2	6·0	10·2	29	20	40	14	9	20	1·7	1·1	2·3
1892	9·6	6·9	12·3	33	26	44	17	11	25	2·0	1·5	2·7
1893	10·1	7·4	13·0	37	29	46	18	10	25	2·2	1·7	2·8
1894	9·3	7·0	11·9	36	26	48	17	11	22	2·2	1·5	2·8
1895	8·5	5·6	12·1	33	20	46	15	10	23	2·0	1·2	2·8
Means	8·8	6·3	11·4	32	23	42	16	10	23	2·0	1·4	2·7
(Non-cyclic Effect) ÷ (Uncorrected range)	+·008	+·033	−·006	+·12	+·19	+·07	−·05	−·08	−·04	−·13	−·21	−·08

In the case of the vertical force and inclination the year 1890 has been omitted, as the results for it are not altogether complete.

[1] The number in most of the earlier years dealt with by Dr. Müller seems, however, to have been considerably greater.

§ 8. Table V. shows how much more important relatively the non-cyclic effect is in the winter than in the summer half-year.

In the winter half-year we see that the non-cyclic effect in both horizontal force and inclination is equal to about one-fifth of the range. This does not of course imply that there is an uncertainty of 20 per cent. in the range, because, whatever be the nature of the correction applied to eliminate the non-cyclic effect, it is hardly likely to introduce more than a small fraction of the observed difference between 0 and twenty-four hours into the algebraic difference of the maximum and minimum readings. The interval of time between these readings is in most cases nearer six hours than twelve. The fact, however, remains that in some individual winters the uncertainty as to the range must be very appreciable. When we come to individual winter months, notably January, when the observed range is least, the uncertainty is apt to be considerable.

The preceding remarks refer exclusively to the uncertainties which the existence of the non-cyclic effect introduces into diurnal ranges deduced from 'quiet' days. Previous reports of the Committee[1] have dealt with differences between the ranges deduced from unrestricted and from 'quiet' days. It seems to me, however, that such comparisons are open to criticism so long as the proper treatment of the non-cyclic effect remains uncertain.

Relation of Non-cyclic Effects to Diurnal Inequalities.

§ 9. In the yearly and half-yearly results the most critical point is the nature of the diurnal inequality in the late night and early morning hours. The observed variation is then small, especially in winter, so that a disturbing element of no great absolute magnitude might completely alter the character of the phenomena. This will appear at once on reference to the curves of declination and horizontal force in last year's report, pp. 212 and 220. The curves on p. 220 are certainly suggestive of the presence of some abnormal influence during the midnight hours; at the same time this is not more true of them than of curves of the same type for Greenwich which Sir G. B. Airy[2] based on data derived from all days but those of considerable disturbance.

Elimination of Non-cyclic Effect.

§ 10. If diurnal inequalities are to be got out at all from 'quiet days' in a form suitable for harmonic analysis, they must be made cyclic, and there is certainly no simpler way of doing this than that adopted last year, viz., treating the observed data as if the non-cyclic effect proceeded uniformly throughout the twenty-four hours. This method of treatment does not prejudice the facts. Supposing the non-cyclic effect to proceed irregularly throughout the twenty-four hours, then it may most conveniently be analysed into terms, one being a linear function of the time, the others periodic functions whose periods are twenty-four hours or submultiples thereof. The linear term is eliminated by the method adopted last year. The cyclic terms of course remain, and are incorporated with the other cyclic terms of like period which go to make up the diurnal inequality on 'quiet'

[1] *B.A. Report*, 1886, p. 71. See also paper by Messrs. Robson and Smith, *Phil. Mag.*, August 1890, p. 143.

[2] *Phil. Trans.* for 1863 and for 1885.

days. It would, however, be impossible to separate the two sets of cyclic terms by any mathematical device, without an addition of physical facts or a supply of theories in their place. One way of obtaining additional facts would be to compare for a series of years the constant coefficients in the harmonic analysis of the diurnal inequalities from 'quiet' and unrestricted days. The accidental features introduced by the arbitrary nature of the choice of 'quiet' days might, however, prove troublesome.

The term in the non-cyclic effect treated as a linear function of the time may in its turn be composed of a series of terms, some possibly fluctuating regularly with the season of the year, others possibly of very long period; its magnitude, at least in individual months, may depend in large measure on the accidental preference of one set of 'quiet' days to another.

Associated Phenomena.

§ 11. It was pointed out last year (*l.c.*, p. 213) that the elimination of the non-cyclic effect through a correction consisting of a linear function of the time was determined solely by considerations of convenience and mathematical simplicity. It was carefully explained (*l.c.*, §§ 5, 6) that General Sabine and Dr. Lloyd had observed phenomena in magnetic storms so exactly the converse of those presented by the non-cyclic effect on 'quiet' days as to suggest that the two classes of phenomena were interdependent; and the conclusion was drawn that if this interdependence were true the non-cyclic effect might be expected in reality to progress irregularly throughout the twenty-four hours.

These conclusions may now, perhaps, be regarded as more than surmises. In the 'Met. Zeitschrift' for September 1895 Dr. van Bemmelen has described phenomena he terms *Nachstörung*, which appear to be of the same general character as, if not identical with, what has been termed here the non-cyclic effect.

As the title he selected implies, Dr. van Bemmelen associates the phenomena very intimately with magnetic storms. His investigations have included data from a variety of stations; and whilst his theoretical conclusions may, perhaps, undergo modification in the future, his work certainly indicates that an increase of knowledge as to this outstanding phenomenon on 'quiet' days is likely to be of service in the general theory of terrestrial magnetism.

§ 12. In the meantime it might be safest not to assume that the non-cyclic element is an effect, and a preceding magnetic storm a cause. The fact that the horizontal force, for instance, tends to rise abnormally fast during a 'quiet' day may, of course, merely represent a recovery from an abnormal loss occasioned by a magnetic storm; but it is at least conceivable that the abnormal fall during a magnetic storm may be partly a consequence of abnormal increase preceding it, or the two phenomena may be effects of a common cause.

If 'quiet' days, with no appreciable disturbance, were the rule, one might possibly determine with ease the relationships of any given 'quiet' day to a preceding or succeeding disturbed day; but appreciable movements will usually be found both before and after a 'quiet' day at no great interval of time. If the causes operating in large and small disturbances are the same, then it is not improbable *à priori* that a small disturbance within a day or two of a 'quiet' day may have more to do with it than a large disturbance a week before or after. It should also be remembered that General Sabine found that whilst, as a rule, large disturbances lowered the horizontal and raised the vertical force, the opposite results ensued in a very considerable number of instances.

In proposing any additions to the existing 'quiet' day system, or any substitute, it must be remembered that one of the main objects aimed at by its introduction was a substantial saving in the labour required to obtain comparable results from different observatories. The tabulation of the whole mass of curves was felt in most cases too serious a burden. Considerable light might be thrown on the question of the uniformity or variableness of the non-cyclic element throughout the day by a very simple addition, viz., curve measurements at the noons preceding and succeeding each 'quiet' day. In the course of this paper other suggestions have been made, but they could be put into effect only at observatories prepared to tabulate all the curves.

In conclusion, I wish to acknowledge the assistance I have derived from discussing a variety of the points involved with Mr. T. W. Baker, Chief Assistant at the Kew Observatory.

APPENDIX.

Remarks by W. Ellis, Esq., *F.R.S.*

Having had the opportunity of reading Dr. Chree's report on non-cyclic magnetic effects, I would beg to be allowed to offer the following remarks:—

I had read with great interest Dr. Chree's 'Comparison and Reduction of Magnetic Observations,' forming the report of the Magnetic Committee for the year 1895, in which he discusses the Kew magnetic results on 'quiet' days for the years 1890 to 1894. I had lately commenced to work up in a similar way the corresponding Greenwich results in order to make comparisons between Greenwich and Kew, when treated for the same years in a similar manner. Interesting questions are involved, since it cannot be said to be at present known how far the magnetic changes at two places not remotely distant one from the other should be expected to be similar, and if not similar to what extent there may be difference, and also whether any part of such difference might be instrumental. It is not satisfactory to compare results for one period with results for another place for a different period, because at any one place the phenomena may vary considerably at different times. But my work is not sufficiently advanced to enable me to put the results at present into shape; still I may perhaps give some information bearing on points now discussed by Dr. Chree. In Table I. he gives the mean non-cyclic effect for 'quiet' days for different magnetic elements for each month of the year, deduced from the Kew observations of the six years 1890 to 1895. My numbers for Greenwich are for the five years 1890 to 1894. At Kew the non-cyclic change in declination is positive in the first five, and in the ninth, tenth, and eleventh months of the year, and negative in the remaining months. At Greenwich it is positive in the first five months and in the eleventh month, and negative in the other months. At both places the largest positive value is in January, Kew $= +\ 0'{\cdot}63$, Greenwich $= +\ 0'{\cdot}46$; the largest negative value is in August, Kew $= -\ 0'{\cdot}30$, Greenwich = − 0′·42. Mean for year at Kew = +0′·072, at Greenwich = +0′·007. In horizontal force the non-cyclic effect at Kew is positive in all months, and similarly at Greenwich. The greatest values at Kew are (effect $\times 10^6$ in C.G.S. units), in January, February, October, and November, +50, +57, +50, and +53 respectively; and similarly at Greenwich, the values being +62, +53, +73, and +57 respectively. Mean for year at Kew = +36, at Greenwich = +40. In vertical force there is considerable difference, both in magnitude and sign, between the non-cyclic effect in different months at the two places. The mean for year at Kew = −8, and at Greenwich = −18. In this comparison it is to be remembered that the Kew results depend on the observations of six years, and the Greenwich results only on those of five years.

As regards now the mean values in separate years (Table III.); of the five years 1890 to 1894 the non-cyclic change in declination is in the same direction in four of the five years at both places; in horizontal force in the same direction in all years, and in vertical force in three years. The actual numbers are :—

Non-cyclic change	1890	1891	1892	1893	1894
			In declination		
At Kew	−0′·36	+0′·29	+0′·14	+0′·26	+0′·15
At Greenwich	−0′·23	+0′·08	−0′·20	+0′·15	+0′·24
			In horizontal force		
At Kew	+23	+23	+53	+40	+33
At Greenwich	+18	+37	+68	+44	+33
			In vertical force		
At Kew	+15	−12	−20	−26	+12
At Greenwich	−12	− 8	−39	−24	− 4

In vertical force there is a tendency to a uniformly greater negative value at Greenwich than at Kew. Considering, however, the values at each station separately, the greatest negative values occur in the same two years, 1892 and 1893, at both places.

One question that I had set myself to discuss was how far the absolute magnetic values, as, for instance, the mean monthly values, differ, as determined from the five 'quiet' days in each month, and as determined from all days (excepting those of excessive magnetic disturbance). In the Greenwich 'Observations' there are given in Tables I., III., and VII. of the magnetic section mean daily values of declination, horizontal force, and vertical force respectively throughout the year (excepting days of excessive disturbance). The means of these values for different months are given in Table XI. Extracting from the different tables the values for the adopted 'quiet' days, and taking the mean in each month, the variation of these means from the corresponding means of Table XI. gives in each case the deviation of the 'quiet' days mean from that for all days. Since the mean of the five selected days falls always near the middle of the month, the comparison, for a first inquiry, sufficiently eliminates the secular variation, considering it uniform, the only possible supposition. The excess of the 'quiet' day monthly mean above the all day or unrestricted monthly mean is, in each month of the year, for each element, as follows (average of five years 1890 to 1894) :—

Greenwich	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Excess of absolute 'quiet' day value above all days value .	*In declination*											
	−0′·04	+0′·12	+0′·24	−0′·10	+0′·12	+0′·10	0′·00	+0′·10	−0′·06	−0′·08	+0′·24	0′·00
	In horizontal force											
	+35	+42	+24	+37	+31	+20	+22	+ 5	+27	+55	+51	+57
	In vertical force											
	+31	−26	−10	−13	−11	+10	−17	− 2	+ 3	−40	− 5	−17

Mean yearly excess of 'quiet' day value in declination = + 0′·05
" " " in horizontal force = + 34
" " " in vertical force = − 8

The corresponding separate yearly differences are :—

Greenwich	1890	1891	1892	1893	1894
Excess of absolute 'quiet' day value above all days value	*In declination*				
	+0′·01	−0′·12	+0′·07	+0′·19	+0′·12
	In horizontal force				
	+ 11	+ 37	+ 31	+ 37	+ 53
	In vertical force				
	− 8	− 7	− 26	− 14	+ 14

I have not sufficient opportunity at the present moment to add much by way of discussion of these numbers, but taking the element in which the difference of absolute value is most marked, that of horizontal force, some few remarks may be offered. We see that the uniformly positive non-cyclic change on 'quiet' days is accompanied by an increased absolute value of horizontal force on such days, as compared with the value from all days, as we should perhaps expect. At Greenwich magnetic disturbance commonly causes diminution of horizontal force, after which the value works back to a more normal one. But there are years in which the magnetic registers are unusually quiet, with few disturbances of even moderate amount, as in the years 1878 and 1879. The inference would be that in such years the difference between the absolute value for the especially 'quiet' days and that for all days should be small, varying to a certain extent in different years with the more or less prevalence of magnetic disturbance. I cannot, however, for the moment refer to the Pawlowsk differences of which Dr. Chree speaks, to ascertain whether they exhibit variations of this character. Further, whether the rise of value on 'quiet' days represents a recovery from abnormal loss during disturbance, or whether the abnormal fall during disturbance is in any way a consequence of preceding abnormal rise, may be a question. But the view that the recovery on 'quiet' days is rather a consequence of abnormal fall during disturbance, that is, that the disturbance is really the primary dominating factor, appears to receive support from the following consideration. When disturbance suddenly arises it seems to break out over the whole earth at precisely the same moment of absolute time (see 'Proc. Roy. Soc.' vol. lii. p. 191). But an instantaneous magnetic shock sensible over the whole globe could scarcely, one would imagine, arise from action from within alone; and since magnetic disturbances are more frequent when sunspots are numerically high, there seems reason to suppose that the exciting cause is in such cases mainly external. To pursue this matter is, however, rather to enter the region of speculation.

It may perhaps be remarked that the mean non-cyclic change for horizontal force and vertical force on 'quiet' days is + 40 and − 18 respectively; also that the mean excess of absolute value on such days over all days is correspondingly + 34 and − 8 respectively. Thus the relation in both elements is of the same character.

A part of my work consisted of a comparison of diurnal inequalities of the magnetic elements on 'quiet' days with those found by including all days (always excepting the excessive magnetic disturbances), and also of a comparison of diurnal range as given: (1) by 'quiet' days as observed; (2) by 'quiet' days corrected for non-cyclic change; and (3) by including all days, in all cases for the different months of the year; but the work is not sufficiently advanced to enable any particulars to be given.

Dr. Chree, referring to a previous report of the Magnetic Committee and to a paper by Messrs. Robson and Smith in the 'Phil. Mag.' for August 1890, speaks of the differences between diurnal ranges deduced from unrestricted days, that is all days, and from 'quiet' days. I may perhaps point out that these comparisons were between 'quiet' days at Kew and all days at Greenwich, and were for the element of declination only. In such a comparison the question of difference of locality must be taken into account, and also possibly to some extent the difference of instruments. But in a paper which I communicated to the 'Phil. Mag.' for January 1891 I made a more direct comparison of results, for the one year 1889, comparing the diurnal inequalities for 'quiet' days (five in each month) at Greenwich with those for all days at the same place. This comparison was made for all the three elements of declination, horizontal force, and vertical force. The five-day results were not corrected for non-cyclic change, but in declination and vertical force this was evidently small. The results show a marked difference between the diurnal inequalities for 'quiet' days and for all days. The later work in this direction, yet incomplete, to which I have above referred, includes a discussion of the diurnal inequalities for the five years 1890 to 1894 for 'quiet' days and for all days, and the results seem likely to support those found for the single year 1889.

Solar Radiation.—Twelfth Report of the Committee, consisting of Sir G. G. STOKES (*Chairman*), Professor H. MCLEOD (*Secretary*), Professor A. SCHUSTER, Mr. G. JOHNSTONE STONEY, Sir H. E. ROSCOE, Captain W. DE W. ABNEY, Mr. C. CHREE, Mr. G. J. SYMONS, *and* Mr. W. E. WILSON, *appointed to consider the best Methods of Recording the Direct Intensity of Solar Radiation.* (*Drawn up by* Sir G. G. STOKES.)

AT the date of the tenth report of this Committee, Professor McLeod, who had undertaken to make some experiments with the Stewart's actinometer used as a 'dynamical' actinometer, tried whether it might not be advantageous to substitute for the internal thermometer a thermo-electric arrangement whereby the solar radiation should be measured by the deflection of a galvanometer. A thin disk of blackened copper was fixed in the position previously occupied by the flattened bulb of the internal thermometer, and two wires led from this disk, namely, a platinoid wire from behind the middle point of the disk and a copper wire from the edge, the second junction of the two metals being embedded in the solid copper of the case, the temperature of which was given by the case-thermometers. A d'Arsonval galvanometer was intercalated in the thermo-electric circuit, and the difference of temperatures of the two junctions was given by the deflection of the mirror, which was read by eye by means of a divided scale. This arrangement was found to work in a very satisfactory manner; the observations could be taken in a shorter time than with the thermometer; and on reducing the results by the formula given in a former report it was found that the numbers obtained for a magnitude theoretically proportional to the radiation came out very consistent with one another when they were deduced from different trios of readings taken on the same occasion. Professor McLeod had not, however, sufficient leisure to continue the experiments as he wished, and Mr. W. E. Wilson took charge of the instrument with a view to continue the experiments.

Mr. Wilson modified the apparatus by introducing an arrangement by which the light reflected by the mirror of the galvanometer, instead of serving for eye observations, was received on a photographic plate which descended by clockwork, and recorded the deviations of the mirror at times which were recorded by a fixed light falling on the plate, which was interrupted at each second, so that the former light traced out a curve, the ordinates of which corresponded to the deflections, while the abscissæ gave the time.

In this manner very neat curves were obtained, which gave a permanent record of the observations. This record was of course exempt from possible errors of reading, and could be dealt with at leisure. In a later arrangement the interruptions at each second were recorded on the curve itself as well as on the line of abscissæ, a method which presents certain advantages for the subsequent reduction.

In order to obtain a base line corresponding to an equality of temperature of the disk and the case, the plate was started, and the permanently fixed light and that reflected from the mirror not yet deflected were allowed to record themselves a few seconds before the sun's rays were allowed to fall on the plate. The latter gave a short straight line, parallel to the axis of abscissæ, corresponding to no deviation, from which the curve started when the light of the sun was let on.

The curves obtained in the preliminary trials were sent to Sir George Stokes for reduction. The rapidity of the change from the straight line traced before incidence of the sun's rays to a curve which showed no sign of the discontinuity of the initial conditions showed that the effect of the inertia of the galvanometer was practically insensible, provided at least a very few seconds were allowed for the instrument to get into train, that is, provided a minute portion of the curve, near the point of sudden change in the conditions, were excluded in the reduction.

The galvanometer was dead-beat, but it is conceivable that the damping force might have been such as to cause a sensible difference between the angular position of the mirror of the galvanometer and that corresponding to equilibrium between the torsional force at the moment and the deflecting force belonging to the thermo-electric current at the same moment. A special experiment showed, however, that such was not the case, and that the difference between the actual position and that corresponding to equilibrium was practically insensible, provided a very few seconds were allowed to elapse after any sudden change of the nature of letting on or cutting off the sun's light.

It follows from this that the simple differential equation mentioned in the report of the Committee for 1892 may be used in this case as well as when the solar rays actuated an internal thermometer. The integral of the differential equation shows that the curve is a logarithmic curve, the parameter of which, or index of the exponential, is constant, provided the constant relating to cooling, the q of that report, is the same under all circumstances.

Measurement of the curves obtained showed that they agreed extremely well with logarithmic curves. Any two logarithmic curves, of which the parameter is the same, may be superposed by moving one relatively to the other without disturbing the parallelism of their axes, but not if the parameters are different. In general the curves obtained seemed to be sensibly superposable, indicating that q was not merely constant during an exposure made under given circumstances, but even when the circumstances were different; as, for example, when one diaphragm was replaced by another of twice the area. In one case, however, it seemed that the coefficient was slightly but sensibly smaller. The constancy or otherwise of q is a point still under examination. Should it prove to be sensibly different when the circumstances are changed, the expression may still be obtained from three observations, that is, from three points of the curve. If, for the sake of simplifying the formula, the intervals of time are chosen equal, the expression $(\Delta u)^2/(-\Delta^2 u)$ has merely to be multiplied by q, the expression for which need not at present be written down, in order to obtain a measure of the radiation. It may be well to remark that this measure is merely relative; the question of obtaining the radiation in absolute measure is one into which the Committee have not as yet entered.

Bibliography of Spectroscopy.—Report of the Committee, consisting of Professor HERBERT MCLEOD, Professor W. C. ROBERTS-AUSTEN, Mr. H. G. MADAN, *and* Mr. D. H. NAGEL.

THE work of collecting and arranging the titles of papers on subjects related to spectroscopy has been continued up to the present date.

In the Report presented by the Committee last year it was proposed to discontinue the work at the end of 1895, and it was suggested that the four sections of the list of titles should be printed as a separate publication. In view, however, of the meeting of the International Committee to consider the preparation of a catalogue of scientific literature, the Committee now proposes to continue the work up to the year 1900, so as to complete the list up to the time when the International Bureau will commence its labours.

The Committee, therefore, asks for reappointment.

The Electrolytic Methods of Quantitative Analysis.—Third Report of the Committee, consisting of Professor J. EMERSON REYNOLDS (*Chairman*), Dr. C. A. KOHN (*Secretary*), Professor P. FRANKLAND, Professor F. CLOWES, Dr. HUGH MARSHALL, Mr. A. E. FLETCHER, Mr. D. H. NAGEL, *and* Professor W. CARLETON WILLIAMS.

THE bibliography of the subject having been completed for the last Report, the Committee have been able to give their full time to experimental work during the past year. In addition to the appended results on the arrangements adopted for the work, the determination of bismuth, antimony and tin, and the separation of the two latter, the work on the determination of cobalt, nickel and zinc is well advanced, and will be included, together with further work on bismuth, in the next Report of the Committee.

The Determination of Bismuth. (Part I.) By Professor J. EMERSON REYNOLDS, *D.Sc., M.D., F.R.S., and* G. PERCY BAILEY, *B.A.*

Bibliography.

Author	Journal	Year	Vol.	Page	Composition of Electrolyte
Luckow, C.	Dingler Polyt. J.	1864	178	42	Sulphuric acid
Luckow, C.	Zeits. anal. Chem.	1880	19	1	Nitric acid
Classen, A., and Reis, M. A.	Ber.	1881	14	1622	Ammonium oxalate and nitric acid
Thomas, N. W. & Smith, E. F.	Amer. Chem. J.	1883	5	114	Sulphuric acid; Citric acid and sodium hydrate; Citric acid
Wieland, J.	Ber.	1884	17	1611	Oxalic acid; Nitric acid
Smith, E. F., & Knerr, E. B.	Amer. Chem. J.	1885	8	206	Sulphuric acid
Classen, A., and Ludwig, R.	Ber.	1886	19	323	Potassium and ammonium oxalates
Moore, T.	Chem. News	1886	53	209	Phosphoric acid
Brand, A.	Zeits. anal. Chem.	1889	28	581	Sodium pyrophosphate, ammonium carbonate, and ammonium oxalate
Vortmann, G.	Ber.	1891	24	2749	Hydrochloric acid and potassium iodide; *as amalgam*; Hydrochloric acid and alcohol; *as amalgam*; Nitric and tartaric acids; *as amalgam*; Ammonium hydrate and tartaric acid; *as amalgam*
Rüdorff, F.	Zeits. angew. Chem.	1892	—	198	Sodium pyrophosphate, potassium oxalate, and potassium sulphate
Freudenberg, H.	Zeits. phys. Chem.	1893	12	97	Sulphuric acid
Smith, E. F., & Saltar, J. B.	J. Analyt. & App. Chem.	1893	7	128	Nitric acid
Thomälen, H.	Zeits. Electro-Chem.	1894	1	304	Sodium pyrophosphate, potassium oxalate, and sulphate

The examination of methods for the electrolytic estimation of this metal was conducted in the chemical laboratory of Trinity College, Dublin.

The electrolytic department of the laboratory is fitted in the usual way. The currents required are derived from the 'Bristol' type of storage cells, made up in sets of six in each case, with connections so arranged that currents of 2 amperes and 4, 8, or 12 volts can be obtained as required. These cells, which are compact and light, have given very satisfactory results during two years' frequent use, and are now in perfectly good order.

The measurements of currents for most purposes is effected by the usual gravity ammeters indicating 0·5 to 2 amperes, but much smaller currents than 0·5 ampere must be used in bismuth estimations; the most satisfactory mode of measuring them was by means of a delicate astatic galvanometer, with silk fibre suspension, and carefully calibrated in the position in which it was used. A curve was plotted for converting deflections into amperes, so that 0·01 ampere could be read directly, and 0·001 ampere current measured by interpolation. Provision was also made for shunting in a gravity voltmeter.

For bismuth estimation a box of coils giving high resistances was used for regulating the current, as the platinoid spiral with slide, in genera' use in the laboratory, did not offer more than 30 ohms resistance.

A long series of preliminary experiments made with bismuth nitrate solutions and different forms of electrodes indicated :—

1. That the conical form of negative electrode is not suitable for use in the estimations of bismuth, as it is difficult to get good adherent deposits on the cones, unless the solutions are very dilute.

2. That the large, smooth surface of a carefully spun platinum dish is best suited for the negative pole in bismuth estimations. The dishes used in the test estimations weighed from 35 to 38 grammes, and the internal areas averaged 190 square centimetres.

3. That a large flat spiral of platinum wire for the positive electrode is more satisfactory than a disc, as it allows free circulation in the liquid.

A large number of experiments were made in the first instance with a view to ascertain the kind of solution most convenient for electrolysis, the nitrate or sulphate being used as the starting point in the production of the different liquids actually electrolysed. Irregular results were obtained with the simple nitrate containing varying proportions of free nitric acid; but good determinations were more easily made in solutions of the sulphate when electrolysed by currents of 0·08 to 0·2 ampere.

On the other hand, for the purposes of actual analysis, it seemed of more practical importance to ascertain how far the more convenient nitrate solution could be made to afford good reguline deposits of bismuth, which should admit of washing without loss or material oxidation. It was found that careful adjustment of the current is one of the elements of success, but not the only one, and that 0·03 ampere is the maximum current that should be used nearly to the end of the operation, though 0·1 may be passed to complete deposition. Regulation of the current did not alone prove sufficient to neutralise the effect of excess of nitric acid, and most of the substances were tried which have been recommended for use in similar electrolyses. Of these, metaphosphoric acid and citric acid proved so much better than any others we employed that our attention was directed chiefly to examine their effects in test experiments with bismuth nitrate.

Test Experiments.

The bismuth used in the preparation of the test solutions was carefully purified. In the first instance it was repeatedly fused with small quantities of nitre and cast. This metal was then heated to low redness for fifteen minutes with potassium cyanide and sulphur, with constant stirring; was again cast, and reheated to bright redness with 5 per cent. of a mixture of pure sodium and potassium carbonate. The fine metal so obtained was dissolved in nitric acid, the solution evaporated to a small bulk, and then precipitated as oxynitrate by water. The washed product was again dissolved in nitric acid, and was fractionally precipitated by ammonia, the first and last fractions being rejected. The middle fraction, after thorough washing, was preserved and used in the preparation of the final test solutions of bismuth.

The first solution of bismuth nitrate prepared contained, in 25 c.c., 0·125 grme. of bismuth. This contained a sufficient excess of nitric acid to prevent precipitation unless diluted with about ten volumes of water.

In the following series of estimations 25 c.c. of the solution were used in each case, and either diluted to 150 c.c. in a platinum dish with water only, or made up to the total volume of 150 c.c. with water after addition of the various substances stated below. The electrolysis was then commenced with the current specified, and the action usually allowed to continue all night. At the end the current was generally increased, in order to complete the deposition.

As slight oxidation takes place at the edge of the liquid even with apparently very good reguline deposits, the latter, when washed, dried, and weighed, were in some cases oxidised by nitric acid, the solution carefully evaporated to dryness, and heated until the bismuth nitrate was converted wholly into Bi_2O_3. From the oxide obtained the weight of Bi was then calculated. This operation is easily executed in the electrolytic dish, and was found to be a useful check, especially when the results of electrolysis seemed too good.

0·125 grme. Bi in solution diluted to 150 c.c.	Currents in Amperes	Bi as Metal grme.	Bi from Bi_2O_3 grme.	Remarks
1. Water and Nitrate only	0·008 increased at end to 0·05	0·13	—	Loose deposit, evident oxidation.
2. Ditto . . .	0·05	0·1238	—	Loose, but reguline.
3. +2 c.c. strong Metaphosphoric acid solution	0·02	0·124	—	Very firm deposit, easily washed. No apparent oxidation.
4. +2 c.c. HPO_3 solution	0·03 increased to 0·05 at end	0·127	—	Not so firm, and not perfectly reguline.
5. +4 c.c. HPO_3 solution	0·03 to 0·05 at end	0·125	0·1248	Very firm and reguline; easily washed.
6. +1 grme. of Citric Acid	0·008 to 0·01	0·130	0·1238	Firm, but coloured owing to oxidation.
7. +1 grme. of Citric Acid	0·01 to 0·05	0·126	—	Firm good deposit; slightly oxidised.
8. +2 grmes. of Citric Acid	0·01	0·1246	—	Very firm, easily washed, and apparently unoxidised.
9. +2 grmes. of Citric Acid	0·01	0·1246	0·1246	" "
10. +2·5 grmes. of Citric Acid	0·01 to 0·1 at end	0·125	0·1249	" "
11. +2·5 grmes. of Citric Acid	0·01 to 0·1 at end	0·125	0·1247	" "
12. 0·05192 grme. of Bi as Nitrate + 2·75 grme. Citric Acid	0·005 to 0·01 at end	0·0526	0·052	" "
13. 0·07 grme. of Bi as Nitrate + 2·2 grme. of Citric Acid	0·005 to 0·01 at end	0·07	0·0697	" "

Operating in this way, the results on the preceding page, from 1 to 11, were obtained with 25 c.c. of bismuth nitrate solution=0·125 grme. of Bi diluted to 150 c.c.

Experiments 12 and 13 were made with solutions of different strengths and larger proportions of nitric acid than those which precede.

So far as experiments with the simple nitrate solutions were concerned the results merely confirmed all our previous experience, as it is very difficult to obtain a good adherent deposit on electrolysis except from very dilute solutions.

The results obtained with metaphosphoric acid under the conditions specified indicate that the reagent controls deposition in a very marked way, and enables us to get good adherent reguline deposits even in presence of much free nitric acid and when using a comparatively strong current. The use of metaphosphoric acid is therefore attended with considerable advantage in the case of simple bismuth nitrate solutions.

Citric acid has proved quite as effective as metaphosphoric acid, and gives a wider range of utility in general analysis. Moreover bismuth can be separated from alkaline citrate solution in good condition and with considerable accuracy; hence we are disposed to prefer the use of citric acid to that of metaphosphoric acid in electrolytic determinations of bismuth.

The separation of bismuth from stronger solutions and from other dissolved metals will be considered in the next report.

The Apparatus employed and the Arrangement of the Circuits for Electrolytic Analysis. By CHARLES A. KOHN, *Ph.D., B.Sc.*

The arrangements for electrolytic work described in this portion of the Report have been fitted up in the Chemical Laboratory of University College, Liverpool, where the work on the determination of antimony and tin and their separation has been carried out.

A set of five secondary cells charged by a dynamo were employed throughout the analyses.

Electrodes.

Platinum dishes of about 200 c.c. capacity, and weighing 37–38 grme., were used as the cathode, and small platinum discs with holes bored through them to admit of the escape of the evolved gases as the anode. For the determination of both antimony and tin, sand-blasted platinum dishes were found preferable to the ordinary polished dishes; this is especially the case when the deposition of a metal is effected from a hot solution. The electrodes were kept 20 mm. apart. Glass stands with brass supports as described by Classen were used to hold the electrodes, the support for the dishes being covered with an asbestos card when heating was necessary.

Voltmeter and Ampere-meter.

A suitable ampere-meter for electrolytic analysis has long been a desideratum. The use of the water voltameter which was formerly employed has for obvious reasons been abandoned, and the ampere-meters on the market are almost all either too restricted in their range or lacking in sensibility; in addition their internal resistance is so high that it must always be allowed for whenever the instrument is not in circuit. The

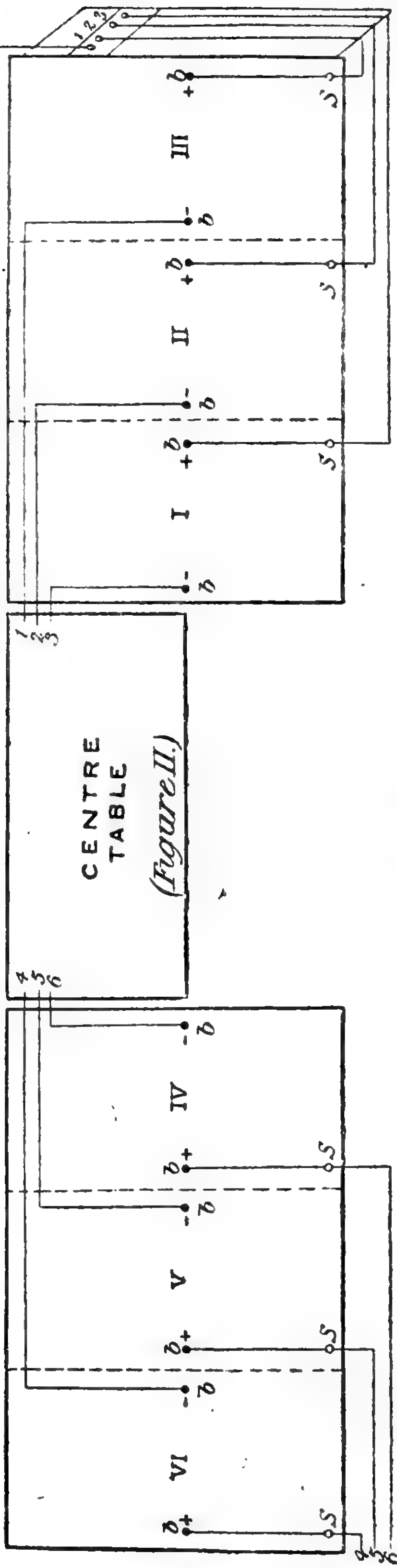


FIG. 1.—Arrangement for Six Circuits.

unipolar instruments recently devised by Mr. B. Davies, of University College, Liverpool, fulfil all the requirements for electrolytic work admirably, and they have been used for the past two years with complete satisfaction. The ampere-meter possesses two marked properties which are especially advantageous :—

1. A very open scale, especially open for the lower readings.

2. A practically negligible resistance.

I am indebted to Mr. Davies for the following description of his instruments :—

The construction of the voltmeter and the ampere-meter depend upon the same principle, the rotation of a coil conveying a current around one pole of a magnet. The *magnetic circuit* is composed almost entirely of iron and steel, with an air-gap of 2 mm. in thickness. The steel is carefully magnetised and '*aged*,' and the circuit is so designed that the demagnetising force is negligible. The chief part of the electric circuit is the moving coil, which conveys the current, or a portion of the current to be measured.

In the voltmeter the coil is placed in series with a resistance of manganin; in the amperemeter it is placed in parallel with a small resistance. The whole length of the scale is about 220° of arc. Currents of all magnitudes may be measured from $\frac{1}{1000}$ ampere upwards, and electromotive forces from $\frac{1}{100}$ volt upwards. Both instruments are practically 'dead-beat'; this is not due to friction, the pivots being jewelled, but is an electro-magnetic effect. The internal resistance of the amperemeters is shown in the following table :—

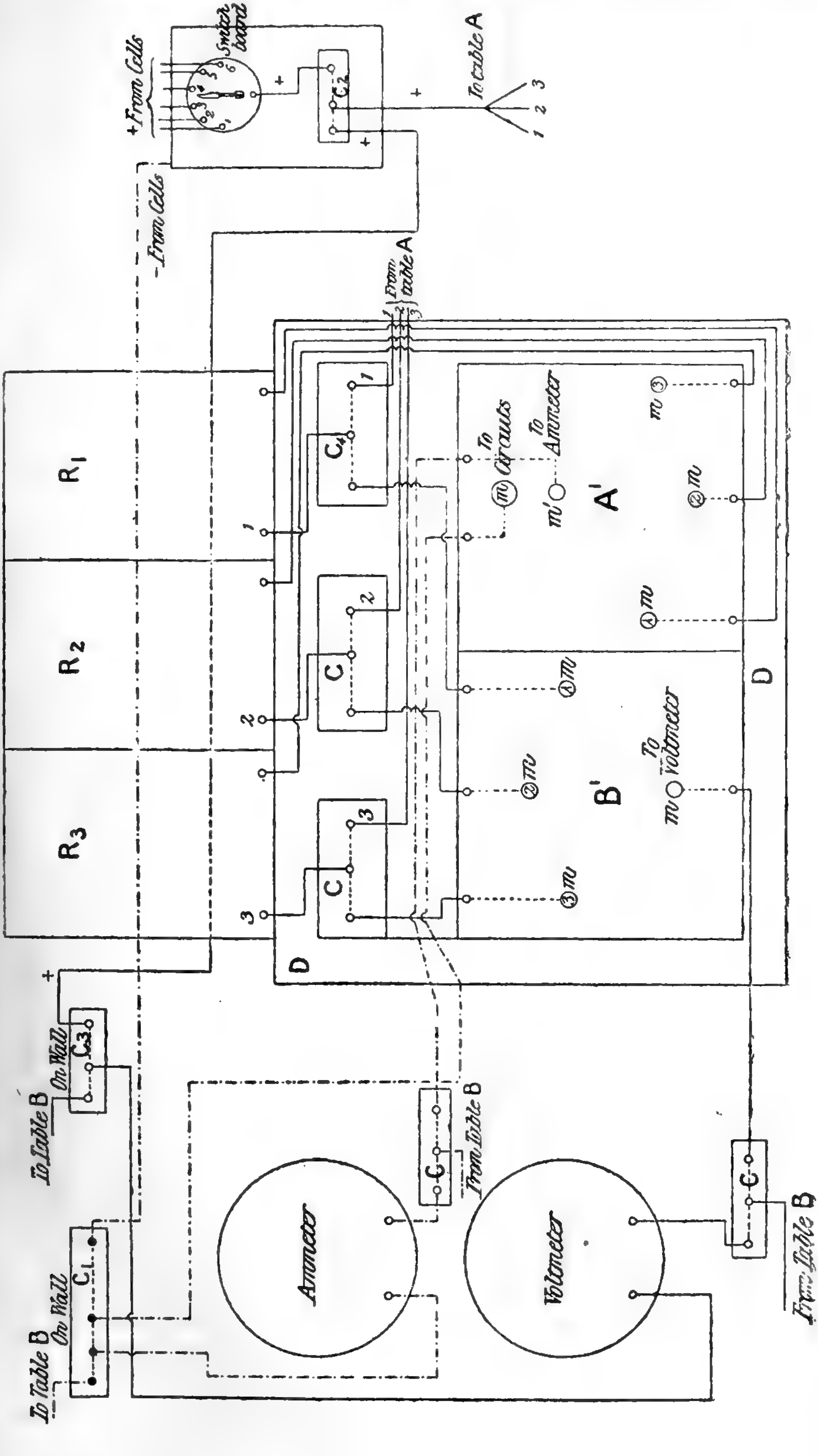


FIG. 2.—Centre Table, showing connections from Table A to Ammeter, Voltmeter, and Resistances.

Scale – 1 : 4.

Range of Ampere-meter	Resistance
0 – 0·1 ampere	0·4 ohm
0 – 1 „	0·08 „
0 – 10 „	0·008 „
0 – 100 „	0·0008 „

The ampere-meter actually employed had a range of from 0–3·5 amperes, the graduations corresponding to 0·02 of an ampere. The internal resistance was 0·03 ohm, and the readings above 0·1 ampere perfectly accurate and constant. For currents below 0·1 ampere an instrument with the range 0 to 0·1 ampere must be substituted, but such small currents are not required for the experiments described in this portion of the report. Small rheostats with mercury connections were used as resistances, one for each circuit, each having a series of resistance coils from $\frac{1}{2}$ up to 40 ohms, and a total resistance of $80\frac{1}{2}$ ohms.

The current density is in all cases calculated on 100 sq. cm. of cathode surface, and expressed as $C.D._{100}$.

Arrangement of the Circuits.

The accompanying plans show the arrangement adopted for six circuits.

The tables A and B are each divided into three parts by thin strips of wood, the current being carried in each case by wires from the brass terminals '*b*' to the stand for the electrodes, which is placed between them. The circuit is completed or broken by an ordinary electric light switch, 'S.'

The centre-table contains all the connections to the ampere-meter, voltmeter, and resistances, in addition to the instruments themselves, thus leaving the tables on which the analyses are carried out perfectly free; this is a decided convenience. This centre-table is provided with a flap-cover, so that the instruments are protected, except when measurements are being taken.

The details of the connections on the centre-table for three of the circuits are shown on Fig. 2. The board D D, which is fixed on to the centre-table, carries two small boards A′ and B′, fitted with mercury-cup connections '*m*'; it also carries three small blocks, C, on each of which are fixed three brass binding-screws, connected underneath by a broad copper strip. R_1, R_2, and R_3 are the resistance boxes.

The negative wire from the secondary cells passes direct to the connecting board C_1, fixed on the wall at the back of the tables, the remaining wires from the batteries passing to the switch-board (Fig. 2), so that any number of cells from one up to six can be put into use. From the terminal of the switch-board a wire passes to the connecting board C_2, and thence to the table A, where it is divided in parallel into the three circuits 1, 2 and 3 by a small connecting board which, together with the necessary wiring, runs under the ledge of the table A (Fig. 1). The circuit is completed from the connecting board C_1 through the mercury cup '*m*' on the board A′ (Fig. 2), marked 'to circuits.' This cup is connected to the other cups 1, 2 and 3 on the same board by spanners of stout copper wire with ebonite handles. The resistance of the spanner is negligible, as is that of the ampere-meter, but in cases where that of the latter has to be considered, a spanner must be used, having an equivalent resistance. Similar spanners are used for the ampere-meter and voltmeter connections; they are all of different lengths so as to prevent mistakes in taking measurements. Supposing the spanner be put to circuit No. 1, the current passes through the resistance box R_1, then to the block C_4, and finally to the table A to complete the circuit. By placing the spanner between m_1 and the cup on the board A′ leading to the ampere-meter, m', the current is similarly completed through the ampere-meter, so that the reading is taken without stopping the current. The connections to the voltmeter will be clear from the diagram; it is simply a branch from each of the circuits.

The Determination of Antimony. *By* Charles A. Kohn, *Ph.D., B.Sc.,* *and* C. K. Barnes, *B.Sc.*

Bibliography.

Author	Journal	Year	Volume	Page	Composition of Electrolyte
Parodi, G., and Mascazzini, A.	Zeits. anal. Chem. .	1879	18	587	Ammonium tartrate. Alkali sulphide.
Luckow, C. . .	Zeits. anal. Chem. .	1880	19	1	Hydrochloric acid. Alkali sulphide.
Classen, A., and Reis, M. A.	Ber. . . .	1881	14	1622	Potassium oxalate. Alkali tartrate. Ammonium sulphide.
Classen, A. . .	Ber. . . .	1884	17	2467	Sodium sulphide. Sodium or potassium sulphhydrate.
Classen, A., and Ludwig, R.	Ber. . . .	1885	18	1104	Sodium sulphide.
Brand, A. . .	Zeits. anal. Chem. .	1889	28	581	Sodium pyrophosphate and ammonium carbonate.
Lecrenier, A. . .	Chem. Zeit. . .	1889	13	1219	Sodium sulphide and sodium sulphite.
Vortmann, G. . .	Ber. . . .	1891	24	2749	Sodium sulphide and hydrate *as amalgam.*
Rüdorff, F. . .	Zeits. angew. Chem.	1892	—	3	Sodium sulphide.
Classen, A. . .	Ber. . . .	1894	27	2060	Sodium sulphide.

The deposition of antimony from solutions of its sulpho-salts, as first suggested by Parodi and Mascazzini, and also by Luckow, has been especially studied by Classen and his pupils. Classen finds that a sodium sulphide solution is best adapted for the deposition; the reagent must be free from polysulphides, which, if present, are oxidised by hydrogen peroxide. The deposition is effected in the cold solution with a current of 1·5–2 c.c. of electrolytic gas per minute, and requires 10 to 12 hours. Nissenson states that 0·15 grme. of antimony can be deposited from a solution of the sulpho-salt in one hour by electrolysing the *warm* solution with a current of 0·5–1·0 ampere.

Of other solutions ammonium tartrate has alone been stated to give accurate results, the deposits obtained from hydrochloric acid, potassium oxalate, and sodium pyrophosphate solutions not adhering sufficiently well to the dish to be of value for quantitative determinations.

Experiments were accordingly restricted to the deposition from sodium sulphide and from ammonium tartrate solution.

Deposition of Antimony from Sodium Sulphide Solution.

A hydrochloric acid solution of antimony chloride, prepared from pure antimony, was employed for the experiments, the solution containing just sufficient acid to keep the chloride of antimony in solution. It is important to use pure sodium sulphide; this was prepared from sodium hydrate purified by alcohol, in the usual way, and concentrated to a sp. gr. of 1·18.

After adding the sodium sulphide to the antimony chloride the solution was filtered into a platinum dish, diluted to 175 c.c. with water and electrolysed. The deposited metal was washed successively with alcohol and ether and dried in the air bath at 80° C. before weighing.

SERIES I.

Influence of varying quantities of Sodium Sulphide on the Deposition of Antimony.

The object of this series of experiments was to ascertain how variations in the quantity of sodium sulphide present, in excess, in the solution of the sulpho-salt, affected the deposition of the antimony, and what degree of accuracy was obtainable with varying quantities of metal under the most favourable conditions.

The electrolyses were in all cases conducted in the cold solution and allowed to go over night; an excess of sodium sulphide above that required to form the sodium sulpho-antimonite was always present. The results are recorded in the following table:—

Experiment	Antimony taken: grme.	Antimony found: grme.	Sodium sulphide solution added	C.D.$_{100}$ Amperes	E.M.F. Volts	Time: hours
1	0·1010	0·1065	15 c.c.	0·14	2·5	19½
2	0·1010	0·1076	15 ,,	0·19	3·1	19½
3	0 1010	0 1062	15 ,,	0·15	3·2	19½
4	0·1515	0·1572	22 5 c.c.	0·18	2·9	17½
5	0·0505	0·0516	7·5 ,,	0·17	2·7	17½
6	0·1010	0·1013	30 c.c.	0·19	1·9	18½
7	0·2020	0 2021	30 ,,	0·15	1·7	17½
8	0·2020	0 2023	30 ,,	0·18	2·3	18½
9	0·0505	0·0508	30 ,,	0·19	2·8	17½
10	0·0202	0·0202	30 ,,	0·20	2·1	17½
11	0·0101	0·0100	30 ,,	0·19	1·8	17½
12	0·0505	0·0508	10 ,,	0·20	2·6	18
13	0·0202	0·0204	10 ,,	0 20	2·7	18
14	0·0101	0·0098	10 ,,	0·20	2·5	18

Experiments 1–5 show that with only 15 c.c. of sodium sulphide solution per 0·1 grme. of antimony high results are obtained, whereas with double the proportion the results are accurate (No. 6). But in experiments 7 and 8, although the quantity of sulphide added is double that in 1 and 2, the proportion to the antimony present is the same. This apparent abnormality is due to the fact that unless a certain excess of sodium sulphide is present a small quantity of sulphur is precipitated with the antimony on the cathode, hence the high results 1–6, and the excess of sulphide is necessary to keep this sulphur in solution The proportion of sulphur thus separated at the cathode appears to be independent of the quantity of antimony present, within limits. According to experiment 5, 30 c.c. of sulphide should be insufficient for 0·2 grme. antimony, but Nos. 7 and 8 show that this is not the case; on the other hand, experiment 12 points to 20 c.c. as the right quantity of sulphide per 0·1 grme. of metal. In all cases sulphur is separated at the anode. Whenever it comes down with the antimony at the anode the deposited metal, which is usually bright and metallic in appearance, is always dull and almost black; this was the case in experiments 1–5.

The normal decomposition can be represented by the equation :—

$$2\,Sb \begin{cases} SNa \\ SNa \\ SNa \end{cases} = \underset{Cathode}{Sb_2} + 3Na_2S + \underset{Anode}{S_3}.$$

The separation of sulphur at the cathode must be due to a secondary decomposition, which is prevented provided there is a certain excess of the sulphide present. It appears immaterial whether this excess is increased or not, for in Nos. 9, 10, and 11 three times as much sulphide was added as in Nos. 12, 13, and 14 for the same quantities of antimony. From this the method is reliable, provided 30 c.c. of sodium sulphide of sp. gr. 1·18 are added for every 0·2 grme. of antimony, and up to 50 c.c. can be used with safety. Classen and others recommend this proportion; the above experiments point out the necessity for it.

The current density of 0·15 to 0·20 ampere per 100 sq. cm. should not be exceeded, otherwise the metal does not adhere so well to the electrode. The completion of the deposition is best tested by withdrawing a little of the solution from the dish with a capillary tube, and testing it with acid for the presence of antimony sulphide.

The addition of caustic soda to the sodium sulphide has no disadvantageous effect on the method as described. Under similar conditions to the above, in which 30 c.c. of sulphide solution and 2 grme. of sodium hydrate were added, 0·1514 grme. antimony were found for 0·1515 taken. Caustic soda is added in the separation of antimony and tin electrolytically, hence it was desirable to ascertain its influence, if any.

The solutions of the sulpho-salt were quite free from polysulphides, but should these be present they must be oxidised with hydrogen peroxide.

Series II.

Deposition of Antimony from a WARM *Solution of the Sulpho-salt.*

The time required for the deposition of antimony is considerably shortened by conducting the electrolysis in the warm solution. The antimony solution is treated with sodium sulphide as described, and electrolysed with a current of 1 ampere; 0·2 grme. of metal can be readily deposited in $2\frac{1}{2}$ hours. Under the right conditions the deposit is bright and metallic in appearance. The following table records the results obtained :—

Experiment	Antimony taken: Grme.	Antimony found: Grme.	Sodium Sulphide. Solution added	$C.D._{100}$ Amperes	E.M.F. Volts	Temperature	Time: hours
1	0·2020	0·2090	30 c.c.	0·98	6·1	50°–60°	$2\frac{1}{3}$
2	0·2020	0·2028	50 c.c.	1·04	6·5	50°–60°	$2\frac{1}{2}$
3	0·1010	0·1009	50 c.c.	1·00	6·7	50°–65°	$2\frac{1}{2}$
4	0·0505	0·0502	50 c.c.	0·94	6·7	50°–65°	$2\frac{1}{2}$
5	0·0202	0·0213	50 c.c.	0·97	6·4	50°–65°	$2\frac{1}{2}$
6	0·0101	0·0093	50 c.c.	1·01	6·4	50°–65°	$2\frac{1}{3}$
7	0·2020	0·2000	50 c.c.	1·03	6·1	80°–90°	$2\frac{1}{3}$

The deposits in Nos. 1 and 7 were dull and dark coloured; this is to be traced to an insufficiency of sodium sulphide in No. 1, and too high a temperature in No. 7. With 50 c.c. of sodium sulphide solution the method is reliable, as shown in Nos. 2 to 6, though rather less so for small quantities of metal than when the electrolysis is conducted in the cold solution. The temperature should not exceed 50° to 60°. The deposit is bright and metallic in appearance, and adheres well to the dish.

SERIES III.

Deposition of Antimony from Ammonium Tartrate Solution.

Parodi and Mascazzini (*loc. cit.*) state that antimony can be deposited from a solution of its chloride in ammonium tartrate, but give no experimental data. According to Classen an adherent deposit is obtained from a potassium tartrate solution, but the separation takes too long to be of value for analysis. As very few results have been published on this method a series of experiments were tried. These show that the complete deposition of antimony from a solution of an alkali tartrate is possible, in about nineteen hours, with a current density per 100 sq. cm. of 0·15 ampere. The deposit, however, does not possess the bright metallic appearance of that obtained from sodium sulphide solution; it is dark and dull and does not adhere very fast to the dish. Still it can usually be washed without loss, although with quantities of metal, above 0·1 grme., this was not possible, hence the low result in No. 1. Also when the current is allowed to exceed 0·15 ampere per 100 sq. cm. the deposit is less adherent and apt to wash off. Nos. 2, 9, and 10 illustrate this. The method of analysis was to neutralise the solution of antimony chloride and add the ammonium tartrate in a 12 per cent. solution, the electrolysis being conducted in the cold solution and over night. The following results were obtained:

Experiment	Antimony taken: Grme.	Antimony found: Grme.	Ammonium Tartrate added: Grme.	$C.D._{100}$ Amperes	E.M.F. Volts	Time: hours
1	0·2036	0·2020	3	0·15	3·6	18½
2	0·2036	0·2003	3	0·18	3·6	18½
3	0·1018	0·1018	2·5	0·14	3·7	19
4	0·1018	0·1019	4	0·13	3·7	19½
5	0·1141	0·1140	6	0·14	3·3	19
6	0·1141	0·1142	6	0·15	3·4	19
7	0·1018	0·1025	3	0·13	3·3	18½
8	0·0509	0·0504	3	0·15	3·4	18½
9	0·1018	0·0983	3	0·18	3·5	18½
10	0·0509	0·0477	3	0·18	3·7	18½

Variations in the quantity of ammonium tartrate added above 2·5 grme. have no influence on the accuracy of the method, as is seen from Nos. 3, 4, and 5.

Summary.

The most reliable method for the electrolytic estimation of antimony is the use of the sulpho-salt in presence of a large excess of sodium sulphide, under the conditions already described. This solution can be electrolysed either hot or cold; the latter is always preferable when only small quantities of antimony are to be deposited. The saving of time by using the warm solution is no great advantage, as the deposition from the cold solution requires no watching and can be allowed to go on overnight.

Although accurate results can be obtained by electrolysing an ammonium tartrate solution of an antimony salt the method requires much greater attention and the conditions are more limited than the above; it is, therefore, not to be recommended from a practical standpoint, whereas the deposition from a solution of the sulpho-salt possesses advantages over the ordinary gravimetric methods for the determination of antimony both in regard to rapidity and accuracy.

The Determination of Tin. By CHARLES A. KOHN, *Ph.D., B.Sc., and* C. K. BARNES, *B.Sc.*

Bibliography.

Author	Journal	Year	Vol.	Page	Composition of Electrolyte
Luckow, C.	Zeits. anal. Chem.	1880	19	1	Hydrochloric acid. Alkali sulphide.
Classen, A., and Reis, M. A.	Ber.	1881	14	1622	Hydrochloric acid. Ammonium oxalate.
Classen, A.	Ber.	1884	17	2467	Ammonium sulphide.
Moore, T.	Chem. News	1886	53	209	Phosphoric acid.
Rüdorff, F.	Zeits.angew.Chem.	1892	—	197	Acid ammonium oxalate.
Freudenberg, H.	Zeits. phys. Chem.	1893	12	97	Ammonium oxalate.
Classen, A.	Ber.	1894	27	2060	Acid ammonium oxalate. Ammonium oxalate and acetic acid.
Thomälen, H.	Zeits. Electrochem	1894	1	304	Acid ammonium oxalate.
Engels, C.	Zeits. Electrochem	1896	2	413	Hydroxylamine sulphate. Ammonium acetate, tartaric acid and Hydroxylamine hydrochloride.

Luckow states that tin can be deposited from a hydrochloric acid solution, or from a solution of the sulphide in alkali sulphide; but no analytical data are given in his paper. According to Classen and Reis (Ber., 1881, **14**, 1622) fair results are obtained by using a hydrochloric acid solution; but the most important methods are those in which an ammonium oxalate or an alkali sulphide solution are employed. The experimental work has therefore been confined to these methods. Moore states that tin is easily deposited from an acid or alkaline solution of the metal in glacial phosphoric acid, but gives no details or experimental data; the method has not been tried.

The Deposition of Tin from an Ammonium Oxalate Solution.

The separation of stannic acid during the electrolysis of ammonium oxalate solutions of tin salts, owing to the solution becoming alkaline, renders it necessary to keep the solution acid during the electrolysis. Classen uses either oxalic acid or acetic acid for this purpose; in both cases a $C.D._{100}$ of 0·3 ampere is employed, which is increased to 0·5 or even 1·0 ampere towards the end of the experiment. 0·3 grme. of metal are deposited in from 6 to 9 hours, according to the strength of the current. Freudenberg has found that in an E.M.F. of 2·3 to 2·7 volts is required to separate tin from an oxalate solution.

A large number of experiments were made with ammonium oxalate solutions, under varying conditions, typical results of which are recorded. The method was not found to be reliable. It is very difficult to effect the complete deposition of the tin before the solution becomes alkaline unless a large excess of acid is employed, and this very much retards the rate of deposition. An increase in current density might overcome this, were it not that the deposit then obtained is always more or less powdery in form, and does not adhere sufficiently well to the dish to admit of being washed without loss. The method can be made to yield fair results if the solution be kept *just acid* throughout the electrolysis by the addition of oxalic or acetic acid from time to time, as required (Series II.); but such a procedure requires constant attention, thus withdrawing at once one of the most marked advantages of electrolytic analysis.

The tin solution used in the following experiments was prepared by dissolving pure tin in pure hydrochloric acid, the acid solution being neutralised with ammonium hydrate before use and diluted to 175 c.c. The other solutions employed were:—

Ammonium oxalate . . .	40 grme. per 1000 c.c.
Oxalic acid	80 ,, ,,
Acetic acid	50 per cent. solution.

PRELIMINARY EXPERIMENTS, in which 120 c.c. of the ammonium oxalate solution were added for 0·1 grme. of tin, showed that the solution becomes alkaline and separates stannic acid after 6 hours, during which time only 60–70 per cent. of the metal is precipitated. The decomposition may be represented by the equation:—

$$\text{(i.)}\ \begin{matrix}CO.ONH_4\\CO.ONH_4\end{matrix} + \begin{matrix}CO.O\\CO.O\end{matrix}\!\!>\!Sn = \underbrace{Sn + H_2 + 2NH_3}_{Cathode} + \underbrace{4CO_2}_{Anode}$$

$$\text{(ii.)}\ 2NH_3 + 2CO_2 + 2H_2O = 2NH_4.HCO_3.$$

Hence the alkalinity of the solution, which must be overcome to prevent the precipitation of stannic acid.

EXPERIMENTAL DATA.

SERIES I.

Ammonium Oxalate Solution Acidified with Oxalic Acid.

Experiment	Tin taken: Grme.	Tin found: Grme.	Ammonium oxalate solution added, c.c.	Oxalic acid solution added, c.c.	$C.D._{100}$ Ampere	E.M.F. Volts	Time: hours
1	0·1050	0·0670	100	50	0·4	3·4	$5\frac{1}{4}$
2	0·0525	0·0247	100	50	0·4	3·0	$5\frac{1}{4}$
3	0·1050	0·0669	100	50	0·3	3·2	$8\frac{1}{2}$
4	0·0201	0·0158	100	50	0·3	3·2	$8\frac{1}{2}$
5	0·1026	0·1015	80	40	0·2–0·5	2·8–3·7	8
6	0·1026	0·1009	80	40	0·25–0·5	2·6–3·2	$8\frac{1}{2}$
7	0·1026	0·0939	80	40	0·24–0·52	2·8–3·5	9
8	0·1026	0·0849	80	40	0·23–0·5	3·3–3·5	9
9	0·1050	0·1030	100	50	0·9–1·2	3·5	6
10	0·1050	0·1042	100	50	0·5–1·0	3·5	7
11	0·1050	0·0740	100	50	0·8–1 0	3·5	6 hot
12	0·1575	0·1526	100	50	0·5	2·8	9 hot
13	0·1050	0·1055	100	75	0·5	2·7	$5\frac{1}{2}$
14	0·1575	0·1250	100	75	0 5	2·6	$5\frac{1}{2}$
15	0·2100	0·2061	100	75	0·5–1·0	3·1–3·8	$6\frac{1}{2}$

The above results are taken from forty-five experiments carried out. In each case the electrolysis was continued until after the solution became alkaline; after the solution has turned alkaline, the further deposition of tin is extremely slow, only 2–3 m. grmes. being deposited by a current of 0·5 ampere in twelve hours. Although a few fair results are recorded above

(Nos. 5, 9, 10 and 13), it is quite evident that the method is unreliable. With a current density of 0·3 to 0·5 ampere, either throughout the experiment, or increased up to 1·0 ampere towards the completion of the electrolysis, as in Nos. 9, 10, the deposition is incomplete, and no advantage is gained by *warming the solution* to 60°–70° C. as in Nos. 11 and 12. The deposits obtained were bright and metallic in appearance.

Series II.

Ammonium Oxalate Solution kept just Acid *by Oxalic Acid.*

Tin taken: Grme.	Tin found: Grme.	Ammonium oxalate solution added, c.c.	Oxalic acid solution added	
			At start	During experiment
0·2160	0·2160	80	40	65
0·2376	0·2382	80	40	60
0·1050	0·1048	100	—	80

In the above three experiments the solution was kept acid throughout the electrolysis by the addition of oxalic acid from time to time; the first addition of acid was necessary after four hours. The results are satisfactory, but the deposits were somewhat powdery in appearance, and required very careful washing. In each case a current of 0·54 ampere was employed, and an E.M.F. of 3·5 volts; the electrolysis was completed after 9½ hours, when the solutions had become alkaline.

Series III.

Ammonium Oxalate Solution Acidified with Acetic Acid.

Experiment	Tin taken: Grme.	Tin found: Grme.	Ammonium oxalate solution added, c.c.	Acetic acid solution added, 50 per cent. c.c.	$C.D_{100}$ Ampere	E.M.F. Volts	Time: hours
1	0·2268	0·2274	100	25	0·67	3·2	9
2	0·2592	0·2576	100	25	0·68	3·3	9½
3	0·2052	0·2041	100	25	0·50	3·3	18½
4	0·2052	0·2034	100	25	0·32	3·3	19
5	0·1539	0·1548	100	25	0·54	3·7	18½
6	0·1539	0·1537	100	25	0·32	3·2	19
7	0·1026	0·1021	100	25	0·28	3·0	19
8	0·1026	0·1012	100	25	0·51	3·4	18½
9	0·1026	0·1024	100	25	0 31	3·4	19½
10	0·0513	0·0518	100	10	0·30	3·7	18½
11	0·0205	0·0208	100	10	0·32	3·6	18½
12	0·01025	0·0103	100	10	0·35	3·2	18½
13	0·1026	0·1009	100	10	0·36	3·7	19
14	0·1026	0·1025	100	15	0·31	3·2	19
15	0·1026	0·1031	100	25	0·34	3·7	19

The tin solution used was the same as in the previous series of experiments; the total contents of the dish were diluted to 175 c.c. in each case, after the addition of the reagents.

Experiments 1 and 2 show that the deposition of tin from an ammonium oxalate solution acidified with acetic acid is fairly complete in from nine to ten hours, with a current of 0·7 ampere, but the deposit obtained is powdery and difficult to wash without loss. By employing a weaker current and allowing the electrolysis to proceed overnight, the deposit obtained is far better; it is dark in colour, but adheres perfectly to the dish, and the results are altogether more reliable. A current of 0·3 ampere is best, and 18–19 hours must be allowed for the complete deposition even of such small quantities as taken in Nos. 10, 11, 12, for the last traces are only very slowly separated from solution. If a stronger current (1·0 ampere) be employed the deposit does not adhere properly. The only way to tell whether the deposition is complete is to expose a fresh portion of the surface of the cathode to the solution, by diluting the contents of the dish, and to observe whether any more metal is separated after continuing the passage of the current for one hour; none of the ordinary tests for tin are sufficiently delicate to indicate the completion of the electrolysis. A comparison of Nos. 13, 14, 15, in which the amount of acetic acid added was varied, show that from 15–25 c.c. of a 50 per cent. solution of acetic acid is most favourable. The larger quantity was found the more reliable.

This method may be regarded as giving accurate results under the conditions mentioned; but it is extremely important to keep the current steady, and not to exceed 0·3 to 0·4 ampere per 100 sq. cm. of cathode surface, otherwise it is impossible to be certain of a firm deposit.

SERIES IV.

Ammonium Oxalate Solution in Presence of Oxalic Acid and Hydroxylamine Sulphate.

Engel (*loc. cit.*) has recently shown that the electrolytic determination of tin is accurately effected in a neutral solution, either by the addition of hydroxylamine sulphate alone, or of the sulphate or hydrochloride in addition to ammonium acetate and tartaric acid. The presence of such a reducing agent as hydroxylamine prevents the separation of stannic acid during the electrolysis. Such an action is just what is required to render the deposition of tin from ammonium oxalate solution reliable, and the following experiments show that it acts favourably in the desired direction.

Experiment	Tin taken: Grme.	Tin found: Grme.	Ammonium oxalate solution added: cc.	Oxalic acid solution added: c.c.	Hydroxylamine sulphate added: grme.	C. D.$_{100}$ Ampere	E.M.F. Volts	Time: hours
1	0·0986	0·0980	80	40	0·4	0·26	2·8	18½
2	0·0986	0·0981	80	40	0·4	0·26	2·8	19½
3	0·0986	0·0986	80	40	0·4	0·27	3·0	19½
4	0·0493	0·0497	80	40	0·4	0·26	3·1	19
5	0·1972	0·1946	80	40	0·4	0·27	3·0	19

The previously mentioned solutions of ammonium oxalate (40 grme. per litre) and of oxalic acid (80 grme. per litre) were used in these experiments, and the tin solution was prepared as described. The solution of stannous chloride was neutralised before the addition of the reagents. A small current was purposely employed in order to secure a firm deposit; the deposit obtained was quite satisfactory in all cases. The deposition is incomplete in No. 5, showing that an increase of current or continuation of the electrolysis was required. In each experiment the solution had become alkaline, however, and this fact is undoubtedly the cause of the slow rate of deposition. The results are interesting, inasmuch as they show the possibility of keeping the tin in solution during the electrolysis, but, from an analytical standpoint, the method possesses no advantages over that described in Series II and III.

Series V.

Ammonium Sulphide Solution.

Luckow and Classen (*loc. cit.*) have both suggested the deposition of tin from a solution of a sulpho-salt, and the latter records a number of accurate results obtained by employing the ammonium sulpho-salt. The following experiments show that the method is reliable and rapid. The tin solution, prepared in the manner previously described, was neutralised with ammonium hydrate, and sufficient pure ammonium sulphide added to form the sulpho-salt, the whole being then diluted to 175 c.c. before being electrolysed.

Experiment	Tin taken: Grme.	Tin found: Grme.	C. D. $_{100}$ Amperes	E.M.F. Volts	Time: hours
1	0·1026	0·1032	1·18	7·3	$5\frac{3}{4}$
2	0·1026	0·1026	1·19	7·7	$5\frac{3}{4}$
3	0·1026	0·1035	1·25	7·6	$5\frac{3}{4}$
4	0·0513	0·0510	1·16	7·3	$4\frac{1}{2}$
5	0·0206	0·0207	0·96	7·1	$4\frac{1}{2}$
6	0·0103	0·0102	0·85	8·1	$4\frac{1}{2}$

The above were six consecutive experiments. In addition to being rapid the method is reliable, and requires no supervision. The deposit is dark in colour, but adheres well to the dish, and does not oxidise at all during the drying. Under the above conditions no deposit of sulphur on the cathode, as has been referred to by others, occurred; provided the ammonium sulphide is carefully prepared this can be quite avoided.

Summary.

The electrolytic deposition of tin from the solution of its ammonium sulpho-salt is a convenient and accurate method for the quantitative estimation of the metal. The double oxalate solution, acidified either with oxalic acid or with acetic acid, can, when carefully worked, be made to yield very fair results, but it cannot be regarded as reliable; and, as an analytical method, it is inferior in accuracy, rapidity, and convenience to the electrolysis of the sulpho-salt solution, this latter being especially handy, as it deals directly with the sulphide of tin, the form in which the metal is always obtained in analysis when not separated as oxide. The addition of a hydroxylamine salt to the oxalate solution certainly renders the method easier to carry out, but it does not obviate the other defects mentioned.

The Electrolytic Separation of Antimony from Tin.

By Charles A. Kohn, *Ph.D., B.Sc., and* C. K. Barnes, *B.Sc.*

Bibliography.

Author	Journal	Year	Vol.	Page	Metals separated from	Composition of Electrolyte
Classen, A., and Ludwig, R.	Ber.	1885	18	1104	As, Sn	Sodium sulphide and hydrate
Classen, A., and Ludwig, R.	Ber.	1886	19	323	As, Sn	Sodium sulphide and hydrate
Classen, A., and Schelle, R.	Ber.	1888	21	2892	Sn	Sodium sulphide and hydrate
Classen, A.	Ber.	1894	27	2060	As, Sn	Sodium sulphide and hydrate

Classen has taken advantage of the fact that tin is not deposited from a concentrated solution of the sodium sulpho-salt upon electrolysis in order to separate it from antimony. The mixed sulphides are dissolved in sodium sulphide, 1–2 grme. of sodium hydrate added, and the solution electrolysed, either cold with a current of 0·2 ampere, or warm with a current of about 1·0 ampere. Any polysulphides present must be oxidised with hydrogen peroxide. The deposited antimony is washed and dried as usual. The residual solution contains the tin, which is determined either by boiling with ammonium sulphate and electrolysing the solution of the ammonium sulpho-salt thus formed, or by converting the sulphide of tin into stannic oxide, and this into the double ammonium oxalate for electrolysis.

Behaviour of Tin in the Electrolysis of its Sodium Sulpho-salt.

A few experiments were first tried to ascertain under what conditions tin is not deposited from its sodium sulpho-salt. The tin was first precipitated as sulphide, the precipitate thoroughly washed, and then dissolved in sodium sulphide solution of sp. gr. 1·18. The solution was diluted to 175 c.c., electrolysed with a current $C.D._{100}$ of 0·2 ampere and 3·2 volts for 20 hours. The following results were obtained :—

Tin taken : Grme.	Tin found : Grme.	Sodium Sulphide Solution added
0·1026	0·0280	10 c.c.
0·1026	No deposit	30 c.c.
0·1026	,,	50 c.c.

The above quite confirm Classen's statement that tin is only incompletely deposited from a *dilute solution* of its sodium sulpho-salt, and *not at all from concentrated solutions.* Provided the presence of antimony has no effect on the behaviour of the tin, the addition of 30 c.c. of sodium sulphide solution under the above conditions is sufficient to prevent the separation of the latter.

The Separation of Antimony from Tin in Sodium Sulphide Solution.

The following method was adopted in the separation. The mixture of antimony and tin solutions (each prepared as described above) were precipitated with sulphuretted hydrogen, and the precipitated sulphides collected and thoroughly washed. They were then dissolved in 50 c.c. of sodium sulphide solution (sp. gr. 1·18), filtered, 1 grme. sodium hydrate added, diluted to 175 c.c., and electrolysed overnight. The tin in the residual solution can be converted into the ammonium sulpho-salt by heating it with 25 grme. of pure recrystallised ammonium sulphate, the solution being boiled for ten minutes after the evolution of the sulphuretted hydrogen has ceased, and the resulting solution electrolysed, as described under the determination of tin (Series V.). This method of procedure is, however, unnecessarily lengthy, and electrolysis presents no advantages after the separation of the antimony. It is much simpler to precipitate the tin from the solution of its sodium sulpho-salt by the addition of acid, and to convert the sulphide direct into the oxide by the usual gravimetric method, and weigh this. This method was adopted in most cases. The conversion into the ammonium sulpho-salt is, however, quite reliable, and equally accurate results were obtained by both methods.

Whenever the sodium sulpho-salt solution was coloured yellow by the presence of polysulphides these were oxidised by gentle warming with a little hydrogen peroxide.

A considerable number of experiments were made, using varying proportions of antimony and tin, from which the following typical results have been chosen :—

Experiment	Antimony taken: grme.	Antimony found: grme.	Tin taken: grme.	Tin found: grme.	Sodium Sulphide Solution added: c.c.	Sodium Hydrate added: grme.	$C.D._{100}$ Amperes	E.M.F. Volts	Time: hours	Ratio Sb : Sn
1	0·2104	0·2084	0·2052	0·2069	50	1	0·19	3·5	18	1 : 1
2	0·2104	0·2107	0·2052	0·2070	50	1	0·20	3·5	17½	1 : 1
3	0·1052	0·1067	0·1026	0·1034	50	1	0·18	3·5	18	1 : 1
4	0·1052	0·1050	0·1026	0·1039	50	1	0·19	4·0	17½	1 : 1
5	0·0840	0·0834	0·0968	0·0964	50	1	0·19	2·8	19	1 : 1
6	0·0505	0·0522	0·0513	0·0516	50	1	0·17	3·9	18	1 : 1
7	0·0420	0·0424	0·0484	0·0465	50	1	0·20	2·9	17½	1 : 1
8	0·0143	0·0143	0·0193	0·0199	50	1	0·20	3·2	19	1 : 1
9	0·1680	0·1700	0·0968	0·0978	50	1	0·20	2·8	17½	2 : 1
10	0·1959	0·1953	0·1026	0·1037	50	1	0·20	3·3	19½	2 : 1
11	0·2145	0·2132	0·0484	0·0515	50	1	0·20	2·8	18	4 : 1
12	0·2024	0·2020	0·0513	0·0517	50	1	0·19	2·7	19½	4 : 1
13	0·1430	0·1440	0·0194	0·0201	50	1	0·21	3·2	18	7 : 1
14	0·2045	0·2049	0·0020	0·0025	50	1	0·19	3·1	18½	10 : 1
15	0·1430	0·1459	0·0097	0·0100	50	1	0·21	3·2	19½	14 : 1
16	0·1024	0·1023	0·2052	0·2082	50	1	0·18	3·0	19½	1 : 2
17	0·0715	0·0730	0·1936	0·1920	50	1	0·19	2·6	20	1 : 2
18	0·0354	0·0450	0·1936	Not de-	50	1	0·21	2·8	17½	1 : 6
19	0·0354	0·0430	0·1936	termined	50	1	0·19	2·8	17½	1 : 6

Other experiments, the details of which need not be recorded, showed that :—

1. The addition of 30 c.c. of the sodium sulphide solution instead of 50 c.c. for 0·2 gramme of the mixed metals is sufficient, but that there is no disadvantage in employing a larger excess of the reagent; it is therefore better to do so as a safeguard against the deposition of tin.

2. The addition of sodium hydrate can be dispensed with if 50 c.c. of sodium sulphide solution are used.

3. The electrolysis of the *warm* sodium sulpho-salt solution of the metals with a $C.D._{100}$ of 1·0 ampere gives low results for the antimony; it is therefore preferable to employ the method described, and to conduct the electrolysis overnight.

4. The current must not exceed $C.D._{100}$ of 0·2 ampere, otherwise traces of tin are deposited with the antimony. With a $C.D._{100}$ of 0·3 ampere, the antimony was 6 per cent. too high from this cause.

Summary.

The accuracy of the method adopted for the separation of antimony from tin by electrolysis compares very favourably with that obtainable by other methods for the separation of the two metals, provided the proportion of tin to antimony is not greater than 1 to 1 (Nos. 1–8). With a larger proportion of tin (Nos. 16 and 17) the results

are less favourable, and with a ratio of tin to antimony above 2 : 1 quite unreliable (Nos. 18 and 19). In presence of an excess of antimony the method is satisfactory (Nos. 9–15). Classen's published results on his method of separation do not give instances of larger proportions of tin to antimony than 2 to 1. The method requires care and special attention to the strength of current employed, the purity of the sodium sulphide used, and the thorough washing of the precipitated sulphides.

Note on the Separation of Arsenic from Antimony and Tin electrolytically.

It has been shown by Classen that antimony is deposited free from arsenic from a solution of their sodium sulpho-salts, provided the latter is first completely oxidised to arsenic acid ; but in the presence of tin the arsenic must be removed from the solution before the electrolytic determination of the tin can be proceeded with, after the antimony has been deposited. Electrolysis, therefore, offers no advantage whatever under these conditions, and no experiments were carried out with mixtures of the three metals. The most rational method of procedure in presence of arsenic is to first remove it from the mixture by Fischer's distillation method, as described by one of us ('J. Soc. Chem. Ind.,' 1889, viii. p. 256), and then to separate the tin and antimony electrolytically in the residual solution.

The Carbohydrates of Cereal Straws.—First Report of the Committee, consisting of Professor R. WARINGTON (*Chairman*), Mr. C. F. CROSS, Mr. MANNING PRENTICE (*Secretary*). (*Drawn up by* Mr. CROSS.)

THE award of a grant of 50*l.* from the funds of the Association has enabled us to prosecute our researches without interruption. The branch of the investigation with which we have been occupied has been the determination of the precise nature of the furfural-yielding constituents of straws.

During the summers of 1894 and 1895 we made investigations on the growing plant (barley) to ascertain the relative rate of accumulation of these furfuroids in the plant tissues. For these investigations we selected two of the typical experimental plots of the Royal Agricultural Society's station at Woburn, the one being permanently unmanured, the other receiving a maximum treatment with fertilisers, the pair thus representing extreme conditions of soil nutrition. For the supplies of material we are indebted to Dr. Voelcker, the Society's chemist. To Messrs. Voelcker we are also indebted for assistance and co-operation in other ways, a large part of our experimental work having been conducted at their laboratories.

These investigations gave us positive indications, in general terms, as to the origin and distribution of the furfuroids, and their relationship to the conditions of assimilation and secondary changes obtaining in the plant. Having laid this necessary foundation, we have during the past year applied ourselves to the particular problem of isolating these carbohydrates in a condition suitable for the direct diagnosis of their constitution. The methods suggested by our general survey of their 'chemical habit' were those of acid hydrolysis, and the problem resolved itself into an investigation of the most favourable conditions of selective attack by suitable acids. To simplify the problem we confined ourselves at first to the celluloses proper, isolated from the straws by the usual methods of treatment.

The results of these investigations, which occupied us for six months, are recorded in a paper communicated to the Chemical Society, and published in the Journal for June 1896, p. 804.

The method of attack employed consisted in digesting the celluloses for fifteen minutes in a 1 per cent. solution of sulphuric acid, at a temperature of 140–150° C.

By this method we are enabled to separate the furfuroids almost quantitatively, and in a condition of molecular simplicity. As obtained from the celluloses, the reactions of these compounds are those of a pentose monoformal $C_5H_8O_3\langle\begin{smallmatrix}O\\O\end{smallmatrix}\rangle CH_2$. It does not follow, however, that when isolated directly from the straws themselves, or from the stems in earlier periods of growth, the whole of the furfuroids will be found to have this constitution. Our subsequent work has been directed especially to this question. The problem involved may be briefly stated as follows :

The pentoses are formed in the plant from the hexoses. In this process a terminal CH_2OH group is eliminated. The mechanism of the change, which must involve an oxidation to CO, is probably one of re-arrangement, and not an oxidation from without. The pentose monoformal represents the intermediate term of the series. The tendency to the transformation must belong either to the special configuration of the hexose, or to the special mode of aggregation of the molecules in the form of a tissue substance or cellulose. Assuming the former, it may result from these investigations that one of the hexoses as yet unknown will be found to have its terminal CH_2OH group in a specially sensitive condition by reason of exceptional configuration, *i.e.*, disposition of its alcoholic OH groups. It is noteworthy, in fact, that the four hexoses, as yet unknown, are of configurations suggesting a wider divergence from the better known carbohydrates than these show amongst themselves. Thus :

$$\begin{array}{rcccl} & H & H & H & OH \\ CH_2OH—C & C & C & & C—COH \\ OH & OH & OH & & \end{array}$$; and its Antilogue

and

$$\begin{array}{rcccl} H & H & H & & H \\ CH_2OH—C & C & C & & C—COH \\ OH & OH & OH & & OH \end{array}$$; and its Antilogue

It is, indeed, not improbable that a special equilibrium might characterise hexoses of this configuration, either in the isolated condition, or in the form of molecular aggregates. This is, of course, a speculative hypothesis.

Actually we do find that the furfuroids are obtained in varying conditions, and an important diagnosis is their greater or lesser susceptibility to alcoholic fermentation by yeast.

Thus, as isolated by acid hydrolysis at high temperatures from the celluloses (obtained from the mature straws), they yield only in small part (20 per cent.) to the action of yeast (in neutral solution). On the other hand, on hydrolysing with $H_2SO_4.2H_2O$, a solution of the furfuroids is obtained which yields much more readily to yeast, and the proportion fermented amounted to 80 per cent.

Again, the early growth (barley) of the present year was submitted to the treatment with dilute acid at high temperatures. In the solution the constants bearing on this point were as under, calculated per cent. of the total dissolved solids :

CuO reduction (calc. to dextrose = 100°) . .	52·1
Furfural	16·1

After fermentation the solution contained traces only of furfuroids, and the CuO reduction had fallen to 7·1.

Then, again, the osazones obtainable from the hydrolysed solutions indicate important variations in the constitution of the furfuroids. The solutions previously obtained from the celluloses at high temperatures gave osazones of m.p. 145–155°. The solutions which we are now obtaining from the plant tissues in their earlier stages of growth give osazones melting at temperatures exceeding 180°. On the other hand again, from the lignocelluloses (which also yield their furfuroids to the acid solution at high temperatures), hydrolysed products are obtained, the osazones of which melt at temperatures as far removed on the other side from the melting points of the pentosazones, viz., at 110–120°.

It appears, therefore, that the furfuroids of the vegetable world are a diversified group. In addition to the pentoses themselves they include monoformal derivatives of the pentoses, and possibly also hexoses, certainly some of their derivatives. In the latter sub-group we may include Glycuronic acid, $COOH\ (CHOH)_4.COH.$, as it also yields furfural as a product of the action of hydrochloric acid.

A complete investigation of these compounds therefore offers not merely developments of the special chemistry of the carbohydrates, but from their wide distribution in the plant world it is clear that they play an important part in the general physiology of tissue formation. A good deal of interest also evidently centres in the problem of their fate in the processes of animal digestion. From the investigations of Stone, Agr. Science, 1893, 6) it appears that the tissue furfuroids of fodder plants are in effect largely digested (60–80 per cent.) by the herbivora. H. Weiske has also recently contributed to the same subject ('Bied. Centr.,' 25, 13); and arrives at a similar conclusion. Though digested however, it is still an open question as to what nutritive value they may have.

It needs no further demonstration at this stage that the subject calls for extended investigation from various points of view : that it is a subject offering more than ordinary promise of positive results.

As stated above in this report, our immediate object at the present time is the isolation of the furfuroids of the cereal stems in the earlier stages of growth. We have already found that the process of acid digestion adopted in the case of the straw celluloses gives an equally satisfactory separation of the furfuroids of the growing tissues. These we have to investigate by the standard methods—1. ultimate analysis ; 2. conversion into osazones ; 3. fermentation ; 4. oxidation to mono- and dibasic acids ; and so forth. Such investigations have been in progress during the last three months.

This concludes our report of progress. We trust to have given satisfactory evidence of useful work, and of having taken advantage of the opportunities provided by the Association in their grant of funds.

Isomeric Naphthalene Derivatives.—Tenth Report of the Committee, consisting of Professor W. A. TILDEN *and* Professor H. E. ARMSTRONG. (*Drawn up by* Professor ARMSTRONG.)

THE completion of the investigation of the fourteen possible *trichloronaphthalenes* (including the proof that there are only fourteen) by Dr. Wynne and the writer (referred to in the last report), following that of the ten possible *dichloronaphthalenes,* marks the termination of a section of our work—perhaps of greater importance than any other, establishing, as it does, two complete series of reference compounds by means of which all other di- and tri-derivatives of naphthalene may be classified; whilst, at the same time, it affords unquestionable confirmation of the accuracy of the train of argument on which our present views of the constitution of benzenoid compounds are based, and places the symmetrical structure of naphthalene beyond all doubt.

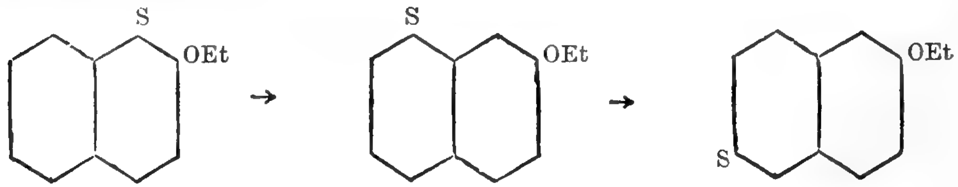
Although great progress has been made in collecting the material needed for the discussion of the laws which govern substitution in the naphthalene series in the case of derivatives containing either halogens, or nitro or other oxylic groups, or amidogen, or hydroxyl, before entering on the final consideration of the results, it is essential to obtain further evidence as to the manner in which the interactions occur, and particularly as to the nature of the 'isomeric changes' involved in the formation of many sulphonic acids—an all-important, but seemingly very complex, problem.

Much has been done during the year towards procuring the information needed, especially in the case of the naphthols, which claim attention on account of the remarkable 'plasticity' they manifest—a plasticity that seems to distinguish them from all other derivatives of naphthalene, due apparently, at least in part, to the readiness with which they are converted into keto-compounds of the type first discovered by Zincke.

In order to study the influence of the OH group *undisturbed*, i.e., to prevent any change taking place in it such as is involved in the formation of a keto-compound, numerous experiments have been made with the methoxy- and ethoxynaphthalenes in the writer's laboratory. Dr. Lapworth has very kindly undertaken the study of the sulphonic acids of the β-compounds, and his results [1] form a valuable addition to our knowledge, as such substances afford well-defined crystalline sulphochlorides, sulphonamides, &c., a class of derivatives which cannot be prepared from the naphthol-acids. One very remarkable result has been arrived at by Dr. Lapworth. The initial product formed on sulphonating a cold solution of β-ethoxynaphthalene is the 2 : 1 acid in a nearly pure state; but if the product be kept at the ordinary temperature it spontaneously changes into a mixture of the 2 : 1′ and 2 : 3′ acids, the change being complete, however, at the end of twelve to fifteen hours. When β-methoxynaphthalene is similarly treated it also yields practically nothing but the 2 : 1 acid,

[1] Cf. *Proceedings of the Chemical Society*, 1895.

which gradually changes on keeping; but in this case the change takes place much more slowly, being incomplete at the end of five or six days. The changes which apparently take place are those indicated by the following symbols:



It is difficult to believe that hydrolysis and resulphonation go on in a stiff, pasty mass at ordinary temperatures, and the transformation would seem to be more probably the result of direct isomeric change; but much must be done before this question can be finally discussed.

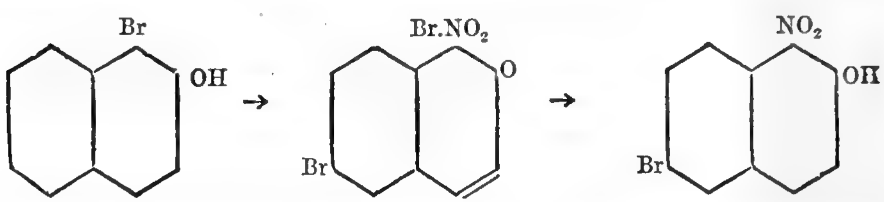
α-Methoxy- and *α*-ethoxynaphthalene do not show any similar behaviour, and yield only the 1 : 4 acid, which apparently does not undergo change when heated. Mr. Shelton, who has examined the acids at my request, has prepared from them a series of crystallised derivatives, viz.—

		M.P.			M.P.
$C_{10}H_6(OMe.)$	$SO_2Cl.$	97°	$C_{10}H_6(OEt.)$	$SO_2Cl.$	102°
	SO_2NH_2	225°		SO_2NH_2	167°
	$SO_2NH.Ph.$	136°		$SO_2NH.Ph.$	176°

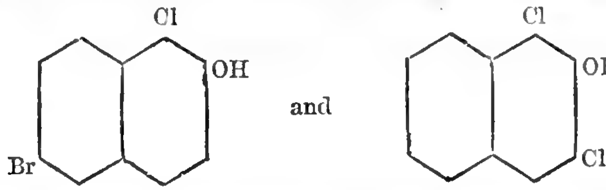
The behaviour of *β*-methoxy- and ethoxynaphthalene towards bromine is normal, products being obtained which correspond to those prepared from *β*-naphthol; the investigation of the crystallographic relationship of these promises to afford interesting results, and is being carried on by Mr. Bennett.

It was shown by Mr. Rossiter and the writer that nitro-*β*-naphthol may be prepared directly from *β*-naphthol by means of nitrogen peroxide; it appears that it may equally well be obtained by means of nitric acid. The acid is carefully added to a very cold solution of the naphthol in acetic acid, and the solution is subsequently mixed with an excess of sodium sulphite. But the yield is poor, seldom exceeding 40 per cent. of the theoretical amount. A better result is obtained by very carefully nitrating chloro- or bromonaphthol and reducing with sulphite.

The nitro-bromo-keto-naphthalene formed on nitrating dibromo-*β*-naphthol is readily and completely reduced by sodium sulphite, thus making it possible to obtain a practically theoretical yield of nitro-bromonaphthol:

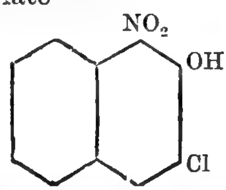


But in many other cases the sulphite is not a sufficiently strong agent to reduce the keto-compound; experiments made by Mr. Rich show that it is impossible to use it in reducing the nitro-keto derivates prepared from—

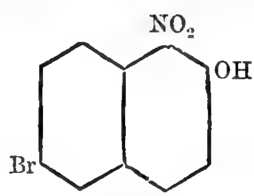


The formation of the corresponding nitro-derivatives—in which the α-atom of chlorine is displaced from the nitro-keto-compound—may, however, be readily effected by means of hydrogen iodide, and the method appears to be of general application.

With the object of ultimately preparing 2 : 3 chloro-β-naphthol, attempts were made to ethylate



But great difficulty was experienced, the yield being most unsatisfactory; yet the allied compound

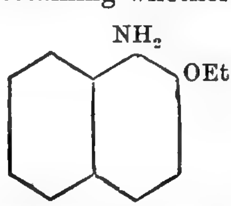


is ethylated with the greatest ease. The case is apparently another illustration of the inhibiting effect of contiguous ortho groups to which Victor Meyer has called attention so frequently.

In seeking to remove the atom of halogen in the α-position in the derivatives of β-naphthol containing halogens, 1-chloro- and 1 : 3 dichloro-β-naphthol were heated with sodium as well as potassium sulphite in the hope of obtaining α-sulphonic acids; the desired change was effected in the case of the mono- but not in that of the di-chloro-compound.

Experiments carried out by Mr. Davis have led to the discovery of a simple means of converting 1 : 3′ dibromo into 3′ bromo-β-naphthol (m.p. 127°), consisting in the mere digestion of the dibromo-compound with a solution of hydrogen iodide; but, again, in this case, we have hitherto failed in extending the use of the method to other derivatives containing halogens.

With the object of ascertaining whether amido-β-ethoxynaphthalene



resembles either α-naphthylamine or β-naphthol, Mr. Davis has subjected its acetyl derivative to the action of bromine; the results show that the amido group is apparently without influence, the behaviour being that of a derivative of β-naphthol in which position 1 is occupied.

Mr. Davis has made much progress in an investigation of the nitro- and nitrobromo-β-ethoxynaphthalenes, paying special attention to their crystallographic characters; they are all intensely yellow-coloured substances, and apparently the colour is an intrinsic property. As the corresponding phenol derivatives are colourless substances, it will be of interest to institute an exact comparison between the two series.

It should also be mentioned that, in the course of their work during the year, Dr. Wynne and the writer have been able to confirm Cleve's observation that the 1 : 3 nitro-acid is among the products of the nitration of naphthalene-β-sulphonic acid ('Proceedings of the Chemical Society,' 1895, No. 158, p. 238). This result is of interest, as no other case is known of the direct formation of a *meta*-di-derivative of naphthalene.

The Teaching of Science in Elementary Schools.—Report of the Committee, consisting of Dr. J. H. GLADSTONE (*Chairman*), Professor H. E. ARMSTRONG (*Secretary*), Professor W. R. DUNSTAN, Mr. GEORGE GLADSTONE, Sir JOHN LUBBOCK, Sir PHILIP MAGNUS, Sir H. E. ROSCOE, and Professor S. P. THOMPSON.

YOUR Committee have the satisfaction of reporting that the return of the Education Department for this year shows continued progress in respect of the teaching of science subjects in Elementary Schools. Under the old *régime*, which existed until 1890, 'English,' by which was meant the elements of English Grammar, including parsing and analysis of sentences, was an obligatory subject if any of the class subjects were taught in a school; and as Geography has always enjoyed a considerable measure of popularity, no room was practically left for Elementary Science. Hence during the eight years ending with 1890 the number of departments of schools in which these three class subjects were taught was as follows:—

Class Subjects.—Departments	1882–83	1883–84	1884–85	1885–86	1886–87	1887–88	1888–89	1889–90
English	18,363	19,080	19,431	19,608	19,917	20,041	20,153	20,304
Geography	12,823	12,775	12,336	12,055	12,035	12,058	12,171	12,367
Elementary Science	48	51	45	43	39	36	36	32

As soon, however, as full liberty of choice was given to managers and teachers, the number of departments in which 'English' was taught commenced to decrease, notwithstanding the natural increase in the number of schools; while the two other subjects named have been taken up more largely, and have continued to receive greater attention year by year. The figures up to 1894–95, which is the latest return issued by the Education Department, are as follows:—

Class Subjects—Departments	1890–91	1891–92	1892–93	1893–94	1894–95
English	19,825	18,175	17,394	17,032	16,280
Geography	12,806	13,485	14,256	15,250	15,702
Elementary Science	173	788	1,073	1,215	1,712

The number of departments in 'schools for older scholars' for the year 1894–95 was 22,798, of which 33 did not take any class subject, leaving 22,765 as the number of departments with which the foregoing table has to deal. But it must be borne in mind that History is taken in 3,597, and Needlework (for girls) in 7,396 departments, making, with the other three subjects in the table, 44,687 in all. This shows an average of nearly two class subjects to each department. As, however, there were no less than 5,872 departments in which only one class subject was taken, it is evident that the plan of teaching one subject in the lower division of a school and another subject in the upper division, thus counting twice over in the statistical table, is largely adopted. This is further borne out by the fact that, while the Education Department only recognises two class subjects taken by any individual scholar, there are 4,458 departments in which three, and 284 in which four or five, of these class subjects are taught. That Elementary Science is taught in 1,712 departments must, therefore, be accepted with the reservation that in many cases it is only a portion of the school that gets the benefit of this instruction.

As a matter of fact, though the means of getting at the precise numbers are not available, it can be asserted that Elementary Science has, in very many cases, been taught only in the lower standards as a preparation for the study of scientific specific subjects in the upper portion of the school. This arrangement has received the approval of Her Majesty's Inspectors, as well as of managers and teachers; and this year the plan has received further recognition by the introduction into the Day School Code of 1896 of 'alternative courses in English, Geography, and History for schools which take other class subjects in the lowest three standards,' the other subjects referred to (though there is nominally a considerable choice) being practically Object Lessons or Elementary Science. Object Lessons, in fact, are now made obligatory as a class subject in the three lowest standards if only one class subject be taken. It is satisfactory to find that there is an actual diminution in the number of girls' departments taking Needlework as a class subject as compared with former years; not that this art is neglected, but that it is more frequently taken now as an additional subject for the one shilling grant, so leaving the field free for two class subjects in addition.

With increased attention to Object Lessons and Elementary Science in the lower portion of the schools, it is reasonable to expect progress in the teaching of the scientific specific subjects in the higher standards; and the return for the last five years confirms this expectation. The number of scholars examined in the following subjects is shown in the table annexed:—

Specific Subjects.—Children	1890–91	1891–92	1892–93	1893–94	1894–95
Algebra	31,349	28,542	31,487	33,612	38,237
Euclid	870	927	1,279	1,399	1,468
Mensuration	1,489	2,802	3,762	4,018	5,614
Mechanics	15,559	18,000	20,023	21,532	23,806
Animal Physiology	15,050	13,622	14,060	15,271	17,003
Botany	2,115	1,845	1,968	2,052	2,483
Principles of Agriculture	1,231	1,085	909	1,231	1,196
Chemistry	1,847	1,935	2,387	3,043	3,850
Sound, Light, and Heat	1,085	1,163	1,168	1,175	914
Magnetism and Electricity	2,554	2,338	2,181	3,040	3,198
Domestic Economy	27,475	26,447	29,210	32,922	36,239
Total	100,624	98,706	108,434	119,295	134,008

The numbers for the last year show a greater proportional increase than in any previous year. This is especially noticeable in Algebra, Domestic Economy, Mensuration, Mechanics, and Chemistry. The principal falling-off is in the subject of Sound, Light, and Heat, probably due to the very wide extent of that subject. Last year it was noted that very nearly half the students in Mechanics had reached the second or third stage in that subject; this year's Report is not so favourable in that particular, nearly three-fifths of the students in 1894–95 being in the first stage. In Chemistry, on the other hand, there is an improvement on last year, more than one-third of the whole number having been examined in the second stage.

Estimating the number of scholars in Standards V., VI., and VII. at 590,000, the percentage of the number examined in these specific subjects as compared with the number of children qualified to take them is 22·7; but it should be remembered that many of the children take more than one subject for examination. The following table gives the percentage for each year since 1882:—

In 1882–83	29·0 per cent.
„ 1883–84	26·0 „
„ 1884–85	22·6 „
„ 1885–86	19·9 „
„ 1886–87	18·1 „
„ 1887–88	16·9 „
„ 1888–89	17·0 „
„ 1889–90	18·4 „
„ 1890–91	20·2 „
„ 1891–92	19·7 „
„ 1892–93	20·2 „
„ 1893–94	20·9 „
„ 1894–95	22·7 „

The Returns of the Education Department given above refer to the whole of England and Wales, and are for the school years ending with August 31. The statistics of the London School Board are brought up to the year ending with Lady Day, 1896. They also illustrate the great advance that has been made in the teaching of Elementary Science as a class subject, and they give the number of children as well as the number of departments.

Years	Departments	Children
1890–91	11	2,293
1891–92	113	26,674
1892–93	156	40,208
1893–94	183	49,367
1894–95	208	52,982
1895–96	246	62,494

The total number of departments for 'older scholars' under the London School Board at the last-named date was 854, showing that a somewhat larger proportion take Elementary Science as compared with the previous year.

The alterations that were made in the Code of 1893 for evening continuation schools give increasing evidence of bearing good fruit. In last year's Report your Committee gave in tabular form the number of 'units for payment' of the grant by the Education Department for the several scientific subjects taken throughout England and Wales during the session 1893–94, together with a similar return for the schools under the London School Board. In the following table these figures are reproduced, together with the corresponding returns for the session 1894–95. It may be desirable to report that the 'unit' means a complete twelve hours of instruction received by each scholar, fractions of twelve hours not counting.

Science Subjects	Units for Payment			
	England and Wales		London School Board	
	1893–94	1894–95	1893–94	1894–95
Euclid	595	1,086	10	29
Algebra	3,940	6,657	316	302
Mensuration	14,521	32,931	279	374
Elementary Physiography	2,554	4,045	37	9
Elementary Physics and Chemistry	6,500	7,850	79	200
Science of Common Things	6,223	10,350	231	262
Chemistry	3,484	7,814	212	455
Mechanics	841	1,148	230	197
Sound, Light, and Heat	500	1,046	—	15
Magnetism and Electricity	2,359	4,451	662	776
Human Physiology	5,695	8,395	91	68
Botany	336	547	5	91
Agriculture	3,579	4,991	—	—
Horticulture	438	1,140	—	—
Navigation	42	69	—	—

The total number of units for the year 1894–95 is (for England and Wales) 92,520, whereas the number of scholars is 55,132, indicating that fully two-thirds of them must have received at least twenty-four hours of instruction. It will be remarked that there has been an unparalleled increase in the subject of Mensuration, considerably more than double, and that it is far and away the most popular subject. In some of the others the figures are more than doubled; but it is interesting to note that the Science of Common Things holds the second place in popular estimation; and that the allied subjects of Chemistry (which has considerably more than doubled itself) and Elementary Physics and Chemistry score between them no less than 15,664 units. It appears there were no less than 18,648 individual students of Mensuration, while the number of students for the three other subjects above referred to were 6,638, 4,691, and 4,961 respectively. There were 5,241 students in Human Physiology. The figures for London show an advance, but not in proportion to those for England and Wales. The principal increase is in Chemical Science and in Botany.

The popular subject of the Science of Common Things is no doubt one that may be made extremely valuable by good teaching. Your Committee are glad to know that Professor Smithells has for the last three years conducted a course for teachers on this subject at the Yorkshire College, Leeds. This course has included practical work.

In last year's Report reference was made to the improved method of teaching Elementary Physics and Chemistry in the schools of the London

School Board in Hackney and the Tower Hamlets. The work has continued to develop, the most satisfactory element being the manner in which the interest of the teachers themselves has been stimulated. Progress has been made in dealing with a much larger number of teachers than hitherto; and the teaching throughout the schools shows marked improvement in quality and enthusiasm; genuine efforts are now made by the teachers to induce their scholars to think. The number of schools attempting experimental work will soon be largely increased, owing to the appointment of an additional demonstrator. The one in the Tower Hamlets and Hackney Division has held classes for women teachers also in Experimental Science, especially in relation to the home; thus a large number of teachers are prepared to give some reality to their teaching in Domestic Economy, and by it to benefit their scholars to a greater extent. It is satisfactory to note that a request emanating from the teachers themselves has led to the establishment of similar classes in South London under another of the Board's demonstrators, and it is hoped before the winter is past that like facilities will be offered to teachers in all parts of the metropolis.

With regard to the instruction of pupil teachers, the expectation referred to in the Report for 1894 has not been realised. No definite course of practical science has been rendered obligatory, but the Education Department has fallen back upon the old plan of giving marks for certificates from the Science and Art Department. These certificates must, however, have been gained either in the year of the Queen's Scholarship Examination or in the preceding year. It is also now provided that no student may be registered in the advanced stage of any subject until he has passed the examination of the Department in the elementary stage, or has passed some corresponding examination which is considered by the Department to sufficiently meet the requirements of the case. A change has also been made in the mode of assessing the grants by the Science and Art Department, which it is believed will conduce to the improvement of the study of science.

With regard to the syllabus used in the schools themselves, that of mechanics is very largely taken, but much of it must necessarily be taught with the sole object of giving information devoid of illustration or experimental proof. It is not planned in accordance with modern ideas of science teaching, and should be materially altered. The Domestic Economy Syllabus (for girls) also needs complete reconstruction for similar reasons.

Your Committee consider that the time has come when Educational authorities should definitely lay down a scheme of Elementary Experimental Science, to be taken by every scholar before he is allowed to specialise into the various branches of science.

The all-important point in elementary schools is to train teachers to regard science teaching as a means of mental culture, and to get them to teach accordingly. The courses in the training colleges and pupil teachers' centres appear to work in exactly the opposite direction; so busy are these institutions in teaching 'sciences' for the sake of the certificates issued by the Science and Art Department, that the teaching of scientific method is apt to be almost entirely ignored.

Wave-length Tables of the Spectra of the Elements and Compounds.—Report of the Committee, consisting of Sir H. E. ROSCOE (*Chairman*), Dr. MARSHALL WATTS (*Secretary*), Professors J. N. LOCKYER, J. DEWAR, G. D. LIVEING, A. SCHUSTER, W. N. HARTLEY, *and* WOLCOTT GIBBS, *and* Captain ABNEY. (*Drawn up by* Dr. WATTS.)

ARGON (VACUUM TUBE).

Eder and Valenta : 'Anzeiger Wien. Akad.,' xxi. (1895).
„ „ 'Sitz. d. k. Akad. d. W. Wien,' civ. (1895).
„ „ 'Denkschr., d. k. Akad. d. W. Wien,' lxiv. (1896).
Kayser : 'Astroph. J.' iv. i. (1896); 'Sitz. Akad. W. Berlin,' xxiv. (1896).
Crookes : 'Chem. News,' lxxi. 58 (1895).

* Common to both 'red' and 'blue' spectra.
† A constituent of the third or 'white' spectrum of argon.
‖ Belongs to Mercury.

RED SPECTRUM OF ARGON.

Wave-length		Intensity	Previous Observations		Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)				λ+	1/λ −	
7723·4		2			2·09	3·5	12942·1
7635·6		2	7646	Crookes	2·06	„	13093·0
7515·1		2			2·04	3·6	13302·9
7503·4		2	7506	„	2·03	„	13323·2
7383·9		2	7377	„	2·01	3·7	13539·3
7271·6		1	7263	„	1·97	„	13748·4
7146·8		1			1·95	3·8	13989·5
7066·6		7	7056·4	„	1·92	„	14147·3
7029·2		1			1·91	„	14222·6
6964·8		8	6965·6	„	1·89	3·9	14354·0
6937·8		1			1·88	„	14409·9
6870·6		1			1·86	„	14550·8
6786·5		1			1·84	4·0	14731·1
6752·7		3	6754	„	1·83	„	14804·9
6676·5		3	6664	„	1·81	„	14974·7
6415·2		5	6407	„	1·74	4·2	15583·8
6384·5		2	6377 ?	„	„	„	15658·7
6368·0		1			1·73	„	15699·3
6307·8		1			1·72	4·3	15849·1
6296·8		2	6302 ?	„	1·71	„	15876·8
*6217·5		1			1·69	4·4	16079·2
6212·5		2	6210	„	„	„	16092·2
*6172·9		2	6173	„	1·68	„	16195·4
6170·3		1			„	„	16202·3
6155·2		1			„	„	16242·0*a*
6145·6		2	6143	„	1·67	„	16267·3*a*
6106·1		2	6099	„	1·66	„	16372·7*a*
6098·8		1			„	„	16392·3*a*
6059·5		4	6056	„	1·65	4·5	16498·5*a*
6052·7		2			„	„	16517·1*a*
6043·0	6043·68	4	6045	„	„	„	16541·7*b*
6031·5	6032·69*	5	6038	„	1·64	„	16571·8*b*
6025·8		1			„	„	16590·8*a*

RED SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	$\frac{1}{\lambda}$−	
6013·6		1		1·64	4·5	16624·5*a*
5999·5		1		1·63	,,	16663·6*a*
5987·5		1		,,	,,	16697·0*a*
5943·5		1		1·62	4·6	16820·5*a*
5928·5	5928·61*	2	5926 Crookes	1·61	,,	16862·7*b*
5912·22	5912·48*	4	5909 ,,	,,	,,	16909·2*ab*
5888·93	5889·02* }	3	5887 ,,	1·60	,,	16976·3*ab*
5881·78	5883·03 }	2		,,	,,	16993·8*ab*
5860·6	5660·69	2	5858 ,,	,,	,,	17059·2*b*
5832·3	5834·63*	2	5834 ,,	1·59	4·7	17134·3*b*
5802·4	5802·45	1	5803 ,,	1·58	,,	17229·4*b*
5772·5	5772·52*	1	5771 ,,	,,	,,	17318·8*b*
	5739·87*†	5		1·56	,,	17417·2*b*
	5701·19	1		1·55	4·8	17535·4*b*
	5691·94*	1		,,	,,	17563·9*b*
5690·1	5690·19*	1		,,	,,	17569·3*b*
5683·0	5682·26*	1	5683 ,,	,,	,,	17593·8*b*
5659·4	5659·47*	1		1·54	,,	17664·7*b*
5650·90	5651·03*†	4	5651 ,,	,,	,,	17691·3*ab*
	5649·02*	3		,,	,,	17697·3*b*
	5641·74*	2		,,	,,	17720·2*b*
	5639·39*	1		,,	,,	17727·6*b*
	5637·68	1		,,	,,	17733·0*b*
	5635·91*	2		,,	,,	17738·6*b*
	5624·06*	1		1·53	,,	17776·0*b*
	5621·28	2		,,	,,	17784·8*b*
	5618·30*	3		,,	,,	17794·2*b*
	5607·44*†	8		,,	4·9	17828·6*b*
5606·84		5	5610 ,,	,,	,,	17830·5*a*
5599·6	5600·91	1		,,	,,	17853·5*b*
	5597·89*†	5		,,	,,	17859·0*b*
5589·4		1		1·52	,,	17886·1*a*
	5582·20*†	3		,,	,,	17900·2*b*
5581·3		1		,,	,,	17912·1*a*
5572·71	5572·87*†	3	5567 ,,	,,	,,	17939·4*ab*
	5559·93*†	3		,,	,,	17980·9*b*
5558·80	5559·02*†	6	5557·0 ,,	,,	,,	17984·2*ab*
5525·2	5525·27*†	4	5520 ,,	1·51	,,	18093·7*b*
5506·7	5506·42*†	3	5501 ,,	1·50	,,	18155·7*b*
5496·02	5496·16*†	6	5496·5 ,,	,,	5·0	18189·5*ab*
	5490·37*	2		,,	,,	18208·7*b*
	5473·76*	3		1·49	,,	18263·5*b*
	5467·41*	3		,,	,,	18285·2*b*
	5459·57	1		,,	,,	18311·4*b*
5458·2	5457·75*	4	5456 ,,	,,	,,	18317·6*b*
5451·87	5451·95*†	6		,,	,,	18337·2*ab*
	5443·54*†	3	5444 ,,	,,	,,	18365·4*b*
5442·1	5442·54*	1		,,	,,	18368·8*b*
	5440·28*†	4		,,	,,	18376·4*b*
5421·9	5421·68*†	4	5421 ,,	1·48	,,	18439·5*b*
5412·8		1		,,	,,	18469·8*a*
	5410·76*	4		,,	,,	18476·7*b*
	5494·20*	1		,,	5·1	18533·3*b*
	5373·76*	3		1·47	,,	18603·8*b*
5275·3		1		1·44	5·2	18951·1*a*

RED SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations		Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)				λ+	1/λ −	
	5254·79*	2			1·44	5·2	19025·1*b*
5254·4	5253·09*	3	5258	Crookes	,,	,,	19031·2*b*
5221·9	5221·65*†	3	5222	,,	1·43	,,	19145·8*b*
5188·46		5			1·42	5·3	19268·2*a*
	5187·47*†	5			,,	,,	19271·9*b*
	5177·81*	2			1·41	,,	19307·7*b*
5162·6	5162·59*†	4	5165	,,	,,	,,	19364·8*b*
5152·7	5151·74*	3			,,	,,	19405·6*b*
5120·0	5118·55*	1			1·40	,,	19531·4*b*
5063·2	5060·39*	2	5065	,,	1·38	5·4	19745·9*b*
	5054·54	1			,,	,,	19778·7*b*
5051·3		1			,,	,,	19780·6*a*
	5049·18	3			,,	,,	19800·2*b*
5010·4		2	5012	,,	1·37	5·5	19953·0*a*
4969·6		1	4965·5	,,	,,	,,	20116·8*a*
	4895·01*	2			1·34	5·6	20423·4*b*
4889·4	4888·21*	1			,,	,,	20450·8*b*
4882·3		2	4879	,,	,,	,,	20476·7*a*
4849·9		1			1·33	5·7	20613·3*a*
4807·8		4			1·32	,,	20801·2*a*
4768·3	4768·79	1			1·30	5·8	20963·9*b*
	4753·02	2			,,	,,	21033·5*b*
	4746·82	1			,,	,,	21060·9*b*
4738·2	4736·03*†	1			,,	,,	21108·9*b*
4732·4		1			,,	,,	21125·1*a*
4702·504	4702·38*	4	4701·2	,,	1·29	5·9	21259·6*b*
	4658·04*†	4			1·28	,,	21462·3*b*
	4647·45	1			1·27	,,	21511·3*b*
4628·628	4628·60	5	4629·5	,,	,,	6·0	21598·1*ab*
	4609·73*†	4			1·26	,,	21687·2*b*
	4602·63	1			,,	,,	21720·7*b*
4596·205	4596·30	5	4594·5	,,	,,	,,	21750·8*ab*
	4523·54	1			1·24	6·1	22100·5*b*
4522·389	4522·49	3	4514·0	,,	,,	,,	22105·9*ab*
4510·851	4510·90	7	4509·5	,,	,,	,,	22162·5*ab*
	4510·66	1			,,	,,	22207·9*b*
	4481·09*†	3			1·23	6·2	22305·3*b*
	4431·16*†	2			1·21	6·3	22561·2*b*
	4430·35*†	4			,,	,,	22565·3*b*
	4426·16*†	6			,,	,,	22586·6*b*
	4424·09	3			,,	,,	22597·2*b*
	4401·19*†	5			,,	,,	22714·9*b*
	4400·25*†	3			,,	,,	22719·7*b*
	4379·79*†	4			1·20	,,	22825·8*b*
	4371·46*†	3			,,	,,	22869·3*b*
4663·970	4363·94	4			,,	6·4	22908·6*ab*
	4348·11*†	8			1·19	,,	22992·1*b*
4345·322	4345·27	7	4345·0	,,	,,	,,	23007·0*ab*
	4337·20*	1			,,	,,	23049·9*b*
4335·491	4335·42	6			,,	,,	23059·2*ab*
4333·714	4333·65*†	8	4333·5	,,	,,	,,	23068·6*ab*
	4331·31*†	1			,,	,,	23081·3*b*
	4321·77	1			,,	,,	23132·3*b*
	4312·27	2			1·18	,,	23183·2*b*
4304·033		1			,,	6·5	23227·6*a*

RED SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	$\frac{1}{\lambda}$−	
4300·249	4300·18	8	4300·5 Crookes	1·18	6·5	23248·5*ab*
	4288·06	1		”	”	23314·1*b*
	4278·21	1		1·17	”	23367·8*b*
	4277·65*	1		”	”	23370·8*b*
4272·304	4272·29*†	8	4272·0 ”	”	”	23399·6*ab*
4266·425	4266·44*†	8	4266·0 ”	”	”	23432·3*ab*
	4265·38	2		”	”	23438·1*b*
4259·491	4259·50†	9	4259·5 ”	”	”	23470·5*ab*
4251·329	4251·27	5	4251·5 ”	”	6·6	23515·6*ab*
	4247·68	1		”	”	23535·7*b*
	4228·27*†	4		1·16	”	23643·7*b*
	4212·37	1		”	”	23733·0*b*
	4210·14	1		”	”	23745·6*b*
4205·007		1		”	”	23774·6*a*
	4202·11*†	4		1·15	”	23791·0*b*
4200·799	4200 75*†	10	4201·0 ”	”	”	23798·5*ab*
4198·162	4198·40†	10	4198·0 ”	”	6·7	23812·6*ab*
4191·841	{4191·02*†	10		”	”	23851·5*ab*
4190·841	{4190·85*†	7	4191·5 ”	”	”	23854·8*ab*
4182·002	4182·03*†	7	4183·0 ”	”	”	23905·2*ab*
4164·309	4164·36*†	7	4164·5 ”	”	”	24006·6*ab*
4162·906		1		”	”	24015·0*a*
4158·722	4158·63*†	10	4159·5 ”	1·14	”	24039·3*ab*
4154·657		1	4156·6 ”	”	”	24062·6*a*
4154·663		2		”	”	24062·6*ab*
	4152·97	5		”	”	24072·5*b*
	4150·18	1		”	”	24088·6*b*
	4147·36	2		”	6·8	24105·0*b*
	4141·65	1		”	”	24138·2*b*
	4134·48	1		”	”	24180·0*b*
	4131·95*	2		”	”	24194·8*b*
	4104·10*	3		1·13	”	24359·1*b*
	4055·91	1		1·12	6·9	24648·5*b*
	4054·65	4		1·11	”	24656·1*b*
	4050·18	3		”	7·0	24683·3*b*
4046·620		2		”	”	24712·0*a*
4046·027	4046·04	3		”	”	24708·6*ab*
4044·565	4044·52†	8	4044·0 ”	”	”	24717·7*ab*
	4033·11	3		”	”	24787·8*b*
	4013·97*†	4		1·10	”	24906·0*b*
	3979·57*	5		”	7·1	25121·2*b*
	3960·24	1		1·09	”	25243·9*b*
	3954·77	1		”	7·2	25278·7*b*
3949·107	3949·08†	8	3948·5 ”	”	”	25315·1*ab*
3947·645	3947·75	5		”	”	25324·0*ab*
	3943·55	2		”	”	25350·6*b*
	3928·78*†	4		1·08	”	25446·0*b*
	3914·93*†	1		”	”	25536·0*b*
3900·065	3900·04	5?		”	7·3	25633·4*ab*
3894·795	3894·78	3		1·07	”	25668·0*ab*
	3868·68*	3		”	”	25841·3*b*
3866·353	3866·23	1		”	”	25858·3*ab*
3850 693	3850·70*†	3		1·06	”	25962·0*ab*
3834·768	3834·83	8	3835·5 ”	”	”	26069·7*ab*
	3809·58*	2		1·05	7·4	26242·2*b*

RED SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ +	$\frac{1}{\lambda}$ −	
3801·049		1		1·05	7·4	26301·1*a*
3781·461	3781·50	3		,,	,,	26437·3*ab*
	3781·07*	2		,,	,,	26440·1*b*
3775·476	3775·62	2		1·04	,,	26478·3*ab*
3770·440	3770·80*	4	3771·5 Crookes	,,	7·5	26513·3*ab*
	3765·48*	2		,,	,,	26549·5*b*
	3760·43	1		,,	,,	26585·2*b*
3743·808	3743·95	1		,,	,,	26702·8*ab*
3738·030	3738·04*	1		,,	,,	26744·5*ab*
	3729·52*†	3		1·03	,,	26805·6*b*
3696·587	3696·70	2		,,	7·6	27044·0*ab*
3691·001	3691·09	3		1·02	,,	27085·0*ab*
	3680·30*	5		,,	7·7	27164·0*b*
	3678·43*	6		,,	,,	27177·8*b*
3675·353	3675·38	2		,,	,,	27200·5*ab*
3670·783	3670·98	2		,,	,,	27234·0*ab*
3663·392		1		,,	,,	27394·4*a*
3659·632	3659·70	3		,,	,,	27317·1*ab*
3654·962		1		1·01	,,	27352·4*a*
3650·258	3649·99	3		,,	,,	27388·6*ab*
3643·227	3643·30	3		,,	,,	27440·2*ab*
3634·586	3634·64	6		,,	,,	27505·5*ab*
3632·766	3632·82	4	3632·5 ,,	,,	,,	27519·2*ab*
3606·677	3606·69†	3	3605·0 ,,	1·00	,,	27718·5*ab*
3599·822	3599·19	1		,,	,,	27773·8*ab*
	3588·64*	2		,,	7·9	27857·8*b*
	3582·72	1		,,	,,	27903·9*b*
	3582·54*	2		,,	,,	27905·3*b*
	3581·82*	1		,,	,,	27910·9*b*
	3576·80*	3		0·99	,,	27950·1*b*
3572·416	3572·44	3		,,	,,	27984·2*ab*
3567·789	3567·88	7	3566·5 ,,	,,	,,	28020·3*ab*
3564·423	3564·54*	3		,,	,,	28046·7*ab*
3563·362	3563·50	6	3562·8 ,,	0·99	7·9	28055·0*ab*
	3561·51*†			,,	,,	28070·1*b*
3559·601	3559·69*	2		,,	,,	28085·4*ab*
3556·135	3556·16	2		,,	,,	28112·4*ab*
	3555·55	2		,,	,,	28117·1*b*
3554·435	3554·48	5	3554·5 ,,	,,	,,	28125·8*ab*
	3551·95	1		,,	,,	28145·5*b*
3545·947	3545·87	3		,,	8·0	28193·5*ab*
3514·513	3514·53*	2		0·98	,,	28445·4*ab*
3509·934				,,	,,	28487·3*a*
3506·650	3506·64	2		,,	8·1	28509·2*ab*
3493·435	3493·40	2		0·97	,,	28617·2*ab*
3476·894	3476·96*	2		,,	,,	28752·9*ab*
3461·192	3461·23	3		,,	8·2	28883·4*ab*
3455·076	3455·14	1		0·96	,,	28934·5*ab*
3442·640	3442·77	1		,,	,,	29038·7*ab*
3406·287	3406·29	1		0·95	8·3	29348·3*ab*
3398·016		1		,,	,,	29420·6*a*
3393·848	3394·03	3		,,	8·4	29456·0*ab*
3392·885	3392·94	2		,,	,,	29464·8*ab*
3389·955	3390·05	1		,,	,,	29490·1*ab*
3388·464		1		,,	,,	29501·5*a*

RED SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	$\frac{1}{\lambda}$−	
3387·698	3387·80	1		0·95	8·4	29509·7*ab*
3381·573	3381·67	1		"	"	29563·2*ab*
3373·586	3373·65	2		0·94	"	29633·4*ab*
3360·146		1		"	8·5	29752·9*a*
3341·637		1		"	"	29916·9*a*
3325·626	3325·63	2		0·93	"	30061·0*ab*
	3323·91	1		"	8·6	30077·5*b*
3319·459	3319·42	2		"	"	30117·0*ab*
3303·08		1		"	"	30266·4*a*
3302·50		3		"	"	30271·5*a*
3295·44		2		0·92	"	30336·4*a*
3244·51		1		0·91	8·8	30812·5*ab*
3175·11		1		0·89	9·0	31486·1*a*
3131·90		2		0·88	9·1	31920·4*a*
3125·70		4		"	"	31983·8*a*
	3034·7	4		0·86	9·4	32943·8*b*
	3029·10*	2		"	"	33003·7*b*
	3027·07*	1		"	"	33025·8*b*
3021·52	3021·9	4		0·85	9·5	33085·4*ab*
	2979·35*	2		0·84	9·6	33554·7*b*
2972·60		1		"	"	33631·1*a*
2968·39		2		"	9·7	33678·6*a*
2967·35	2967·3	5		"	"	33690·4*ab*
	2943·17*	1		"	9·8	33967·1*b*
	2893·5	1		0·82	10·0	34550·2*b*
	2891·87*	3		"	"	34569·7*b*
	2873·5	3		"	"	34790·8*b*
	2866·0*	1		"	10·1	34880·7*b*
	2833·6	3		0·81	10·2	35280·6*b*
	2802·2	3		0·80	10·3	35675·9*b*
	2614·6	4		0·76	11·1	38235·7*b*
	2614·2*	1		"	"	38241·7*b*
	2577·6	1		0·75	11·3	38784·5*b*
	2571·5*	1		"	"	38876·6*b*
	‖2536·7	8		0·74	11·4	39409·8*b*
	2516·3	4		0·73	11·6	39729·3*b*
	2478·65	3		"	11·8	40332·8*b*
	2476·35	2		"	"	40370·2*b*

BLUE SPECTRUM OF ARGON.

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	$\frac{1}{\lambda}$−	
6684·2		2		1·82	4·0	14956·7
6644·2		3		1·80	4·1	15046·6
6638·6		2	6628? Crookes	"	"	15059·3
6482·8		1		1·76	4·2	15421·2
6243·7		2	6232? "	1·70	4·3	16011·8
6215·6*		1		1·69	4·4	16084·3

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	$\frac{1}{\lambda}$−	
6172·3*		3	6173 Crookes	1·68	4·4	16197·1
6140·9		1		1·67	,,	16279·9
6114·1		3	6120 ,,	1·66	,,	16351·2
	6032·69*	2		1·64	4·5	16571·8
	5928·61*	1		1·61	4·6	16862 7
	5912·48*	1		,,	,,	16908·8
	5889·02*	1		1·60	,,	16976·2
	5834·63*	1		1·59	4·7	17134·3
	5772·52*	1		1·57	,,	17318·8
	5739·87*†	2		1·56	,,	17417·3
	5691·94*	1		1·55	4·8	17563·9
	5690·19*	1		,,	,,	17569·0
	5682·26*	1		,,	,,	17593·8
	5659·47*	2		1·54	,,	17664·7
	5651·03*†	5		,,	,,	17691·1
	5649·02*	1		,,	,,	17697·3
	5641·74*	1		,,	,,	17720·2
	5639·39*	1		,,	,,	17727·6
	5635·91*	1		,,	,,	17738·6
	5624·06*	1		1·53	,,	17776·0
	5618·30*	1		,,	,,	17794·2
	5607·44*†	6		,,	4·9	17828·6
	5597·89*†	3		,,	,,	17859·0
	5582·20*†	1		1·52	,,	17909·2
	5577·98	2		,,	,,	17922·7
	5572·87*†	4		,,	,,	17939·2
	5559·93*†	2		,,	,,	17980·9
	5559·02*†	8		,,	,,	17983·8
	5554·37	2		,,	,,	17998·9
	5534·73*	1		1·51	,,	18062·8
	5529·18*	1		,,	,,	18051·0
	5525·27*†	2		,,	,,	18093·8
	5506·43*†	3		1·50	,,	18155·6
	5498·55	2		,,	5·0	18181·6
	5496·16*†	6		,,	,,	18189·0
	5490·37*	1		,,	,,	18208·0
	5473·76*	1		1·49	,,	18264·0
	5467·41*	1		,,	,,	18385·2
	5457·75*	2		,,	,,	18317·6
	5454·71	2		,,	,,	18327·8
	5451·95*†	4		,,	,,	18337·1
	5443·54*†	2		,,	,,	18365·4
	5442·54*	1		,,	,,	18368·7
	5440·28*†	2		,,	,,	18376·4
	5421·68*†	4		1·48	,,	18439·5
	5410·76*	2		,,	,,	18476·7
	5407·70	2		,,	,,	18487·1
	5402·95	2		,,	,,	18503·4
	5397·90	2		1·47	5·1	18520·6
	5394·20*	1		,,	,,	18533·3
	5375·76*	1		,,	,,	18603·8
	5306·04†	4		1·45	,,	18841·3
	5287·24†	5		,,	5·2	18908·3
	5265·05	1		1·44	,,	18988·0
	5254·79*	1		,,	,,	19025·1

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	$\frac{1}{\lambda}$−	
	5253·09*	2		1·44	5·2	19031·2*b*
	5221·65*†	4		1·43	5·2	19145·8*b*
	5217·17†	3		,,	,,	19162·3*b*
	5187·47*†	3		1·42	5·3	19271·9*b*
	5177·81*	1		,,	,,	19307·9*b*
	5176·56†	4		,,	,,	19312·5*b*
	5166·03†	5		1·41	,,	19351·9*b*
	5162·59*†	3		,,	,,	19364·8*b*
	5151·74*	2		,,	,,	19404·7*b*
5145·565	5145·57	4		,,	,,	19428·9*ab*
5141 909	5142·20	4	5140 Crookes	,,	,,	19442·2*ab*
	5126·14	2		1·40	,,	19502·5*b*
	5118·55*	1		,,	,,	19531·4*b*
	5090·81	2		1·39	5·4	19637·8*b*
	5076·25†	1		,,	,,	19694·0*b*
5062·199	5062·35†	5	5065 ,,	1·38	,,	19748·6*ab*
	5060·39*	2		,,	,,	19755·9*b*
	5024·47	3		1·37	5·5	19897·1*b*
5017·331	5017·46†	4	5012 ,,	,,	,,	19925·2*ab*
5009·426	5009·63†	5	5007 ,,	,,	,,	19956·5*ab*
	4972·40†	4		1·36	,,	20105·5*b*
4965·239	4665·38†	4	4965·5 ,,	,,	,,	20134·2*ab*
	4955·31	4		,,	,,	20174·9*b*
	4949·53	2		1·35	,,	20198·4*b*
	4943·17†	4		,,	,,	20224·3*b*
4933·406	4933·49†	4	4938 ,,	,,	5·6	20264·2*ab*
	4905·05†	4		1·34	,,	20381·6*b*
	4893·57	4		,,	,,	20429·4*b*
	4888 88†	4		,,	,,	20449·4*b*
	4888·21*	2		,,	,,	20451·8*b*
	4882·46	4		,,	,,	20475·9*b*
4880·004	4880·14†	8	4879 ,,	,,	,,	20485·9*ab*
	4867·72†	5		1·33	,,	20537·9*b*
	4866·14†	6		,,	,,	20544·6*b*
	4861·44	2		,,	,,	20564·3*b*
4847·963	4847·94†	6	4847·5 ,,	,,	5·7	20621·5*ab*
	4834·32	1		1·32	,,	20679·7*b*
	4819·43	2		,,	,,	20743·6*b*
4806·173	4806·17†	8	4805·0 ,,	,,	,,	20801·4*ab*
	4792·29	1		1·31	,,	20861·1*b*
	4791·49	1		,,	,,	20864·7*b*
	4771 75†	3		,,	5·8	20950·9*b*
4765·028	4765·04†	4	4763·0 ,,	,,	,,	20980·4*ab*
	4754·64	2		1·30	,,	21026·3*b*
4736·065	4736·03*†	6	4734·5 ,,	,,	,,	21108·8*ab*
4727·027	4727 90†	4	4726·6 ,,	1·29	,,	21149·2*ab*
	4708·66	3		,,	,,	21231·6*b*
	4702 40*	1		,,	5·9	21259·8*b*
4658·079	4658·04*†	4	4656·5 ,,	1·28	,,	21462·4*ab*
	4640·21	2		1·27	,,	21544·8*b*
4637·351	4637·35†	3		,,	,,	21558·1*ab*
4609·742	4609·73*†	7	4608·0 ,,	1·26	6·0	21687·2*ab*
4590·081	4590·05*†	5	4586·9 ,,	,,	,,	21775·8*ab*
4579·527	4579·53†	6	4579·5 ,,	1·25	,,	21830·0*ab*
	4565·42	2		,,	,,	21897·8*b*

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	$\frac{1}{\lambda}$−	
	4564·55	3		1·25	6·0	21901·9*b*
	4563·87	3		,,	,,	21905·1*b*
	4561·20	1		,,	6·1	21918·0*b*
	4547·88	2		,,	,,	21982·1*b*
4545·220	4545·26†	6	4543·5 Crookes	,,	,,	21949·9*ab*
	4535·70	3		1·24	,,	22041·2*b*
	4530·73	3		,,	,,	22064·1*b*
4503·111	4503·15	5		1·23	,,	22200·7*ab*
	4493·68	4		,,	,,	22222·6*b*
	4491·22†	4		,,	6·2	22259·5*b*
4482·003	4481·99†	5	4478·3 ,,	,,	,,	22305·2*ab*
4475·015	4475·15	2		,,	,,	22339·8*ab*
4460·682	4460·70	2		1·22	,,	22411·9*ab*
4449·123	4449·13	2		,,	,,	22469·9*ab*
4443·545	4443·50	1		,,	,,	22498·4*ab*
4439·539	4439·50	1		,,	,,	22518·9*ab*
4434·037	4434·10	2		,,	,,	22546·5*ab*
4431·172	4431·16*†	3		,,	,,	22561·8*ab*
4430·355	4430·35*†	5	4426·5 ,,	1·21	6·3	22565·3*ab*
4426·165	4426·16*†	8	4422·5 ,,	,,	,,	22587·2*ab*
4421·113	4421·06†	1		,,	,,	22612·5*ab*
4408·095	4408·06	1		,,	,,	22679·3*ab*
4401·156	4401·19*†	5	} 4399·5 ,,	,,	,,	22715·0*ab*
4400·271	4400·25*†	3		,,	,,	22719·7*ab*
4383·900	4383·94	2		1·20	,,	22803·3*ab*
4379·827	4379·79*†	5	4376·5 ,,	,,	,,	22825·7*ab*
4376·112	4376·15†	3		,,	,,	22845·4*ab*
4375·201	4375·25	1		,,	,,	22849·7*ab*
4371·504	4371·46*†	4	} 4369·0 ,,	,,	,,	22869·4*ab*
4370·928	4370·92†	3		,,	,,	22872·2*ab*
4367·952	4368·04†	1		,,	,,	22887·4*ab*
4362·229	4362·20†	2		,,	6·4	22917·7*ab*
4352·368	4352·40†	4		1·19	,,	22969·5*ab*
4348·222	4348·11*†	9	4348·5 ,,	,,	,,	22992·3*ab*
4343·904	4343·90	2		,,	,,	23014·4*ab*
4337·244	4337·20*	1		,,	,,	23049·9*ab*
4333·70	4333·65*†	4		,,	,,	23068·7*ab*
4332·205	4332·15	3		,,	,,	23076·7*ab*
4331·354	4331·31*†	4	4333·5 ,,	,,	,,	23081·2*ab*
4309·311	4309·31†	2		1·18	,,	23199·2*ab*
4300·824	4300·82†	2	4299·0? ,,	,,	6·5	23244·9*ab*
4298·222	4298·20	1		,,	,,	23259·0*ab*
4283·054	4283·03†	3		,,	,,	23341·3*ab*
4277·718	4277·65*	6	4277·0 ,,	1·17	,,	23370·6*ab*
4275·327	4275·34	1		,,	,,	23383·5*ab*
4266·684	4266·44*†	6	4266·0 ,,	,,	,,	23431·6*ab*
	4255·73	1		,,	,,	23491·2*b*
4237·395	4237·34	3		1·16	6·6	23593·0*ab*
4229·813		1		,,	,,	23636·1*a*
4229·015		1		,,	,,	23639·6*a*
4228·310	4228·27*†	5	4228·5 ,,	,,	,,	23642·5*ab*
4227·146	4227·14	2		,,	,,	23650·6*ab*
4222·839	4222·76	3		,,	,,	23674·4*ab*
4218·843	4218·79	3		,,	,,	23696·7*ab*
4203·609	4203·54	1		1·15	,,	23782·7*ab*

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length Kayser (a)	Wave-length Eder & Valenta (b)	Intensity	Previous Observations	Reduction to Vacuum λ+	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4202·106	4202·11*†	2		1·15	6·6	23791·0*ab*
4189·774	4200·75*†	1		,,	,,	23798·6*b*
	4191·02*†	1		,,	6·7	23853·8*b*
	4190·85*†	1		,,	,,	23854·8*b*
4183·106	4182·03*†	2	4183·0 ? Crookes	,,	,,	23905·1*b*
4179·479	4179·45	3		,,	,,	23919·9*ab*
4178·504	4178·53	3		,,	,,	23925·1*ab*
	4164·36*†	1		1·14	,,	24006·6*b*
	4158·65*†	1		,,	,,	24039·6*b*
4156·295	4156·36	2		,,	,,	24053·2*ab*
4146·761	4146·68	1		,,	6·8	24108·4*ab*
4131·913	4131·95*	3	4131·5 ,,	,,	,,	24195·0*ab*
	4129·89	2		1·13	,,	24206·9*b*
	4128·87†	4		,,	,,	24212·9*b*
4112·916	4113·04†	3		,,	,,	24306·5*ab*
4104·107	4104·10*	7	4105·0 ,,	,,	,,	24359·6*ab*
4099·602	4099·59	2		,,	,,	24385·8*ab*
	4098·33	3		,,	6·9	24393·2*b*
4097·265	4097·36	1		,,	,,	24399·4*ab*
4089·041	4089·04	1		1·12	,,	24448·7*ab*
4082·535	4082·59†	2		,,	,,	24487·5*ab*
4080·872	4080·85 } †	1		,,	,,	24497·7*ab*
4079·712	4079·80 }	2		,,	,,	24504·4*ab*
4077·207	4077·15	2		,,	,,	24519·9*ab*
4076·854	4076·85	5		,,	,,	24521·8*ab*
4072·579	4072·58 }	3		,,	,,	24547·5*ab*
4072·159	4072·18 } †	4	4072·5 ,,	,,	,,	24550·0*ab*
4068·171		1		,,	,,	24574·7*a*
4053·111	4053·12	4		1·11	,,	24665·5*ab*
4043·039	4043·04	3	4044·0 ,,	,,	7·0	24726·9*ab*
4038·966	4038·99†	4		,,	,,	24751·7*ab*
4035·624	4035·58†	4		,,	,,	24772·4*ab*
4034·022	4033·99†	4	4033·0 ,,	,,	,,	24782·2*ab*
4023·730	4023·68	3		,,	,,	24845·7*ab*
4017·986		1		,,	,,	24881·1*a*
4014·002	4013·97*†	7	4013·0 ,,	1·10	,,	24905·0*ab*
4011·527	4011·38	1		,,	,,	24921·6*ab*
4010·052		1		,,	,,	24930·3*a*
3995·035	3994·81	3		,,	7·1	25024·7*ab*
3992·196	3992·17†	4		,,	,,	25041·8*ab*
3988·378	3988·37	1		,,	,,	25065·8*ab*
3979·541	3979·57*	5	3978·5 ,,	,,	,,	25121·3*ab*
3974·859		1		1·09	,,	25151·0*a*
3974·646	3974·70†	4		,,	,,	25152·2*ab*
3968·496	3968·54	3	3967·8 ,,	,,	,,	25191·3*ab*
3960·591	3960·62	3		,,	,,	25241·6*ab*
3958·529	3958·58	3		,,	,,	25254·7*ab*
3952·892	3952·82	1		,,	7·2	25290·8*ab*
3946·290	3946·20	4		,,	,,	25333·3*ab*
3944·409	3944·50	4	3943·5 ,,	,,	,,	25344·8*ab*
3937·208		1		,,	,,	25391·5*a*
	3934·20	3		1·08	,,	25411·0*b*
3932·717	3932·71	4	3931·8 ,,	,,	,,	25420·5*ab*
3931·382	3931·32†	2		,,	,,	25429·4*ab*
3928·749	3928·78*†	7	3928·5 ,,	,,	,,	25446·1*ab*

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	1/λ −	
3925·903	3925·93	3	3927·5 Crookes	1·08	7·2	25464·6*ab*
3924·798		1		,,	,,	25471·8*a*
3914·931	3914·93*†	3	3915·4 ,,	,,	,,	25536·0*ab*
3911·721	3911·69	1		,,	,,	25557·1*ab*
3907·896	3907·80	1		,,	7·3	25581·9*ab*
3900·763		2		,,	,,	25628·7*a*
3892·128	3892·15†	4	3892·6 ,,	1·07	,,	25685·5*ab*
3891·550	3891·53†	2		,,	,,	25689·6*ab*
3880·432	3880·46	3		,,	,,	25762·9*ab*
3875·406	3875·40†	5	3875·5 ,,	,,	,,	25796·4*ab*
3874·288		1		,,	,,	25803·9*a*
3872·326	3872·26	4	3871·8 ,,	,,	,,	25817·2*ab*
3868·718	3868·68*	7	3868·5 ,,	,,	,,	25841·2*ab*
3858·456		2		,,	,,	25909·8*a*
3856·210		1		1·06	,,	25924·9*a*
3855·366		1		,,	,,	25930·5*a*
3854·522		1		,,	,,	25936·3*a*
3850·715	3850·70*†	8	3851·5 ,,	,,	,,	25961·9*ab*
3846·860		1		,,	,,	25987·9*a*
3845·535	3845·51†	3	3845·5 ,,	,,	,,	25997·0*ab*
3844·921	3844·90	3		,,	,,	26001·8*ab*
3841·709	3841·63	3		,,	,,	26023·1*ab*
3830·585	3830·58†	3		,,	,,	26099·4*ab*
3826·976	3826·92	3	3827·5 ,,	,,	,,	26123·2*ab*
3825·865	3825·89	1		,,	,,	26130·5*ab*
3819·300	3819·15	1		,,	,,	26176·1*ab*
3809·649	3809·58*	3	3809·5 ,,	1·05	7·4	26242·0*ab*
3808·746	3808·72†	3		,,	,,	26248·1*ab*
3803·381	3803·38	3	3803·5 ,,	,,	,,	26285·6*ab*
3800·429	3800·40†	2		,,	,,	26305·5*ab*
3799·596	3799·65	3	3799·5 ,,	,,	,,	26311·0*ab*
3796·882	3796·83	2		,,	,,	26330·1*ab*
3795·509	3795·56†	3		,,	,,	26339·3*ab*
3786·536	3786·60†	4		,,	,,	26401·8*ab*
3781·018	3781·07*	7	3780·8 ,,	,,	,,	26440·4*ab*
3776·885		1		1·04	,,	26469·5*a*
3770·719	3770·80*	2	3770·5 ,,	,,	,,	26512·3*ab*
3766·286	3766·30	3		,,	,,	26473·7*ab*
3765·463	3765·48*	5	3766·0 ,,	,,	7·5	26549·6*ab*
3763·715	3763·76	4		,,	,,	26561·8*ab*
3756·541		1		,,	,,	26612·7*a*
	3754·28	3		,,	,,	26626·8*b*
3753·722	3753·60	3		,,	,,	26633·3*ab*
3750·428	3750·79	2		,,	,,	26654·8*ab*
3747·135	3747·25	1		,,	,,	26679·1*ab*
	3739·88	2		,,	,,	26731·3*b*
3738·094	3738·04*	3	3738·5 ,,	,,	,,	26744·3*ab*
3735·542		1		1·03	,,	26765·2*a*
	3734·70	5		,,	,,	26768·2*b*
3733·122		1		,,	,,	26780·5*a*
3729·450	3729·52*†	9	3729·8 ,,	,,	,,	26805·9*ab*
3725·665		1		,,	7·6	26833·2*a*
3724·697	3724·67	3		,,	,,	26840·3*ab*
3720·617	3720·61	1		,,	,,	26869·6*ab*
3718·403	3718·39	5	3718·0 ,,	,,	,,	26886·7*ab*

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	1/λ −	
3717·367	3717·36	3		1·03	7·6	26893·1*ab*
3716·704		1		,,	,,	26898·0*a*
3714·744		1		,,	,,	26912·2*a*
3712·941	3713·19	2		,,	,,	26925·1*ab*
3710·167	3710·11	1		,,	,,	26945·2*ab*
3696·160		1		1·02	,,	27047·5*a*
3692·739		1		,,	,,	27072·6*a*
3680·124	3680·30*	1		,,	7·7	27164·7*ab*
3678·478	3678·43*	2		,,	,,	27176·8*ab*
3670·071		1		,,	,,	27239·7*a*
3669·700	3669·63	2		,,	,,	27242·7*b*
3660·635	3660·70	1		,,	,,	27309·7*ab*
3656·270	3656·26	3		1·01	,,	27344·1*ab*
3655·474	3655·52	5		,,	,,	27348·4*ab*
3651·141	3651·04	4		,,	,,	27381·4*ab*
3650·313		1		,,	,,	27387·0*a*
3640·022	3640·00	2		,,	,,	27464·7*ab*
3638·015		7	3631·7 Crookes	,,	7·8	27479·8*a*
3637·212	3637·25	3		,,	,,	27485·7*ab*
3622·354	3622·31	2		,,	,,	27598·6*ab*
	3612·00	2		1·00	,,	27677·7*b*
	3611·11	1		,,	,,	27684·5*b*
3606·056		2		,,	,,	27723·3*a*
	3605·05	3		,,	,,	27731·1*b*
3603·981	3603·70	1		,,	,,	27740·4*ab*
	3601·68	2		,,	,,	27757·0*b*
	3601·10	1		,,	,,	27761·5*b*
	3600·24	2		,,	,,	27768·1*b*
	3598·60	3		,,	,,	27780·7*b*
3592·198		1		,,	7·9	27830·2*a*
3588·633	3588·64*	9	3587·0 ,,	,,	,,	27857·8*ab*
3587·122		1		,,	,,	27869·6*a*
3586·122		1		,,	,,	27877·4*a*
3585·203		1		,,	,,	27884·6*a*
3582·547	3582·54*	7 }	3580·3 ,,	,,	,,	27905·2*ab*
3581·802	3581·82*	4 }		,,	,,	27910·9*ab*
3580·439		1		,,	,,	27921·6*a*
3579·000		1		,,	,,	27932·9*a*
3576·808	3576·80*	8	3575·0 ,,	0·99	,,	27950·1*ab*
3573·290		1		,,	,,	27977·5*a*
3565·221	3565·20	3	3564·0 ,,	,,	,,	28041·0*ab*
3564·586	3564·54*	2		,,	,,	28046·0*ab*
	3564·50	4		,,	,,	28046·5*b*
3563·198	3563·46	1		,,	,,	28055·8*ab*
3562·388		1		,,	,,	28063·2*a*
3561·213	3561·51*†	7	3560·0 ,,	,,	,,	28071·3*ab*
	3561·20	5		,,	,,	28072·5*b*
3559·695	3559·69*	8	3558·2 ,,	,,	,,	28084·3*ab*
3558·670		1		,,	,,	28092·5*a*
3557·029		1		,,	,,	28104·7*a*
3556·167		1		,,	,,	28112·2*a*
3555·107		1		,,	,,	28120·5*a*
3548·680	3548·69	3		,,	8·0	28171·5*ab*
3546·005	3546·03	7	3547·5 ,,	,,	,,	28192·5*ab*
3545·792	3545·78	7	3544·5 ,,	,,	,,	28194·5*ab*

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length: Kayser (a)	Wave-length: Eder & Valenta (b)	Intensity	Previous Observations	Reduction to Vacuum: λ+	Reduction to Vacuum: $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3535·514	3535·53	4	3534·3 Crookes	0·98	8·0	28276·4*ab*
3522·100	3522·14†	3		,,	,,	28384·1*ab*
3521·431	3521·46	3		,,	,,	28390·5*ab*
3520·191	3520·15	5		,,	,,	28399·7*ab*
	3519·52	3		,,	,,	28405·0*b*
3518·079		1		,,	,,	28416·6*a*
3514·576	3514·53*	4	3513·5 ,,	,,	,,	28445·1*ab*
3514·351		4		,,	,,	28446·8*a*
3511·804	3511·79	1		,,	,,	28467·4*ab*
3511·286	3511·35	6	3508·8 ,,	,,	,,	28471·3*ab*
3509·961	3509·93	5		,,	,,	28482·4*ab*
3509·475	3509·54	3		,,	8·1	28485·9*ab*
3507·795		1		,,	,,	28499·9*a*
3507·268		1		,,	,,	28504·1*a*
3506·426		1		,,	,,	28510·9*a*
	3505·08	3		,,	,,	28521·9*b*
3503·730	3503·76†	2		,,	,,	28532·8*ab*
3502·841	3502·00	2		,,	,,	28543·6*ab*
3500·724		1		,,	,,	28557·5*a*
3499·815	3499·85†	3		,,	,,	28564·7*ab*
3498·419		1		0·97	,,	28576·3*a*
3497·219		1		,,	,,	28586·1*a*
3495·193		1		,,	,,	28602·7*a*
3493·562		1		,,	,,	28616·0*a*
3491·723	3491·71†	9	3490·0 ,,	,,	,,	28631·1*ab*
3491·440		5		,,	,,	28633·4*a*
3491·030		2		,,	,,	28636·7*a*
3488·316		1		,,	,,	28659·0*a*
3484·121		1		,,	,,	28694·3*a*
3480·636	3480·69†	5		,,	,,	28722·0*ab*
3478·410	3478·42†	2		,,	,,	28740·7*ab*
3476·926	3476·96*	6	3475·7 ,,	,,	,,	28752·9*ab*
3473·368		1		,,	,,	28782·4*a*
3472·713		1		,,	,,	28787·3*a*
3471·443		1		,,	,,	28798·4*a*
3466·533	3466·40	3		,,	8·2	28839·6*ab*
	3466·07	4		,,	,,	28842·9*b*
3464·364	3464·33	2		,,	,,	28857·3*ab*
3455·572		1		0·96	,,	28930·6*a*
3454·298	3454·30	4	3453·5 ,,	,,	,,	28941·2*ab*
3450·223		1		,,	,,	28975·7*a*
	3448·46	2		,,	,,	28990·2*b*
3445·254		1		,,	,,	29017·2*a*
3438·174		2		,,	,,	29077·1*a*
	3432·75	2		,,	,,	29122·9*b*
3430·650	3430·58	1		,,	8·3	29140·7*ab*
3429·846	3429·81	3		,,	,,	29147·5*ab*
3424·385	3424·41	2		,,	,,	29193·9*ab*
3421·821	3421·80	4		,,	,,	29216·0*ab*
3417·608		1		0·95	,,	29251·9*a*
	3414·61	3		,,	,,	29277·6*b*
3413·665		1		,,	,,	29285·7*a*
	3406·43	2		,,	,,	29347·9*b*
3404·432		1		,,	,,	29365·2*a*
	3397·97	2		,,	,,	29421·0*b*

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length Kayser (a)	Wave-length Eder & Valenta (b)	Intensity	Previous Observations	Reduction to Vacuum λ+	Reduction to Vacuum 1/λ−	Oscillation Frequency in Vacuo
	3393·46	1		0·95	8·4	29460·1*b*
3391·959	3391·86	5		,,	,,	29473·5*ab*
3388·706	3388·65	5	3388·0 Crookes	,,	,,	29501·8*ab*
	3384·94	2		,,	,,	29534·2*b*
	3383·87	1		,,	,,	29543·6*b*
	3381·27	2		,,	,,	29570·3*b*
3379·674	3379·73	2		,,	,,	29580·0*ab*
3376·618	3376·61	5		0·94	,,	29607·1*ab*
3371·077	3371·07	3		,,	,,	29655·8*ab*
3366·758	3366·75	3		,,	,,	29693·8*ab*
3365·660	3365·67	2		,,	,,	29703·4*ab*
3361·973	3361·33	1		,,	,,	29738·9*ab*
3361·418		2		,,	,,	29740·6*a*
3358·633	3358·67	4		,,	8·5	29765·5*ab*
3355·298		1		,,	,,	29795·1*a*
3352·248		2		,,	,,	29822·2*a*
3351·112	3351·10	4		,,	,,	29832·4*ab*
3348·161		1		,,	,,	29858·6*a*
3344·857	3344·89	5		,,	,,	29888·0*ab*
3342·532		1		,,	,,	29908·5*a*
3341·518	3341·88	1		,,	,,	29916·4*ab*
3339·602		1		,,	,,	29935·2*a*
3336·269	3336·32	4		0·93	,,	29964·9*ab*
3332·972		1		,,	,,	29995·0*a*
3327·441		1		,,	,,	30044·6*a*
3323·671		2		,,	8·6	30078·6*a*
3314·622		1		,,	,,	30160·8*a*
3311·318	3311·34	5		,,	,,	30190·7*ab*
3308·040		1		,,	,,	30220·7*a*
3307·368	3307·37	5		,,	,,	30226·9*ab*
3306·499		1		,,	,,	30243·9*a*
3305·720		1		,,	,,	30242·0*a*
3305·249		2		,,	,,	30246·3*a*
3301·938	3301·97	6		,,	,,	30276·5*ab*
3298·652		2		0·92	,,	30306·8*a*
3293·768	3293·82	4		,,	,,	30351·5*ab*
3289·201		2		,,	,,	30388·4*a*
3285·913	3285·91	7		,,	8·7	30424·3*ab*
3282·661		2		,,	,,	30454·4*a*
3281·867	3281·83	5		,,	,,	30461·9*ab*
3273·476	3273·40	2		,,	,,	30540·2*ab*
3271·122		1		,,	,,	30561·8*a*
3263·953		1		,,	,,	30629·0*a*
3261·722	3263·71	3		,,	,,	30631·2*ab*
	3259·73	1		0·91	,,	30668·1*b*
	3258·95	1		,,	,,	30776·0*b*
3251·888	3251·90	2		,,	8·8	30742·5*b*
3249·972	3249·95	4		,,	,,	30760·8*ab*
3245·638		1		,,	,,	30801·8*a*
3243·845	3243·85	3		,,	,,	30818·8*ab*
3237·920	3237·05	2		,,	,,	30879·4*ab*
3236·812		1		,,	,,	30885·8*a*
	3230·30	1		,,	,,	30948·1*b*
	3226·16	2		,,	,,	30977·6*b*
3222·183	3222·62	1		,,	,,	31026·9*a*

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length Kayser (a)	Wave-length Eder & Valenta (b)	Intensity	Previous Observations	Reduction to Vacuum λ+	Reduction to Vacuum 1/λ−	Oscillation Frequency in Vacuo
	3221·41	2		0·91	8·8	31033·3*b*
	3217·89	1		0·90	,,	31067·4*b*
	3216·98	2		,,	,,	31076·2*b*
3212·737	3212·76	3		,,	8·9	31117·1*ab*
3210·678		1		,,	,,	31137·2*a*
	3207·85	1		,,	,,	31164·6*b*
3204·469	3204·49	4		,,	,,	31197·5*ab*
3196·109		1		,,	,,	31279·1*a*
3194·400	3194·52	3		,,	,,	31295·3*ab*
3187·970		1		,,	,,	31359·3*a*
	3186·42	2		,,	,,	31374·2*b*
3183·171		1		,,	,,	31406·4*a*
3181·174	3181·26	5		0·89	,,	31425·5*ab*
	3179·30	1		,,	9·0	31445·5*b*
	3173·26	1		,,	,,	31504·3*b*
3171·767		1		,,	,,	31519·1*a*
3169·812	3169·88	4		,,	,,	31538·6*ab*
	3167·70	2		,,	,,	31559·6*b*
3165·480	3165·36	2		,,	,,	31582·4*ab*
3161·519	3161·64	5		,,	,,	31620·8*ab*
	3159·47	1		,,	,,	31641·9*b*
3157·577	3157·13	2		,,	,,	31663·1*ab*
	3154·06	2		,,	,,	31696·2*b*
	3152·89	1		,,	,,	31707·9*b*
	3150·70	1		,,	,,	31729·9*b*
	3148·53	1		,,	,,	31751·8*b*
	3146·63	1		,,	,,	31770·9*b*
3139·156	3139·26	5		0·88	9·1	31846·5*ab*
	3137·88	2		,,	,,	31859·5*b*
3127·996		1		,,	,,	31960·2*a*
3125·980		1		,,	,,	31980·9*a*
3116·162		1		,,	,,	32081·7*a*
3110·441		1		,,	9·2	32140·6*a*
	3104·63	2		,,	,,	32200·7*b*
	3102·88	1		,,	,,	32218·9*b*
	3100·21	1		0·87	,,	32246·7*b*
3093·478	3093·57	6	3092·7 Crookes	,,	,,	32316·3*ab*
	3085·29	1		,,	,,	32402·7*b*
3083·720	3083·15	2	3084·8 ,,	,,	,,	32421·9*ab*
3078·212		2		,,	9·3	32477·1*a*
3066·998	3067·16	2		,,	,,	32595·0*ab*
3064·830		2	3064·7 ,,	,,	,,	32619·9*a*
3054·846		3		0·86	9·4	32725·3*a*
3048·552		1		,,	,,	32793·1*a*
3046·130	3046·28	2		,,	,,	32818·4*ab*
3039·477		1		,,	,,	32819·0*a*
3033·620	3033·76	3		,,	,,	32953·8*ab*
3031·759		1		,,	,,	32974·8*a*
3029·015	3029·10*	4		,,	,,	33004·2*ab*
3027·181	3027·07*	2		,,	,,	33025·3*ab*
3024·078		3		,,	9·5	33058·4*a*
	3014·70	1		0·85	,,	33161·3*b*
3002·67		4		,,	,,	33294·2*a*
3000·63	3000·70	3	2998·2 ,,	,,	,,	33316·6*ab*
2979·16	2979·35*	6	2978·6 ,,	0·84	9·6	33555·9*ab*

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	$\frac{1}{\lambda}$−	
	2960·45	3		0·84	9·7	33768·9*b*
2955·37	2955·67	4		,,	,,	33825·3*ab*
2942·94	2943·17*	7	2942·7 Crookes	,,	9·8	33968·5*ab*
	2932·90	2		0·82	,,	34086·1*b*
2931·52	2931·72	3	2929·6 ,,	,,	,,	34101·0*ab*
2924·68	2924·92	4		,,	,,	34180·6*ab*
	2916·3	2		,,	9·9	34280·1*b*
2896·91	2896·97	4		,,	,,	34509·2*ab*
2891·73	2891·87*	4		,,	10·0	34570·5*ab*
2884·24	2884·1	4		,,	,,	34661·2*a*
	2879·0	4		,,	,,	34724·3*b*
2878·79		2		,,	,,	34726·8*a*
	2874·6	3		,,	,,	34777·4*b*
	2866·0*	5		,,	10·1	34881·7*b*
	2860·9	1		0·81	,,	34943·9*b*
2855·29	2855·4	3		,,	,,	35012·7*a*
2853·27	2853·5	2		,,	,,	35037·5*a*
	2847·0	3		,,	10·2	35114·5*b*
	2843·7	3		,,	,,	35155·2*b*
2842·88	2842·6	3		,,	,,	35165·4*a*
2824·47	2824·2	1	2830·2 ,,	0·80	,,	35394·7*ab*
	2818·4	1		,,	10·3	35470·8*b*
	2809·7	1		,,	,,	35581*b*
	2806·3	8		,,	,,	35624*b*
	2800·7	1		,,	,,	35695*b*
2796·66	2797·0	3	2794·4 ,,	,,	10·4	35746·5*a*
	2795·65	3		,,	,,	35759·5*b*
	2789·1	1		,,	,,	35844*b*
	2785·3	1		,,	,,	35893*b*
	2784·6	2		,,	,,	35902*b*
2774·90	2775·1	1		0·79	,,	36026·8*a*
	2769·7	8		,,	10·5	36094*b*
	2764·5	4		,,	,,	36162*b*
2762·11	2762·1	3		,,	,,	36193·7*a*
	2757·2	3		,,	,,	36258*b*
	2753·9	8		,,	,,	36302*b*
	2744·88	8		,,	10·6	36420·8*b*
	2741·1	2		0·78	,,	36471*b*
	2732·67	6		,,	,,	36583·6*b*
	2724·8	1		,,	10·7	36689*b*
	2720·4	1		,,	,,	36748*b*
	2708·40	8		,,	,,	36911·4*b*
	2701·8	1		,,	10·8	37001*b*
	2692·8	4		0·77	,,	37125*b*
	2683·6	2		,,	,,	37252*b*
	2678·6	2		,,	,,	37322*b*
	2674·3	2		,,	10·9	37382*b*
	2663·7	3		,,	,,	37531*b*
	2662·9	1		,,	,,	37544*b*
	2660·8	1		,,	,,	37572*b*
	2660·3	1		,,	,,	37578*b*
	2654·8	2		0·76	,,	37657*b*
	2652·4	1		,,	11·0	37691*b*
	2650·0	2		,,	,,	37725*b*
	2647·6	8		,,	,,	37759*b*

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	$\frac{1}{\lambda}$−	
	2640·9	1		0·76	11·0	37855
	2637·7	1		„	„	37901
	2634·4	1		„	„	37948
	2632·3	1		„	„	37979
	2627·8	2		„	11·1	38044
	2625·0	2		„	„	38084
	2621·4	3		„	„	38137
	2617·0	2		„	„	38201
	2614·2*	1		„	„	38242
	2592·3	2		0·75	11·2	38565
	2585·0	1		„	11·3	38674
	2579·7	1		„	„	38753
	2571·5*	4		„	„	38877
	{2570·0	2		„	„	38900
	{2569·3	2		„	„	38910
	2568·1	1		„	„	38928
	{2566·4	1		„	11·4	38954
	{2565·8	1		„	„	38963
	2564·7	4		0·74	„	38980
	2562·3	6		„	„	39016
	2559·5	3		„	„	39059
	2556·8	3		„	„	39100
	2553·6	1		„	„	39149
	2549·8	3		„	„	39208
	2547·4	1		„	11·5	39244
	2546·0	1		„	„	39266
	2544·8	6		„	„	39284
	2540·1	3		„	„	39357
	2536·0	3		„	„	39421
	2534·8	5		„	„	39439
	2528·6	4		„	11·6	39536
	2525·6	4		„	„	39582
	2522·5	3		„	„	39621
	2516·8	8		0·73	„	39721
	2515·6	8		„	„	39740
	2512·3	3		„	„	39792
	2510·6	3		„	11·7	39819
	2507·3	2		„	„	39872
	2504·7	1		„	„	39913
	2503·9	2		„	„	39926
	2501·8	3		„	„	39959
	2500·4	5		„	„	39982
	2499·5	4		„	„	39996
	2497·2	2		„	„	40033
	2496·0	3		„	„	40052
	2494·2	2		„	„	40081
	2492·0	2		„	11·8	40116
	2491·0	6		„	„	40123
	2488·9	2		„	„	40166
	2487·0	1		„	„	40197
	2484·1	1		„	„	40244
	2483·2	1		„	„	40259
	2482·3	4		„	„	40275
	2481·6	4		„	„	40284
	2480·9	5		„	„	40296

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	1/λ −	
	2479·2	6		0·73	11·8	40324
	2477·0	1		,,	,,	40359
	2475·6	3		,,	11·9	40382
	2474·2	4		,,	,,	40405
	2473·1	2		,,	,,	40423
	2470·4	2		,,	,,	40467
	2468·8	1		0·72	,,	40504
	2460·2	3		,,	,,	40635
	2458·2	2		,,	12·0	40669
	2457·6	1		,,	,,	40679
	2456·4	1		,,	,,	40698
	2455·3	3		,,	,,	40716
	2454·5	6		,,	,,	40729
	2453·0	1		,,	,,	40754
	2447·9	1		,,	,,	40839
	2444·9	2		,,	,,	40889
	2443·2	2		,,	,,	40918
	2442·7	2		,,	,,	40926
	2441·3	1		,,	,,	40950
	2440·1	3		,,	,,	40970
	2438·8	6		,,	,,	40992
	2436·9	2		,,	,,	41024
	2432·8	4		,,	,,	41093
	2430·5	1		,,	,,	41132
	2430·1	2		,,	,,	41138
	2429·4	1		,,	,,	41150
	2425·4	2		,,	12·2	41218
	2424·5	2		,,	,,	41233
	2423·9	3		,,	,,	41244
	2423·6	2		,,	,,	41249
	2422·7	2		,,	,,	41264
	2421·6	2		0·71	,,	41283
	2420·6	4		,,	,,	41300
	2418·9	3		,,	,,	41329
	2417·3	2		,,	,,	41356
	2415·7	6		,,	,,	41384
	2414·3	3		,,	,,	41408
	2413·2	3		,,	,,	41427
	2412·6	2		,,	12·3	41437
	2411·2	4		,,	,,	41461
	2410·4	2		,,	,,	41475
	2409·6	1		,,	,,	41488
	2408·2	1		,,	,,	41512
	2406·7	3		,,	,,	41538
	2405·2	2		,,	,,	41564
	2404·4	4		,,	,,	41578
	2403·4	2		,,	,,	41595
	2403·3	1		,,	,,	41597
	2400·0	1		,,	,,	41654
	2399·3	3		,,	,,	41667
	2398·4	3		,,	,,	41682
	2397·5	1		,,	12·4	41698
	2395·7	4		,,	,,	41729
	2391·0	1		,,	,,	41811
	2388·2	2		,,	,,	41860

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	$\frac{1}{\lambda}$−	
	2386·8	3		0·71	12·4	41885
	2383·6	3		,,	,,	41941
	2382·6	1		,,	12·5	41958
	2381·2	1		,,	,,	41983
	2380·0	1		,,	,,	42004
	2372·0	1		0·70	,,	42146
	2369·4	1		,,	,,	42192
	2367·1	1		,,	12·6	42233
	2364·2	4		,,	,,	42285
	2362·9	1		,,	,,	42308
	2361·9	1		,,	,,	42326
	2360·2	3		,,	,,	42357
	2358·5	1		,,	,,	46387
	2357·7	3		,,	,,	42402
	2355·1	1		,,	,,	42448
	2354·3	3		,,	12·7	42463
	2353·7	1		,,	,,	42474
	2350·6	4		,,	,,	42530
	2346·7	1		,,	,,	42600
	2345·4	1		,,	,,	42624
	2344·4	5		,,	,,	42642
	2339·9	3		,,	12·8	42724
	2337·8	5		,,	,,	42762
	2333·2	1		,,	,,	42847
	2331·7	4		,,	,,	42874
	2328·2	1		,,	,,	42939
	2324·7	1		0·69	12·9	43003
	2319·5	1		,,	,,	43100
	2318·0	2		,,	,,	43128
	2317·6	2		,,	,,	43135
	2316·5	4		,,	,,	43156
	2315·0	3		,,	,,	43184
	2314·0	4		,,	13·0	43202
	2309·4	4		,,	,,	43288
	2307·5	1		,,	,,	43324
	2305·8	1		,,	,,	43356
	2302·1	3		,,	,,	43426
	2300·9	1		,,	13·1	43448
	2300·3	2		,,	,,	43459
	2295·4	1		,,	,,	43552
	2293·0	1		,,	,,	43598
	2292·2	3		,,	,,	43613
	2290·6	1		,,	,,	43644
	2289·9	2		,,	,,	43657
	2288·8	3		,,	,,	43678
	2287·1	1		,,	13·2	43710
	2285·8	2		,,	,,	43735
	2284·0	2		,,	,,	43770
	2283·3	3		,,	,,	43783
	2282·6	5		,,	,,	43796
	2275·3	1		0·68	13·3	43937
	2275·0	2		,,	,,	43943
	2272·7	1		,,	,,	43987
	2269·8	1		,,	,,	44043
	2268·7	1		,,	,,	44065

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previous Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	$\frac{1}{\lambda}$ −	
	2267·1	1		0·68	13·3	44096
	2265·2	3		,,	,,	44133
	2263·0	2		,,	13·4	44176
	2257·0	1		,,	,,	44293
	2256·6	1		,,	,,	44301
	2255·4	1		,,	,,	44325
	2254·4	2		,,	,,	44344
	2252·4	4		,,	,,	44384
	2251·5	1		,,	,,	44401
	2249·4	1		,,	13·5	44443
	2246·1	1		,,	,,	44508
	2243·7	4		,,	,,	44556
	2241·8	1		,,	,,	44594
	2241·1	3		,,	,,	44607
	2237·9	1		,,	13·6	44671
	2236·6	1		,,	,,	44697
	2235·7	3		,,	,,	44715
	2234·7	4		,,	,,	44735
	2233·6	1		,,	,,	44757
	2231·6	2		,,	,,	44797
	2230·1	1		,,	,,	44827
	2229·7	3		0·67	,,	44835
	2227·4	3		,,	,,	44882
	2225·8	3		,,	13·7	44914
	2221·7	1		,,	,,	44997
	2221·4	1		,,	,,	45003
	2219·9	4		,,	,,	45033
	2219·0	2		,,	,,	45052
	2216·3	2		,,	,,	45107
	2211·0	1		,,	13·8	45215
	2210·5	2		,,	,,	45225
	2205·8	2		,,	,,	45321
	2195·6	2		,,	13·9	45532
	2191·7	1		,,	14·0	45613
	2181·4	1		,,	,,	45619
	2190·6	1		,,	,,	45636
	2187·3	2		,,	,,	45704
	2185·5	2		,,	,,	45742
	2181·2	2		,,	14·1	45832
	2175·6	3		0·66	,,	45950
	2174·7	2		,,	,,	45969
	2171·5	3		,,	,,	46037
	2165·8	3		,,	14·2	46158
	2164·6	1		,,	,,	46184
	2162·1	1		,,	,,	46237
	2159·3	1		,,	14·3	46297
	2154·1	1		,,	,,	46409
	2153·3	1		,,	,,	46426
	2151·2	2		,,	,,	46471
	2130·6	3		0·65	14·5	46921
	2129·5	1		,,	,,	46945
	2126·7	2		,,	14·6	47007
	2120·0	1		,,	,,	47155
	2116·1	1		,,	14·7	47242
	2106·1	1		,,	14·8	47466

BLUE SPECTRUM OF ARGON—*continued.*

Wave-length		Intensity	Previ us Observations	Reduction to Vacuum		Oscillation Frequency in Vacuo
Kayser (a)	Eder & Valenta (b)			λ+	$\frac{1}{\lambda}-$	
	2103·6	1		0·65	14·8	47523
	2092·1	1		,,	14·9	47784
	2078·3	1		,,	15·0	48101
	2077·2	1		,,	,,	48126
	2063·9	1		0·64	15·2	48437
	2057·6	1		,,	,,	48585
	2050·5	1		,,	15·3	48753

TITANIUM (ARC SPECTRUM)

Hasselberg : 'Kongl. Svenska Vetenskaps—Akadem. Handl,' Bd. 28, No. 1, 1895.

* Coincident with a solar line.

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
*5899·56	6	5900·2 Thalén	1·61	4·6	16945·8
5880·55	3		1·60	,,	17000·6
*5866·69	7	5866·5 ,,	,,	,,	17040·8
5823·95	3		1·59	4·7	17165·8
*5804·45	6n		1·58	,,	17223·5
*5786·21	6n		,,	,,	17277·8
*5781·04	3		,,	,,	17293·2
*5774·27	6		1·57	,,	17313·5
*5766·56	5n		,,	,,	17336·7
*5762·52	5n		,,	,,	17348·8
*5757·08	3		,,	,,	17365·2
*5740·20	3s		1·56	,,	17416·3
*5739·69	5	5739·2 ,,	,,	,,	17417·8
*5720·70	4s		,,	4·8	17475·6
5716·71	4		,,	,,	17487·8
*5715·30	5	5715·2 ,,	,,	,,	17492·1
5714·12	4		,,	,,	17495·7
*5712·07	4s		,,	,,	17502·0
5708·46	4		,,	,,	17513·1
*5702·92	5	5702·7 ,,	1·55	,,	17530·1
*5689·70	6	5689·8 ,,	,,	,,	17570·8
*5680·15	4	5680·3 ,,	,,	,,	17600·4
*5675·61	7	5675·7 ,,	,,	,,	17614·5
*5663·16	4		1·54	,,	17653·2
*5662·37	6	5662·8 ,,	,,	,,	17655·6
*5648·81	5	5648·3 ,,	,,	,,	17698·0
*5644·37	6	5644·3 ,,	,,	,,	17712·0
*5565·70	6	5566·0 ,,	1·52	4·9	17962·3
*5514·78	6	} 5514·8 ,,	1·50	,,	18128·2
*5514·58	6		,,	,,	18128·8
*5512·72	6	5513·2 ,,	,,	,,	18135·0

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
5512·00	3		1·50	4·9	18137·3
*5504·10	5	5504·2 Thalén	,,	5·0	18163·3
*5490·38	6	5490·2 ,,	,,	,,	18208·7
*5488·44	5	5488·1 ,,	,,	,,	18215·1
*5482·09	5	5481·5 ,,	,,	,,	18236·2
*5481·64	5		,,	,,	18237·7
*5477·92	5	5477·8 ,,	,,	,,	18250·1
*5474·43	4	5474·6 ,,	1·49	,,	18261·7
*5472·90	3		,,	,,	18266·8
*5471·43	4	5471·8 ,,	,,	,,	18271·8
*5460·72	3		,,	,,	18307·6
*5453·88	3		,,	,,	18330·6
5449·40	3	5449·3 ,,	,,	,,	18345·6
*5446·80	4	5447·1 ,,	,,	,,	18354·4
5438·53	3		1·48	,,	18382·3
5436·93	3s		,,	,,	18387·7
5429·37	5	5429·9 ,,	,,	,,	18413·3
*5426·48	3	5426·3 ,,	,,	,,	18423·2
*5419·00	3	5419·2 ,,	,,	,,	18448·6
*5409·81	5	5409·9 ,,	,,	,,	18479·9
5404·25	3	5404·4 ,,	,,	,,	18499·0
*5397·28	4	5397·3 ,,	1·47	5·1	18522·7
*5396·78	3		,,	,,	18524·5
*5390·23	4		,,	,,	18547·0
5389·36	3		,,	,,	18550·0
*5381·20	3	5381·4 ,,	,,	,,	18578·1
*5369·81	5	5370·0 ,,	,,	,,	18617·5
5366·85	3		,,	,,	18627·8
*5351·28	4	5351·7 ,,	1·46	,,	18682·0
5341·68	2		,,	,,	18715·6
*5338·54	2	5338·1 ,,	,,	,,	18726·6
*5336·96	3		,,	,,	18732·2
*5300·18	2	5299·6 ,,	1·45	5·2	18862·1
5298·61	4		,,	,,	18867·7
*5297·42	5	5297·8 ,,	,,	,,	18871·9
*5295·95	4	5296·6 ,,	,,	,,	18877·2
5289·02	3	5288·9 ,,	,,	,,	18901·9
*5284·61	3		1·44	,,	18917·7
*5283·63	5	5283·9 ,,	,,	,,	18921·2
*5282·61	3		,,	,,	18924·8
*5266·20	5	5266·1 ,,	,,	,,	18983·8
5263·71	3	5264·0 ,,	,,	,,	18992·8
5260·18	3	5260·7 ,,	,,	,,	19005·6
5256·01	4	5256·1 ,,	,,	,,	19020·6
*5252·26	4	5252·1 ,,	,,	,,	19034·2
*5251·14	2		,,	,,	19038·3
*5247·48	3	5247·4 ,,	1·43	,,	19051·6
5246·75	2		,,	,,	19054·2
5246·30	2		,,	,,	19055·9
*5238·77	4	5239·6 ,,	,,	,,	19083·2
*5226·70	3	5227·1 ,,	,,	,,	19127·3
*5225·15	5		,,	,,	19133·0
*5224·71	4	5224·1 ,,	,,	,,	19134·6
*5224·46	5		,,	,,	19135·5
*5223·80	3		,,	,,	19138·0

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum λ+	Reduction to Vacuum 1/λ −	Oscillation Frequency in Vacuo
*5222·87	4		1·43	5·2	19141·4
*5219·88	4		,,	,,	19152·3
*5212·50	3		1·42	,,	19179·5
*5210·55	6	5210·6 Thalén	,,	,,	19186·6
*5208·08	3		,,	5·3	19195·6
*5206·30	3	5206·6 ,,	,,	,,	19202·2
*5201·32	3	5201·6 ,,	,,	,,	19220·6
*5194·25	3		,,	,,	19246·8
*5193·15	6	5193·4 ,,	,,	,,	19250·8
*5188·87	4‖	5189·4 ,,	,,	,,	19266·7
5186·57	3	5186·2 ,,	,,	,,	19275·3
*5173·94	6	5174·1 ,,	1·41	,,	19322·3
*5152·36	5	5152·3 ,,	,,	,,	19403·3
*5147·63	5	5148·1 ,,	,,	,,	19421·1
*5145·62	5	5145·6 ,,	,,	,,	19428·7
5133·12	2		1·40	,,	19476·0
*5129·32	3	5129·7 ,,	,,	,,	19490·5
*5120·60	5	5121·0 ,,	,,	,,	19523·7
*5113·64	5	5114·1 ,,	,,	5·4	19550·1
5109·65	3	5109·7 ,,	,,	,,	19565·4
5103·39	2	5803·5 ,,	,,	,,	19589·4
*5087·24	6	5087·5 ,,	1·39	,,	19651·6
5085·55	3		,,	,,	19658·2
*5071·66	4	5071·2 ,,	,,	,,	19712·0
*5069·56	3		,,	,,	19720·2
*5068·47	3		,,	,,	19724·4
*5066·12	4	5066·5 ,,	,,	,,	19733·6
*5064·82	7	5065·4 ,,	,,	,,	19738·6
5064·26	3		,,	,,	19740·8
*5062·30	4	5062·3 ,,	1·38	,,	19748·5
5054·30	2		,,	,,	19779·7
*5053·06	4	5053·3 ,,	,,	,,	19784·6
*5045·58	3		,,	,,	19813·9
*5043·77	4	5044·4 ,,	,,	,,	19821·0
*5040·78	4		,,	,,	19832·8
*5040·12	7	5040·2 ,,	,,	,,	19835·4
*5038·55	7	5039·2 ,,	,,	,,	19841·6
*5036·65	7	} 5036·6 ,,	,,	,,	19849·1
*5036·10	7		,,	,,	19851·2
*5025·72	6	5025·8 ,,	1·37	5·5	19892·1
*5025·00	6	5024·8 ,,	,,	,,	19895·0
*5023·02	7	5022·2 ,,	,,	,,	19902·8
*5020·17	7	5020·4 ,,	,,	,,	19914·1
*5016·32	7	5016·3 ,,	,,	,,	19929·4
*5014·40	8	5014·3 ,,	,,	,,	19937·1
*5013·45	6	5013·2 ,,	,,	,,	19940·8
*5009·81	4		,,	,,	19955·3
*5007·42	8	5007·6 ,,	,,	,,	19964·9
*5001·16	5	5002·0 ,,	,,	,,	19989·9
*4999·67	8	4999·6 ,,	,,	,,	19995·8
*4997·26	5		,,	,,	20005·5
*4991·24	8	4991·1 ,,	,,	,,	20029·6

‖ Solar line double { Ca 5189·05. Ti 5188·87.

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
*4989·33	5	4989·1 Thalén	1·36	5·5	20037·3
*4981·92	8	4981·8 „	„	„	20067·1
*4978·39	4	4978·6 „	„	„	20081·3
*4977·92	3		„	„	20083·2
*4975·52	5	4976·0 „	„	„	20092·9
*4973·25	4	4973·0 „	„	„	20102·1
*4968·75	4	4968·5 „	„	„	20120·3
4964·90	3	4965·3 „	„	„	20135·9
*4948·40	3	4947·8 „	1·35	„	20203·1
4941·77	3		„	5·6	20230·1
4938·51	4	4938·0 „	„	„	20243·4
4937·94	3		„	„	20245·8
*4928·50	5	4928·3 „	„	„	20284·6
4926·31	3	} 4925·8 „	„	„	20293·6
*4925·53	3	}	„	„	20296·8
*4921·90	5	4921·6 „	„	„	20311·8
*4919·99	5	4919·8 „	„	„	20319·6
4915·40	3		1·34	„	20338·6
*4913·76	6	4914·0 „	„	„	20345·4
*4911·38	3		„	„	20355·3
*4900·08	6	4900·1 „	„	„	20402·2
4893·62	2		„	„	20429·2
4893·25	3		„	„	20430·7
4892·03	3		„	„	20435·8
*4885·25	7	4885·4 „	„	„	20464·2
4882·53	2		„	„	20475·6
*4881·08	3		„	„	20481·7
*4870·28	6	4869·9 „	1·33	„	20527·1
*4868·44	6	4868·4 „	„	„	20534·9
4864·37	3		„	„	20552·0
*4856·18	6	4855·9 „	„	5·7	20586·6
*4848·62	4	4848·9 „	„	„	20618·7
4844·13	3		„	„	20637·8
*4841·00	7	4840·9 „	1·32	„	20651·2
*4836·25	4	4135·9 „	„	„	20671·5
*4827·74	3		„	„	20707·9
*4825·63	3		„	„	20717·0
*4820·56	6	4820·4 „	„	„	20738·2
4819·20	3		„	„	20744·6
4812·40	3		„	„	20774·0
*4811·24	4		„	„	20779·0
*4808·70	4		„	„	20789·9
*4805·56	5		„	„	20803·5
*4805·25	3	4805·2 „	„	„	20804·9
*4799·95	5‖		1·31	„	20827·8
*4798·13	4	4798·3 „	„	„	20835·8
*4796·36	4		„	„	20843·4
*4792·65	5	4792·4 „	„	„	20859·6
*4781·91	4		„	5·8	20906·3
*4778·44	5		„	„	20921·5
*4769·94	4		„	„	20958·8
4766·48	4		1·30	„	20974·0

‖ Solar line double { Fe 4800·05. Ti 4799·95.

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)		Reduction to Vacuum		Oscillation Frequency in Vacuo
				$\lambda +$	$\frac{1}{\lambda} -$	
*4759·44	6	4759·3	Thalén	1·30	5·8	21005·1
*4759·08	3			„	„	21006·7
*4758·30	6	4757·8	„	„	„	21010·1
*4747·84	4			„	„	21056·4
*4742·94	6	4742·6	„	„	„	21078·2
4742·28	4			„	„	21081·1
*4734·83	3			„	„	21114·3
*4733·58	4			„	„	21119·9
*4731·33	5			„	„	21129·9
*4723·32	5	4723·6	„	1·29	„	21165·7
*4722·77	5			„	„	21168·2
*4715·46	4			„	„	21201·0
*4710·34	6‖	4709·8	„	„	„	21224·1
*4698·94	6	4698·9	„	„	5·9	21275·5
4697·10	4			„	„	21283·8
*4693·83	5			„	„	21298·7
*4691·50	6	4691·5	„	1·28	„	21309·2
4690·97	4			„	„	21311·7
*4688·56	3			„	„	21322·6
4687·97	3			„	„	21325·3
4687·08	3			„	„	21329·3
*4684·68	3			„	„	21340·3
*4682·08	7	4682·4	„	„	„	21352·1
*4675·27	5			„	„	21383·2
4668·54	3			„	„	21414·1
*4667·76	8§	4667·4	„	„	„	21417·7
*4657·35	3			„	„	21465·5
*4656·60	7	4656·9	„	„	„	21469·0
*4656·20	4			„	„	21470·8
*4655·82	4			„	„	21472·6
*4650·16	5			1·27	„	21498·7
*4645·36	5	4644·9	„	„	„	21521·0
*4640·60	2			„	„	21543·0
*4640·11	5			„	„	21545·3
*4639·83	5	{ 4639·7	„	„	„	21546·6
*4639·50	5			„	„	21548·1
*4638·04	3			„	„	21554·9
*4637·34	2			„	„	21558·2
*4635·71	3			„	„	21565·8
*4635·04	3			„	6·0	21568·8
*4634·87	3			„	„	21569·6
*4629·47	5	4629·9	„	„	„	21594·7
*4623·24	6	4623·9	„	„	„	21623·9
*4619·67	3			„	„	21640·6
*4617·41	7	4617·6	„	1·26	„	21651·2
4614·47	2			„	„	21665·0
4609·55	3			„	„	21688·1
*4599·40	4			„	„	21736·0
*4594·28	2			„	„	21760·2
*4590·11	4			„	„	21780·0
4575·71	2			1·25	„	21848·5
*4572·15	6	4572·4	„	„	„	21865·5

‖ Solar line double { Fe 4710·44. Ti 4710·34.   § Solar line double { Ti 4667·75. Fe 4667·60.

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4571·07	3		1·25	6·0	21870·7
*4563·94	5	4564·1 Thalén	,,	6·1	21904·8
*4563·60	3		,,	,,	21906·4
*4562·80	4		,,	,,	21910·7
*4560·08	4		,,	,,	21923·3
*4558·28	3		,,	,,	21932·0
4558·02	3		,,	,,	21933·3
*4555·64	6	4556·2 ,,	,,	,,	21944·7
*4552·62	7‖	4552·7 ,,	,,	,,	21959·3
*4549·79	6§	4549·8 ,,	,,	,,	21972·9
*4548·93	7		,,	,,	21977·1
*4544·83	7	4544·4 ,,	,,	,,	21996·9
*4536·25	6 ⎫		1·24	,,	22038·5
*4536·12	6 ⎪		,,	,,	22039·2
*4535·75	6 ⎪	4536·5 ,,	,,	,,	22041·0
*4534·97	7 ⎬	to	,,	,,	22044·8
*4534·15	5 ⎪	4533·0 ,,	,,	,,	22048·8
*4533·42	7 ⎭		,,	,,	22052·3
*4527·48	6	4527·1 ,,	,,	,,	22081·2
*4522·97	6	4522·9 ,,	,,	,,	22103·3
*4518·84	4		,,	,,	22123·5
*4518·18	7	4518·4 ,,	,,	,,	22126·7
4515·76	3		,,	,,	22138·6
*4512·88	6	4512·4 ,,	,,	,,	22152·7
4511·32	3		,,	,,	22160·4
4508·21	2		,,	,,	22175·7
*4506·51	3		,,	,,	22184·0
*4503·92	4		1·23	,,	22196·8
*4501·43	6	4501·6 ,,	,,	,,	22209·1
*4497·90	3		,,	,,	22226·5
*4496·33	6	4496·9 ,,	,,	6·2	22234·2
*4495·19	6		,,	,,	22239·8
*4492·70	3		,,	,,	22252·1
*4489·24	5		,,	,,	22269·3
*4488·47	3		,,	,,	22273·1
*4482·84	4		,,	,,	22301·1
*4481·41	5	4481·8 ,,	,,	,,	22308·2
*4480·72	4		,,	,,	22311·6
*4479·86	4		,,	,,	22315·9
*4475·00	5		,,	,,	22340·2
*4471·40	5		,,	,,	22358·2
*4471·00	3		,,	,,	22360·2
*4469·32	2		,,	,,	22868·6
*4468·65	6	4469·3 ,,	1·22	,,	22371·9
*4465·96	5		,,	,,	22385·4
*4464·60	3		,,	,,	22392·2
*4463·70	4		,,	,,	22396·7
*4463·52	4		,,	,,	22397·6
4462·26	3		,,	,,	22404·0
4459·62	2		,,	,,	22417·2
*4457·59	7	4458·3 ,,	,,	,,	22427·4

‖ Solar line double { Fe 4552·72. Ti 4552·62. }

§ Solar line triple { 4549·94. Ti 4549·79. Fe 4549·60. }

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
*4455·48	6	4455·8 Thalén	1·22	6·2	22438·1
*4453·87	5		"	"	22446·2
*4453·48	6	4453·3 "	"	"	22448·2
*4451·40	3		"	"	22458·6
*4451·07	6		"	"	22460·3
*4450·66	4	} 4450·3 "	"	"	22462·4
*4449·32	6		"	"	22469·1
*4444·72	2		"	"	22492·4
*4444·41	3		"	"	22494·0
*4443·97	6	4443·8 "	"	"	22496·2
*4443·16	3		"	"	22500·3
*4441·86	3		"	"	22506·9
*4441·45	4		"	"	22509·0
*4440·49	5		"	"	22513·8
*4438·38	3		"	"	22524·5
*4436·75	4		"	"	21532·8
*4434·54	2		"	"	22544·1
*4434·15	6		"	"	22546·0
*4433·75	3		"	"	22548·1
*4432·76	3		"	"	22553·1
4431·46	4		"	6·3	22559·6
*4430·55	5		1·21	"	22564·3
*4430·19	3		"	"	28566·1
*4427·28	8	4427·6 "	"	"	22580·9
*4426·24	5		"	"	22586·2
*4426·01	3		"	"	22587·4
4424·58	3		"	"	22594·7
*4423·00	5		"	"	22602·8
*4421·92	4		"	"	22608·3
*4418·52	3		"	"	22625·7
*4417·88	5	} 4418·6 "	"	"	22629 0
*4417·46	6		"	"	22631·1
*4416·70	4		"	"	22635·0
*4414·29	2		"	"	22647·4
*4412·61	3		"	"	22656·0
*4409·71	2		"	"	22670·9
*4409·41	2		"	"	22672·5
*4408·70	3		"	"	22676·1
*4408·39	3		"	"	22677·7
*4407·85	3		"	"	22680·5
*4405·86	4		"	"	22690·7
4405·07	4		"	"	22694·8
*4404·57	4		"	"	22697·4
*4404·42	6	4403·8 "	"	"	22698·2
*4400·74	3		"	"	22717·2
*4399·92	5	4399·3 "	"	"	22721·4
*4395·99	3		"	"	22741·7
*4395·17	7		"	"	22745·9
4394·19	3		"	"	22751·0
*4394·04	6	4393·8 "	"	"	22751·8
*4390·11	4		1·20	"	22772·2
4388·69	2		"	"	22779·5
4388·22	3		"	"	22782·0
*4387·00	2		"	"	22788·3
*4384·85	4		"	"	22799·5

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
*4379·40	4		1·20	6·3	22827·9
4375·61	2		„	„	22847·7
*4374·97	2		„	„	22851·0
*4372·54	4		„	„	22863·7
4369·82	5		„	„	22877·9
4369·11	3		„	„	22881·7
*4367·81	3		„	6·4	22888·4
4361·31	2		„	„	22922·5
*4360·60	4		„	„	22926·2
*4355·44	2		1·19	„	22953·4
4354·20	3		„	„	22959·9
4353·01	2		„	„	22966·2
*4350·99	2		„	„	22976·9
*4346·76	2		„	„	22999·2
*4346·76	4		„	„	23001·9
*4344·47	3		„	0·69	23011·4
4343·93	2		„	„	23014·2
*4341·51	3		„	„	23027·1
*4338·62	2		„	„	23042·4
*4388·05	6	4338·3 Thalén	„	„	23045·4
*4334·98	3		„	„	23061·8
*4330·85	3		„	„	23083·8
*4327·12	3		„	„	23103·7
*4326·50	6		„	„	23107·0
*4325·30	6	4324·3 „	„	„	23113·4
*4321·82	6		„	„	23132·0
*4321·12	3	4320·8 „	„	„	23135·7
*4318·83	7	4318·8 „ †	1·18	„	23148·0
*4316·96	4		„	„	23158·0
*4315·15	4‖		„	„	23167·8
*4314·95	7		„	„	23168·8
*4314·50	5	4314·3 „	„	„	23171·3
*4313·01	6	4313·3 „	„	„	23179·3
4311·80	3		„	„	23185·8
4308·64	3	4308·3 „	„	6·5	23202·7
*4306·07	8	4306·0 „	„	„	23216·5
*4302·08	5		„	„	23238·1
*4301·23	7		„	„	23242·7
*4300·73	7		„	„	23245·4
*4300·19	6	4299·8 „	„	„	23248·3
*4299·79	6		„	„	23250·4
*4299·38	6		„	„	23252·7
*4298·82	7		„	„	23255·7
*4295·91	7	4295·6 „	„	„	23271·5
*4294·28	6	4294·4 „	„	„	23280·3
*4291·32	4		„	„	23296·4
*4291·07	6	4291·3 „	„	„	23297·7
*4290·37	5		„	„	23301·5
*4290·07	3		„	„	23303·1
*4289·23	7		„	„	23307·7
*4288·29	3		„	„	23312·8
*4287·55	7	4287·6 „	„	„	23316·8

† See Calcium.

‖ Solar line double { Fe 4315·28. Ti 4315·15.

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
*4286·15	7		1·18	6·5	23324·5
*4285·15	5		,,	,,	23829·9
*4282·85	6	4282·6 Thalén	,,	,,	23342·4
*4281·49	5		,,	,,	23349·9
*4280·17	3		1·17	,,	23357·1
4278·95	2		,,	,,	23363·7
*4278·34	4		,,	,,	23367·1
*4276·55	4		,,	,,	23376·8
*4274·73	6	4273·6 ,,	,,	,,	23386·8
*4273·45	3		,,	,,	23393·8
4272·57	4		,,	,,	23398·6
*4270·30	4		,,	,,	23411·1
*4266·37	3		,,	,,	23432·6
*4265·85	3		,,	,,	23435·5
*4265·42	3		,,	,,	23437·9
*4263·28	6	4263·6 ,,	,,	,,	23449·6
4261·75	5		,,	,,	23458·0
*4260·91	2		,,	,,	23462·7
*4258·68	4		,,	,,	23475·0
*4256·18	5		,,	,,	23488·7
*4251·93	4		,,	6·6	23512·1
*4251·77	4		,,	,,	23513·0
4249·29	4		,,	,,	23526·7
4245·66	3		,,	,,	23546·9
*4238·00	5	4237·1 ,,	1·16	,,	23589·4
4227·80	4		,,	,,	23646·4
4224·96	4		,,	,,	23662·3
*4211·85	3		,,	,,	23735·9
*4203·58	4		1·15	,,	23782·6
*4200·88	3		,,	,,	23797·9
4188·84	4		,,	6·7	23866·3
*4186·27	7	4185·6 ,,	,,	,,	23880·9
*4183·45	3		,,	,,	23897·0
*4174·61	3		,,	,,	23947·6
*4174·20	2		,,	,,	23950·0
*4173·66	3		,,	,,	23953·1
*4172·04	4	} 4171·6 ,,	,,	,,	23962·4
*4171·15	5‖		,,	,,	23967·5
*4169·46	4		,,	,,	23977·2
*4166·45	4		1·14	,,	23994·5
*4164·80	2		,,	,,	24004·1
*4164·27	3		,,	,,	24007·1
*4163·80	5	4163·6 ,,	,,	,,	24009·8
*4161·67	2		,,	,,	24022·1
*4158·79	5		,,	,,	24033·0
*4151·11	5		,,	,,	24083·2
4143·16	3n		,,	6·8	24129·4
*4137·39	5n		,,	,,	24163·0
*4134·60	3		,,	,,	24179·3
4131·38	3		,,	,,	24198·2
*4129·30	3		1·13	,,	24210·4
4128·20	4		,,	,,	24216·8

‖ Solar line double { Ti 4171·15. Fe 4171·00.

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4127·67	5		1·13	6·8	24219·9
*4123·68	5n		,,	,,	24243·4
*4123·42	4n		,,	,,	24244·9
*4122·31	4		,,	,,	24251·4
4121·79	3s		,,	,,	24254·5
*4116·64	3		,,	,,	24284·9
*4115·32	4s		,,	,,	24292·6
*4112·86	5s		,,	,,	24307·2
*4111·91	5s		,,	,,	24312·8
*4109·92	3		,,	,,	24324·6
*4105·31	3		,,	,,	24351·9
*4101·08	2		,,	,,	24377·0
*4099·94	3s		,,	,,	24383·8
*4099·32	4		,,	6·9	24387·4
*4095·65	2		,,	,,	24409·2
*4092·83	3		1·12	,,	24426·1
*4090·73	2		,,	,,	24438·6
*4082·57	5s		,,	,,	24487·5
4079·85	4		,,	,,	24503·8
*4078·61	6‖		,,	,,	24511·3
*4077·30	2		,,	,,	24519·1
4076·50	2		,,	,,	24523·9
4074·50	2		,,	,,	24536·0
*4065·23	4s		,,	,,	24592·0
*4064·36	4s		,,	,,	24597·2
*4060·42	5		,,	,,	24621·1
4058·28	4n		,,	,,	24634·1
4057·76	3n		,,	,,	24637·2
*4055·18	5		,,	,,	24652·9
*4053·96	3		1·11	,,	24660·3
4035·98	4		,,	7·0	24770·1
*4035·05	3		,,	,,	24775·8
*4034·05	3		,,	,,	24782·0
4030·60	5n		,,	,,	24803·2
*4028·48	3		,,	,,	24816·3
4027·66	3		,,	,,	24821·3
4026·64	5n		,,	,,	24827·6
*4025·26	2		,,	,,	24836·1
*4024·71	6		,,	,,	24839·5
4021·98	5n		,,	,,	24856·4
4017·93	4		,,	,,	24881·4
4017·13	2		,,	,,	24886·4
4016·44	3n		,,	,,	24890·7
4015·56	4n		1·10	,,	24896·1
4013·72	5n		,,	,,	24907·5
*4012·55	3s		,,	,,	24914·8
4009·80	4		,,	,,	24931·9
*4009·06	6		,,	,,	24936·5
4008·20	4n		,,	,,	24941·9
4007·38	3n		,,	,,	24947·0
4006·14	3n		,,	,,	24954·7
4003·99	4n		,,	,,	24968·1

‖ Solar line double {Ti 4078·61. / Fe 4078·50.}

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
4002·63	4n		1·10	7·1	24976·5
3999·53	3n	3999·6 Lockyer	,,	,,	24995·8
*3998·77	8	3998·9 ,,	,,	,,	25000·6
3994·84	3n		,,	,,	25025·2
*3989·92	8‖	3990·1 ,,	,,	,,	25056·1
3985·76	3n		,,	,,	25082·2
3985·57	3n		,,	,,	25083·4
3984·48	3		,,	,,	25090·3
*3982·62	5	3982·4 ,,	,,	,,	25102·0
*3981·91	7	3981·7 ,,	,,	,,	25106·5
*3964·40	5s	3964·2 ,,	1·09	,,	25217·4
*3962·98	5s	3962·6 ,,	,,	,,	25226·4
*3958·33	7	3958·1 ,,	,,	,,	25256·1
*3956·45	7§	3956·4 ,,	,,	,,	25268·1
*3948·80	7†	3948·6 ,,	,,	7·2	25317·0
*3947·90	6	3947·7 ,,	,,	,,	25322·7
*3938·18	2	*3938·1 ,,	,,	,,	25385·2
3934·37	3	3934·1 ,,	1·08	,,	25409·8
*3930·02	5	3929·9 ,,	,,	,,	25438·0
*3926·48	5	3926·4 ,,	,,	,,	25460·9
*3924·67	5	3924·7 ,,	,,	,,	25472·7
*3221·56	4	3921·3 ,,	,,	,,	25492·9
*3919·95	3	3919·8 ,,	,,	,,	25503·3
3916·27	3		,,	,,	25527·3
3916·00	3		,,	,,	25529·1
*3914·86	3s		,,	,,	25536·5
*3914·45	5	3914·3 ,,	,,	,,	25539·2
*3913·58	5	3913·5 ,,	,,	,,	25544·9
*3911·34	4n	3911·2 ,,	,,	,,	25559·5
*3904·95	7	3904·9 ,,	,,	7·3	25601·2
*3901·13	5	3901·2 ,,	,,	,,	25626·3
*3900·68	5	3900·7 ,,	,,	,,	25629·3
*3898·68	4s		,,	,,	25642·4
*3895 42	7		1·07	,,	25663·9
*3890·12	4s		,,	,,	25698·8
*3888·20	4n		,,	,,	25711·5
*3883·02	7n		,,	,,	25745·8
*3882·49	5n		,,	,,	25749·4
*3882·28	6n		,,	,,	25750·8
*3881·58	3		,,	,,	25755·4
3877·75	3n		,,	,,	25780·9
*3875·44	6n		,,	,,	25796·2
3874·32	4		,,	,,	25803·7
3873·40	5n		,,	,,	25809·8
*3870·28	3		,,	,,	25830·6
*3869·75	3		,,	,,	25834·2
3869·47	5n		,,	,,	25836·0
3869·13	2		,,	,,	25838·3

‖ Solar line double { Fe 3990·00. Ti 3989·92.

§ Solar group { Fe { 3957·10. 3956·75. 3956·55. } Ti 3956·45.

† Solar line triple { 3949·00. Fe 3948·90. Ti 3948·80.

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
*3868·56	5n		1·07	7·3	25842·1
*3867·92	4n		,,	,,	25846·4
*3866·60	6n		,,	,,	25855·2
*3866·17	2		,,	,,	25858·1
*3864·66	2		,,	,,	25868·2
*3862 98	5n		,,	,,	25879·5
*3861·89	3n		,,	,,	25886·8
3861·25	4		,,	,,	25891·1
*3860·61	3		,,	,,	25895·3
*3858·26	5n		,,	,,	25911·1
*3858·04	3		,,	,,	25912·6
*3855·99	3		1·06	,,	25926·4
*3853·87	5n		,,	,,	25940·6
*3853·18	5n		,,	,,	25945·3
*3848·48	3s		,,	,,	25977·0
*3846 57	4		,,	,,	25989·9
*3845·28	3		,,	,,	25998·6
3842·77	2		,,	,,	26015·6
3841·79	2		,,	,,	26022·2
*3840·90	2		,,	,,	26028·3
3840·48	2		,,	,,	26031·1
*3836·90	4		,,	,,	26055·4
*3836·22	3s		,,	,,	26060·0
3834·06	3		,,	,,	26074·7
*3833·80	4s		,,	,,	26076·5
*3833·33	4s		,,	,,	26079·7
3829·87	3		,,	,,	26103·2
*3828·31	4		,,	,,	26113·9
*3828·16	3		,,	,,	26114·9
3827·80	2		,,	,,	26117·4
3827·61	2		,,	,,	26118·7
*3827·12	3		,,	,	26122·0
*3823·03	2		,,	,,	26150·0
*3822·16	5s§		,,	,,	26155·9
*3821·86	2		,,	,,	26158·0
*3818·38	4		,,	,,	26181·8
*3817·78	4		,,	7·4	26185·8
*3815·01	3		1·05	,,	26204·9
*3814·72	4		,,	,,	26206·8
*3813·54	3		,,	,,	26215·0
*3813·42	3		,,	,,	26215·8
*3811·56	2		,,	,,	26228·6
3807·93	2		,,	,,	26253·6
3807·37	2		,,	,,	26257·4
*3806·60	2		,,	,,	26262·8
3806·19	2		,,	,,	26265·6
*3805·64	2		,,	,,	26269·4
3805·25	2		,,	,,	26272·1
*3801·73	2s		,,	,,	26296·4
*3801·25	3s		,,	,,	26299·7
*3798·47	3		,,	,,	26319·0

§ Solar line triple { Ti 3822·16. Fe 3822·06. Ti 3821·16.

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	1/λ −	
*3796·06	4		1·05	7·4	26335·7
3789·46	4		,,	,,	26381·6
*3786·44	3		,,	,,	26402·6
*3786·20	5§		,,	,,	26404·3
*3782·26	3		,,	,,	26431·8
*3776·20	2		1·04	,,	26474·2
*3771·80	5		,,	7·5	26505·0
*3766·60	2		,,	,,	26541·6
*3762·01	2		,,	,,	26574·0
*3761·46	7		,,	,,	26577·9
*3759·42	7		,,	,,	26592·3
*3757·82	4s		,,	,,	26603·7
*3753·75	5		,,	,,	26632·5
*3753·00	7		,,	,,	26637·8
3748·26	4		,,	,,	26671·5
*3741·78	4s		,,	,,	26717·8
*3741·19	6		,,	,,	26722·0
3739·17	3		,,	,,	26736·4
*3735·84	3		1·03	,,	26760·2
*3733·96	3		,,	,,	26773·7
*3729·92	7		,,	,,	26802·7
*3725·28	5		,,	7·6	26836·0
*3724·70	5		,,	,,	26840·2
*3722·70	5		,,	,,	26854·6
*3721·75	4		,,	,,	26861·5
*3717·53	3		,,	,,	26892·0
*3710·10	4		,,	,,	26945·9
3708·83	3		,,	,,	26955·1
*3707·68	3		,,	,,	26963·4
*3706·37	3		,,	,,	26973·0
*3704·84	2		,,	,,	26984·1
*3704·42	4		,,	,,	26987·2
3703·13	2		,,	,,	26996·6
*3702·42	4		,,	,,	27001·8
3700·22	3		,,	,,	27017·8
3698·33	3		,,	,,	27031·6
*3697·05	2		1·02	,,	27041·0
*3694·58	5		,,	,,	27059·1
3692·35	4n		,,	,,	27075·4
*3690·04	6		,,	,,	27092·4
*3688·19	2		,,	,,	27106·0
3687·48	4		,,	,,	27111·2
3686·10	4		,,	,,	27121·3
*3685·30	8n		,,	,,	27127·2
*3681·38	3		,,	7·7	27156·0
*3679·88	4n		,,	,,	27167·1
3677·90	2		,,	,,	27181·7
*3671·82	6		,,	,,	27226·8
*3669·08	5		,,	,,	27247·1
*3666·71	2		,,	,,	27264·7
*3663·82	2		,,	,,	27286·2

§ { Fe 3786·34.
Ti 3786·20.
Fe 3786·12.

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
*3662·37	5		1·02	7·7	27297·0
*3660·75	6		,,	,,	27309·1
*3659·91	5s		,,	,,	27315·4
*3658·22	7		,,	,,	27328·0
*3654·72	6		1·01	,,	27354·2
*3653·61	10n		,,	,,	27362·5
*3646·32	5s		,,	,,	27417·2
*3644·87	4		,,	,,	27428·1
*3642·82	10n		,,	,,	27443·6
*3641·48	5s		,,	,,	27453·7
3638·10	4		,,	7·8	27479·1
*3636·05	2		,,	,,	27494·6
*3635·61	9n		,,	,,	27497·9
*3635·33	4		,,	,,	27500·0
*3633·60	4		,,	,,	27513·1
*3626·22	3s		,,	,,	27569·1
*3624·97	4s‖		,,	,,	27578·6
3623·25	4n		,,	,,	27591·7
*3621·37	4n		,,	,,	27606·1
*3620·15	2		,,	,,	27615·4
3614·35	4n		1·00	,,	27659·7
3613·89	4		,,	,,	27663·2
3612·40	3n		,,	,,	27674·6
*3610·29	6		,,	,,	27690·8
3609·72	3		,,	,,	27695·2
*3607·26	4n		,,	,,	27714·1
3606·18	1		,,	,,	27722·4
*3605·46	4s		,,	,,	27727·9
*3604·39	3s		,,	,,	27736·1
*3603·98	3		,,	,,	27739·3
*3601·52	2		,,	,,	27758·3
*3601·31	2		,,	,,	27759·9
*3599·25	5		,,	,,	27775·8
*3598·87	5		,,	,,	27778·7
*3596·17	5		,,	,,	27799·6
*3594·13	2		,,	7·9	27815·2
*3580·40	3		,,	,,	27921·9
3578·40	3		,,	,,	27937·6
*3576·00	2		0·99	,,	27956·3
*3574·38	4		,,	,,	27969·0
*3573·85	4§		,,	,,	27973·1
*3566·16	3		,,	,,	28033·5
*3561·72	3		,,	,,	28068·4
*3558·66	4		,,	,,	28092·6
3556·32	3n		,,	,,	28111·1
*3547·15	5		,,	8·0	28183·6
*3545·11	2		,,	,,	28199·9
*3542·69	3		,,	,,	28219·1
*3535·56	5		0·98	,,	28276·1
*3530·53	6s		,,	,,	28316·4
3527·62	3		,,	,,	28339·7
*3526·18	3		,,	,,	28351·3

‖ Solar line double { Ti Fe 3625·00. / Ni 3624·87. }

§ Solar line double { Fe 3574·05. / Ti 3573·85. }

TITANIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Observations (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
*3525·28	3		0·98	8·0	28358·5
*3524·37	4		"	"	28365·9
*3520·39	4s		"	"	28397·9
*3520·15	3n		"	"	28399·9
*3516·97	3		"	"	28425·6
*3512·23	4b		"	"	28463·9
*3511·74	2		"	"	28467·9
*3510·98	6s		"	"	28474·1
*3507·55	3		"	8·1	28501·8
*3506·76	4‖		"	"	28508·3
*3505·02	6		"	"	28522·4
*3500·48	3		"	"	28559·4
*3499·24	4		"	"	28569·5
*3495·88	4		0·97	"	28597·0
*3393·44	2		"	"	28617·0
*3491·20	6s		"	"	28635·3
*3489·90	3		"	"	28646·0
*3485·84	3		"	"	28679·4
3481·83	2		"	"	28712·4
*3480·67	5		"	"	28722·0
3479·07	3		"	"	28735·2
*3477·33	5		"	"	28749·6

‖ Solar line double { Ti 3506·77. Fe 3506·66.

562 Titanium lines coincide with solar lines, and 156 are doubtful or do not coincide.

Rowland's Normal Solar Lines (on which these measurements of the Titanium Lines rest): **5893·10, 5884·05, 5831·84, 5805·45, 5791·21, 5772·36, 5754·89, 5731·98, 5688·43, 5658·09, 5569·84, 5513·19, 5487·96, 5466·60, 5447·12, 5424·27, 5397·34, 5367·67, 5300·82, 5266·73, 5230·01, 5202·49, 5155·94, 5121·80, 5090·96, 5060·25, 5036·10, 5007·42, 4978·78, 4934·24, 4903·48, 4890·94, 4859·93, 4824·31, 4805·25, 4783·60, 4754·22, 4727·62, 4703·98, 4679·02, 4668·30, 4637·67, 4611·44, 4578·72, 4563·94, 4536·25, 4508·45, 4494·72, 4468·65, 4447·90, 4425·60, 4407·85, 4376·10, 4343·98, 4318·83, 4293·24, 4267·94, 4254·49, 4215·65, 4185·05, 4157·94, 4121·96, 4088·71, 4062·60, 4048·88, 4029·79, 4003·91, 3971·48, 3942·55, 3924·67, 3897·60, 3875·23, 3843·40, 3821·32, 3794·02, 3770·12, 3747·09, 3716·57, 3695·19, 3684·25, 3658·68, 3640·53, 3612·21, 3583·48, 3564·68, 3540·27, 3518·48, 3491·47, 3478·00.**

Copper (Spark Spectrum).

Eder and Valenta: 'Denkschr. kaiserl. Akad. Wissensch. zu Wien,' 1896.
Exner and Haschek: 'Sitz-ber. kaiserl. Akad. Wissench. Wein,' civ. (1895), cv. (1896).

* Observed in the Arc spectrum by Kayser and Runge.
† Observed only in air; the spark was usually taken between copper poles in hydrogen.

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum λ+	Reduction to Vacuum 1/λ −	Oscillation Frequency in Vacuo
6381·1	6s	6381·2 Thalén	1·73	4·2	15667·1
6219·5	4s	6219·7 ,,	1·69	4·4	16074·1
*5782·30	8s	5782·4 ,, 5782·5 Neovius	1·58	4·7	17289·5
5768·65	1nb		1·57	,,	17330·4
5760·49	1nb		,,	,,	17354·9
*5732·50	1nb		1·56	,,	17439·7
*5700·39	6s	5701·8 ,, 5700·8 ,,	1·55	4·8	17537·9
5696·68	3b		,,	,,	17549 3
5685·03	1b		,,	,,	17585·3
5679·42	3s		,,	,,	17602·6
5675·85	2b		,,	,,	17613·7
5672·92	2b		,,	,,	17622·8
5668·77	2b		,,	,,	17635·7
5666·62	3s		,,	,,	17642·4
5663·52	1n		1·54	,,	17652·1
5652·16	4b		,,	,,	17687·5
*5646·13	3b		,,	,,	17706·4
5644·39	1n		,,	,,	17711·9
5639·50	1n		,,	,,	17727·3
5636·84	1b		,,	,,	17735·6
5624·71	1b		1·53	,,	17773·9
5621·17	3b		,,	,,	17785·1
5618·70	3b		,,	,,	17792·9
5608·83	3s		,,	4·9	17824·1
5574·10	3b		1·52	,,	17935·2
5571·47	1n		,,	,,	17943·7
5566·35	3s		,,	,,	17960·2
5563·83	2s		,,	,,	17968·3
*5555·15	2b		,,	,,	17996·4
5543·11	2b		1·51	,,	18035·5
*5535·90	3b		,,	,,	18059·0
5500·09	2s		1·50	5·0	18176·5
5498·14	2s		,,	,,	18183·0
5495·12	4s		,,	,,	18193·0
5487·30	3s		,,	,,	18218·9
5475·49	2n		1·49	,,	18258·2
5472·00	3b		,,	,,	18269·8
5463·55	4b		,,	,,	18298·1
5460·25	2b		,,	,,	18309·2
5456·02	2s		,,	,,	18323·4
5453·93	1n		,,	,,	18330·4
5450·62	2s		,,	,,	18341·5
5440·90	1n		,,	,,	18374·3
5438·79	4s		1·48	,,	18381·4
*5432·26	2b		,,	,,	18403·5
5429·01	1b		,,	,,	18414·6

COPPER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum λ+	Reduction to Vacuum 1/λ−	Oscillation Frequency in Vacuo
5422·93	1b		1·48	5·0	18435·2
5418·61	4s		,,	,,	18449·9
5410·97	2b		,,	,,	18476·0
*5408·55	3n		,,	,,	18484·2
*5391·92	2n		1·47	5·1	18541·2
5389·70	3s		,,	,,	18548·8
5380·75	3s		,,	,,	18579·7
5369·63	3s		,,	,,	18618·2
*5360·20	2s†		1·46	,,	18650·9
5357·27	2n		,,	,,	18661·1
*5355·10	1n†		,,	,,	18668·7
*5352·85	1n		,,	,,	18676·5
5340·71	1b		,,	,,	18719·0
5338·19	1b		,,	,,	18727·8
5325·38	3s		1·45	,,	18772·9
5317·60	4b		,,	,,	18800·4
5309·41	2s		,,	,,	18829·4
5295·71	2s		,,	5·2	18878·0
*5292·75	6s	5293·1 Thalén 5293·0 Neovius	,,	,,	18888·6
5287·66	2s		1·44	,,	18906·8
5285·77	2s		,,	,,	18913·5
5282·34	2b		,,	,,	18925·8
5270·13	1s†		,,	,,	18969·7
5268·38	3s		,,	,,	18976·0
5255·62	1s		,,	,,	19022·1
*5250·82	2n		1·43	,,	19039·4
5232·80	2s		,,	,,	19105·0
*5220·25 }	6s	} 5218·1 ,, 5218·1 ,,	,,	,,	19151·0
*5218·45 }	10sr		,,	,,	19157·6
5208·37	2s		1·42	5·3	19194·6
5203·74	3s		,,	,,	19211·6
*5201·14	2n		,,	,,	19221·3
*5153·40	10sr	5153·3 ,, 5153·6 ,,	1·41	,,	19399·4
*5144·40	1s		,,	,,	19433·3
5139·03	2n		,,	,,	19453·6
5133·86	1n		1·40	,,	19473·2
5130·97	1s		,,	,,	19484·2
5124·70	1n double		,,	,,	19508·0
5120·00	2s		,,	,,	19526·0
5112·18	2s		,,	5·4	19555·7
*5105·75	8s	5105·5 ,, 5105·9 ,,	,,	,,	19580·4
5095·08	2n		1·39	,,	19621·4
5094·29	2n		,,	,,	19624·4
5089·54	2n		,,	,,	19642·7
*5076·49	1n		,,	,,	19693·2
5067·33	2b		,,	,,	19728·9
5060·86	1s		1·38	,,	19754·1
5059·58	1b		,,	,,	19759·1
5053·02	2n		,,	,,	19784·7
*5034·49	1n		,,	,,	19857·6
5016·99	2n		1·37	5·5	19926·8
5013·40	2n		,,	,,	19941·0
5007·49	1s		,,	,,	19964·6
5005·38	2s		,,	,,	19973·0
5001·50	1s		,,	,,	19988·5

COPPER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4985·94	2n		1·36	5·5	20050·9
4954·83	4n	4956·5 Thalén 4955·8 Neovius	,,	,,	20176·8
4945·17	1n		1·35	,,	20216·3
4938·56	1b		,,	5·6	20243·2
4932·86	4b	4933·4 ,, 4932·5 ,,	,,	,,	20266·6
4927·66	1s		,,	,,	20288·0
4921·82	1n		,,	,,	20312·1
4919·65	1n		,,	,,	20321·0
4913·98	1n		1·34	,,	20344·5
4910·77	3n	4912·3 ,, 4911·0 ,,	,,	,,	20357·8
4889·89	2s		,,	,,	20444·8
*4867·33	2n		1·33	,,	20539·5
4856·48	1n		,,	5·7	20585·3
*4767·74	1n		1·31	5·8	20968·5
4758·61	2n	4758·5 Neovius	1·30	,,	21008·7
4748·85	2s		,,	,,	21051·9
§*4704·76	5s	4704·0 Thalén 4703·2 Neovius	1·29	5·9	21249·2
§*4697·83	3n		,,	,,	21280·5
4683·35	2n		1·28	,,	21346·3
*4674·98	6s		,,	,,	21384·6
§*4651·29	8s	4651·5 ,, 4651·3 ,,	1·27	,,	21493·5
4649·31	2s		,,	,,	21502·7
*4643·05	2b		,,	,,	21531·7
4634·47	1n		,,	6·0	21571·4
4630·77	4s		,,	,,	21588·7
4623·26	1n		,,	,,	21623·8
4621·52	2s		,,	,,	21631·9
4614·30	2n		1·26	,,	21665·8
4607·45	2s		,,	,,	21698·0
4601·80	2s		,,	,,	21724·6
§*4587·17	8s	4587·4 Neovius	,,	,,	21793·9
§*4555·94	1n	4556·2 ,,	1·25	6·1	21943·3
§*4539·60	3b	4540·1 ,,	1·24	,,	22022·3
§*4530·98	2s	4531·1 ,,	,,	,,	22064·2
§*4509·50	4b	4509·9 ,,	,,	,,	22169·3
*4507·77	1n		,,	,,	22177·8
4505·65	1n		1·23	,,	22188·3
4492·57	2b		,,	6·2	22252·8
§*4480·52	3b	4480·6 ,,	,,	,,	22312·6
§*4416·06	1b		1·21	6·3	22638·3
§*4378·30	1n	4378·2 ,,	1·20	,,	22833·6
§*4275·36	10s	4275·5 Thalén 4275·3 Neovius	1·17	6·5	23383·3
§*4260·17	1n		,,	,,	23466·7
§*4249·17	3b	4249·4 Neovius	,,	6·6	23527·4
§*4228·37	1n		1·16	,,	23643·2
§*4177·92	2b		1·15	6·7	23928·7
§*4062·89	7bʳ	4063·0 ,,	1·12	6·9	24606·1
§4043·70	3s		1·11	7·0	24722·8
§*4022·91	4s	4022·9 ,,	,,	,,	24850·6
3983·31	1n		1·10	7·1	25097·6
3981·84	1n		,,	,,	25106·9
3979·74	1n		,,	,,	25120·2
§3962·77	1n		1·09	,,	25227·8
3959·60	1n		,,	,,	25248·0
3954·98	1n		,,	7·2	25277·4

COPPER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum λ+	Reduction to Vacuum $\frac{1}{\lambda}$−	Oscillation Frequency in Vacuo
3952·02	1n		1·09	7·2	25296·3
3948·18	1n		"	"	25320·9
§3934·15	2s		1·08	"	25411·3
3923·10	2s		"	"	25482·8
3919·72	2n		"	"	25504·8
3917·67	1n		"	"	25518·2
3914·00	2n		"	"	25542·1
3912·35	1n		"	"	25552·9
*3899·90	2s		"	7·3	25634·4
3894·64	1n		1·07	"	25669·0
3888·77	1n		"	"	25707·8
Several	indistinct	lines here			
3887·12	1n		"	"	25718·7
§*3861·88	1s		"	"	25886·8
§*3860·95	2n		"	"	25893·1
3839·03	2n	3860·7 Neovius	1·06	"	26040·9
3834·86	1n		"	"	26069·3
3831·97	1n		"	"	26088·9
3826·40	2n		"	"	26126·9
§3813·77	2n		1·05	7·4	26213·4
§*3812·05	1n		"	"	26225·2
§3809·29	3n		"	"	26244·2
§3807·84	2n		"	"	26254·2
§3804·50	1n		"	"	26277·3
§3801·29	1n		"	"	26299·5
3799·47	1n		"	"	26312·1
§3791·12	4n		"	"	26370·0
3784·24	2n		"	"	26418·0
3781·97	1n		"	"	26433·8
3780·31	1n		"	"	26445·5
§3777·17	3n		"	"	26467·4
§3775·15	2n		1·04	"	26481·6
§3772·17	1n		"	7·5	26502·4
§3764·21	1n		"	"	26558·5
* { 3762·23§	1n		"	"	26572·5
{ 3754·78§	1n		"	"	26625·2
§3752·29	2n		"	"	26642·9
3748·50	1n		"	"	26669·8
§3744·94	2n		"	"	26695·2
§*3741·44	2s		"	"	26720·2
3737·62	1n		1·03	"	26747·5
§*3734·68	2s		"	"	26768·6
3726·43	1n		"	7·6	26827·7
§3720·32	1n		"	"	26871·8
§3715·27	1n		"	"	26908·3
§3703·10	2n		"	"	26996·8
§*3700·56	1n		"	"	27015·3
3697·99	1n		1·02	"	27034·1
*3687·75	2b		"	"	27109·2
§*3686·70	3s	3686·6 "	"	"	27116·9
§*3659·54	1n		"	7·7	27318·1
§*3656·22	1s		1·01	"	27343·0
§*3654·59	1n		"	"	27355·2
§*3645·00	1n		"	"	27427·1
§*3642·00	1n		"	"	27449·7

COPPER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
3639·47	1n		1·01	7·7	27468·8
§*3636·10	2n		,,	7·8	27494·2
§3633·14	1n		,,	,,	27516·6
§*3627·64	1n		,,	,,	27558·3
3625·61	1n		,,	,,	27573·8
§3624·44	1n		,,	,,	58272·7
§*3621·31	2n		,,	,,	27606·5
§*3620·46	1n		,,	,,	27613·0
§*3613·89	2n		1·00	,,	27663·2
§3611·08	1n		,,	,,	27684·7
§*3602·10	4n		,,	,,	27753·8
§*3599·24	1n	{ 3599·7 Neovius { 3599·6 Hartley & Adeney	,,	,,	27775·8
3549·09	2n		0·99	8·0	28168·2
§*3533·79	2n		0·98	,,	28290·2
§*3530·44	3s		,,	,,	28317·1
§*3527·56	2s		,,	,,	28340·2
§*3524·36	3s	3524·4 H. & A.	,,	,,	28365·9
§*3520·20	2s		,,	,,	28399·5
3516·86	1s		,,	,,	28426·5
§*3512·16	3s	3511·2 ,,	,,	,,	28464·5
§*3483·82	4s	3483·8 ,,	0·97	8·1	28696·0
§*3476·03	3s	3478·8 ,,	,,	,,	28760·4
§3472·26	1n	3472·4 ,,	,,	,,	28791·6
§*3454·64	1n	3455·8 ,,	0·96	8·2	28938·4
§*3450·43	3s	3450·6 ,,	,,	,,	28973·7
§*3415·74	1b		0·95	8·3	29267·9
§*3413·27	1b		,,	,,	29289·1
§*3404·62	1b		,,	,,	29363·6
§*3402·31	1b		,,	,,	29383·5
*3393·51	3s		,,	8·4	29459·6
§*3381·43	2n	3382·0 ,,	,,	,,	29564·9
§*3365·45	3s		0·94	,,	29705·3
§*3349·43	2s		,,	8·5	29847·3
§*3338·00	4s		0·93	,,	29949·6
§3335·59	1b		,,	,,	29971·2
*3329·64	1b		,,	,,	30024·8
§*3319·74	2s		,,	8·6	30114·2
§*3317·35	2s		,,	,,	30135·9
§*3308·10	7s	3307·8 ,,	,,	,,	30220·2
§*3292·77	1n		0·92	,,	30361·0
§*3290·60	3b	3290·7 ,,	,,	,,	30381·0
§*3282·79	2s	3282·4 ,,	,,	8·7	30453·2
§*3279·89	3s	3280·4 ,,	,,	,,	30480·1
§*3274·09	8s	3275·0 ,,	,,	,,	30534·1
§*3266·03	1s	3267·0 ,,	,,	,,	30609·5
§*3247·65	10s	3248·4 ,,	0·91	8·8	30782·7
§*3243·13	3b	3245·4 ,,	,,	,,	30825·6
§*3235·68	3s	3235·2 ,,	,,	,,	30896·6
§*3231·25	2s		,,	,,	30939·0
§*3226·60	1n		,,	,,	30983·6
§*3224·67	2n		,,	,,	31002·1
§*3223·47	2n		,,	,,	31013·7
§*3208·41	1n		0·90	8·9	31159·2
§3204·64	2b		,,	,,	31195·9

COPPER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
3200·20	2s		0·90	8·9	31239·1
§*3194·15	6s		,,	,,	31298·3
§*3169·68	3n		0·89	9·0	31539·9
*3159·85	6n		,,	,,	31638·1
§*3146 84	1n		,,	9·1	31768·8
§*3142·38	1n		,,	,,	31813·9
§*3140·33	1n	3139·7 H. & A.	0·88	,,	31834 7
§*3126·16	6s		,,	,,	31979 0
§*3116·34	1n	3116·5 ,,	,,	,,	32079·8
§*3108·55	5s	3108·2 ,,	,,	9·2	32160·1
§*3099·93	5s	3098·7 ,,	0·87	,,	32249·6
*3094·01	3s		,,	,,	32311·3
§3088·10	1n		,,	,,	32373·2
§*3073·82	1s		,,	9·3	32523·5
*3070·86	1s		,,	,,	32554·9
§*3063·50	3s		,,	,,	32633·1
§*3036·15	3s	3036·9 ,,	0·86	9·4	32927·1
§*3010·93	3s		0·85	9·5	33202·8
§3007·42	1n		,,	,,	33241·6
§*2997·47	1s		,,	9·6	33351·9
*2982·21	1n		0·84	,,	33522·6
§*2979·31	1n		,,	,,	33555·2
§2976·00	1n		,,	,,	33592·5
2971·80	1n		,,	,,	33640·0
§*2961·20	5s	2959·6 ,,	,,	9·7	33760·4
§2884·50	1n		0·82	10·0	34658·1
§*2883·05	1s	2882·9 ,,	,,	,,	34675·5
§2878·02	3s	2878·0 ,,	,,	,,	34736·1
2860·45	3s		0·81	10·1	34949·4
2858·28	1n		,,	,,	34976·0
§2837·66	2n	2837·1 ,,	,,	10·2	35230·1
§2824·47	6s		0·80	,,	35394·7
§2813·25	2s		,,	10·3	35535·8
2799·55	1b		,,	10·4	35709·6
2795·60	2s		,,	,,	35760·1
2780·25	1s		0·79	,,	35957·6
§2777·15	1s		,,	,,	35997·7
§*2769·88	4s	2769·4 ,,	,,	10·5	36092·1
§*2766·45	2s	2766·5 ,,	,,	,,	36136·9
2763·80	1s		,,	,,	36171·6
§*2751·30	2b		,,	10·6	36335·9
§2745·54	6s	2746·3 ,,	,,	,,	36412·1
§2739·98	3s		0·78	,,	36486·0
§2737·63	3s		,,	,,	36517·3
§2734·07	2n		,,	,,	36564·9
§2731·8	2n		,,	,,	36595·3
2730·4	1n		,,	,,	36614·1
§*2724·1	2n		,,	10·7	36698·7
§2721·98	4s	2721·8 ,,	,,	,,	36727·3
§2719·14	5n	2718·9 ,,	,,	,,	33765·6
§2713·82	8s	2713·7 ,,	,,	,,	36837·7
§2703·48	9s	2703·0 ,,	,,	,,	36978·7
§2701·34	10s	2701·3 ,,	,,	10·8	37007.9
2698·8	1s		0·77	,,	37042·7
§*2696·70	2s		,,	,,	37071·6

COPPER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum λ+	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
§2689·66	10s	2689·4 H. & A.	0·77	10·8	37168·6
§*2680·0	1n		,,	,,	37302·6
§2666·61	6s	2666·7 ,,	,,	10·9	37489·9
§2658·7	1n		,,	,,	37601·5
§*2649·9	1n		0·76	11·0	37726·3
§2644·10	5s	2643·8 ,,	,,	,,	37809·1
§2641·75	2s		,,	,,	37842·7
*2635·1	1n		,,	,,	37938·2
*2630·1	1n		,,	11·1	38010·3
2624·4	1n		,,	,,	38092·9
§*2618·46	8s	2618·3 ,,	,,	,,	38179·3
§2609·43	7s	2609·4 ,,	0·75	11·2	38311·3
§2600·51	10s	2600·3 ,,	,,	,,	38442·8
§2599·15	8s	2598·9 ,,	,,	,,	38462·9
§2592·9	1n		,,	,,	38555·7
§2590·78	5s	2590·8 ,,	,,	,,	38587·2
§2587·6	1n		,,	11·3	38634·6
§2586·5	1n		,,	,,	38651·0
2584·0	1n		,,	,,	38688·4
§2581·3	1s		,,	,,	38728·9
§*2580·3	1s		,,	,,	38743·9
*2578·1	1n		,,	,,	38777·0
2576·8	1n		,,	,,	38796·5
2575·2	2s		,,	,,	38820·6
§2573·4	3s	2573·4 ,,	,,	,,	38847·8
§2572 0	4s	2572·4 ,,	,,	,,	38868·9
§2571·2	7n	2571·3 ,,	,	,,	38881·0
§*2569·7	1n		,,	,,	38903·8
§*2566·5	5s	2565·7 ,	,,	11·4	38952·2
2564·4	1s		0·74	,,	38984·1
*2563·1	1s		,,	,,	39003·9
2561·5	1n		,,	,,	39028·2
2557·4	1n		,,	,,	39090·8
§2554·4	2s		,,	,,	39136·7
§*2553·2	2b	2554·3 ,,	,,	,,	39155·1
2552·9	1n	2552·6 ,,	,,	,,	39159·7
2552·1	1n		,,	,,	39172·0
§2550·4	2b		,,	,,	39198·1
§2545·08	10s	2544·9 ,,	,,	11·5	39280·0
§2538·8	4s	2538·6 ,,	,,	,,	39377·2
§2535·5	4s		,,	,,	39428·5
§2533·8	1n	2534·4 ,,	,,	,,	39454·9
2533·0	2n		,,	,,	39467·4
2532·1	2n	2531·9 ,,	,,	,,	39481·4
§2529·60	8s	2529·3 ,,	,,	11·6	39520·3
§2526·90	5s	2526·6 ,,	,,	,,	39562·6
§2525·2	3s		,,	,,	39589·2
§2523·3	4s	2523·1 ,,	,,	,,	39619·0
§2522·4	4s	2522·3 ,,	,,	,,	39633·2
2521·2	2s		,,	,,	39652·1
§2519·1	2s		,,	,,	39685·1
§2518·5	3s	2518·8 ,,	,,	,,	39694·6
§2517·0	2s	2517·9 ,,	0·73	,,	39718·2
2516·6	2s		,,	,,	39724·6
2515·0	1s		,,	,,	39749·8

COPPER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
2513·2	5s	2513·4 H. & A.	0·73	11·6	39778·3
§2511·5	5s	2511·7 ,,	,,	11·7	39805·1
§2508·7	5b	2509·0 ,,	,,	,,	39849·6
§2506·50	10s	2506·6 ,,	,,	,,	39884·6
2504·8	1b		,,	,,	39911·6
2503·6	1n		,,	,,	39930·8
2503·1	1n		,,	,,	39938·8
2501·0	2n		,,	,,	39972·3
2497·7	3s	2497·8 ,,	,,	,,	40025·1
§2496·2	4b	2496·3 ,,	,,	,,	40049·2
2493·6	1n		,,	11·8	40090·9
§*2492·2	6s	2491·9 ,,	,,	,,	40113·4
§2489·75	8s	2489·5 ,,	,,	,,	40152·9
§2486·5	4b	} 2486·1 ,,	,,	,,	40205·4
§2485·9	4b		,,	,,	40215·1
§2482·5	5s	2482·2 ,,	,,	,,	40270·2
2481·2	1s		,,	,,	40291·3
2479·8	1s		,,	,,	40314·0
§2478·4	3n	2478·5 ,,	,,	,,	40336·8
2475·4	1n	2475·5 ,,	,,	11·9	40385·6
§2473·6	8s	2473·6 ,,	,,	,,	40415·0
§2468·7	8s	2469·0 ,,	0·72	,,	40495·3
§2466·0	4n	2465·7 ,,	,,	,,	40539·6
2464·1	2n		,,	,,	40570·9
2463·2	2n		,,	,,	40585·7
*2462·1	3n	2461·9 ,,	,,	,,	40603·8
2460·5	1n		,,	,,	40630·2
§2459·4	2s		,,	12·0	40648·3
*2458·9	4s	2458·5 ,,	,,	,,	40656·6
2457·9	1n		,,	,,	40673·1
§2453·1	5s	2452·6 ,,	,,	,,	40752·7
2451·9	1s		,,	,,	40772·7
2449·5	1s		,,	,,	40812·7
§2447·6	2n		,,	,,	40844·3
2446·8	2n	2447·0 ,,	,,	,,	40857·7
2445·5	2n		,,	,,	40879·4
§2444·54	5s	2444·4 ,,	,,	,,	40895·5
2443·5	2n		,,	12·1	40912·8
2442·6	2n		,,	,,	40927·9
§*2441·72	6s	2441·9 ,,	,,	,,	40942·6
§2440·2	3b	2440·2 ,,	,,	,,	40968·2
§2436·0	5s	2436·0 ,,	,,	,,	41038·8
2433·5	3s		,,	,,	41081·0
§2430·5	4s	2430·8 ,,	,,	,,	41131·7
2429·0	2n		,,	,,	41157·1
2428·3	2n	2428·7 ,,	,,	,,	41169·0
§2424·70	5s	2425·8 ,,	,,	12·2	41230·0
2421·8	3s	2422·7 ,,	0·71	,,	41279·4
2420·0	1n		,,	,,	41310·1
2418·5	1n		,,	,,	41335·7
2414·9	1n		,,	,,	41397·4
2414·3	2s		,,	,,	41407·7
2413·2	1s		,,	,,	41426·6
§2412·45	5s	2412·5 ,,	,,	12·3	41439·3
2408·6	1n		,,	,,	41505·6

COPPER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)		Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ+	1/λ −	
*2406·8	1s			0·71	12·3	41536·6
§2405·64	4s	2405·3 H. & A.		„	„	41556·7
§2403·63	6b	2403·5 „		„	„	41591·4
§*2400·23	6s	2400·5 „		„	„	41650·4
§*2392·8 ⎫	4 ⎫ s	2393·3 „		„	12·4	41779·6
§2391·8 ⎭	3 ⎭	2392·5 „		„	„	41797·1
2385·1	2s	2385·5 „		„	„	41914·6
§2376·6	5s	2377·1 „		„	12·5	42064·4
§2370·9	2n	2372·0 „		0·70	„	42165·6
§*2369·97	10s	2369·9 T. &. S.	2370·6 H. & A.	„	„	42182·1
2368·8	2s	2368·8 „	2369·1 „	„	„	42203·0
§2368·4	2s			„	12·6	42210·0
§2364·2	1n		2366·3 „	„	„	42285·0
*2363·3	1n			„	„	42301·1
2362·8	1n			„	„	42310·1
2361·6	1n			„	„	42331·6
§*2356·68	6s	2356·7 „	2357·7 „	„	„	42420·0
§2355·2	4n	2355·2 „	2355·3 „	„	„	42446·6
§2348·8	3n		2349·1 „	„	12·7	42562·2
§2346·2	2s	2346·2 „	2346·5 „	„	„	42609·4
2339·1	1n			„	12·8	42738·7
§2336·3	4s	2336·3 „	2337·0 „	„	„	42789·9
2324·1	1n			0·69	12·9	43014·5
2323·1	1n			„	„	43033·0
2320·4	2s			„	„	43083·1
2319·7	1s			„	„	43096·1
2315·9	1n			„	„	43166 9
2315·3	1s			„	„	43178·0
2312·3	1s			„	13·0	43234·0
§2309·7	2s			„	„	43282·7
§2303·18	4s			„	„	43405·2
§2299·6	2s	2299·6 „	2300·8 „	„	13·1	43472·7
			2297·8 „			
§2294·40	6s	2294·4 „	2295·3 „	„	„	43571·3
2293·93	3s	2293·9 „	2294·9 „	„	„	43580·4
§2291·1	4s	2291·1 „	2291·7 „	„	„	43634·1
§2286·7	4s	2286·7 „	2287·0 „	„	13·2	43717·9
2280·9	1s			„	„	43829·1
§2278·4	2s	2278·4 „	2279·9 „	„	„	43877·3
§2276·30	6s	2276·3 „	2277·3 „	0·68	„	43917·7
2274·9	1s			„	13·3	43944·7
§2265·5	2s	2265·5 „	2266·1 „	„	„	44127·1
§2263·7	3b	2263·9 „	2264·2 „	„	„	44162·2
2263·2	2b	2263·2 „	2263·5 „	„	13·4	44171·8
2260·6	2b		2260·0 „	„	„	44222·6
§2255·1	2b	2255·1 „		„	„	44330·5
2252·0	1b		2250·3 „	„	„	44391·6
§2248·9	3b	2249·0 „	2248·5 „	„	13·5	44452·7
§2247·14	7s	2247·0 „	2248·0 „	„		44487·5
§2244·4	1s		2244·3 „	„		44541·8
§2242·6	7s	2242·7 „	2243·8 „	„		44576·8
§2231·8	1s		2233·3 „	„	13·6	44793·3
2231·1	2s	2231·0 „	2231·5 „	„	„	44807·3
§2230·2	3b	2230·1 „	2230·5 „	„	„	44825·4
§2229·0	4b	2228·9 „	2229·4 „	0·67	„	44849·6

COPPER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)		Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ +	$\frac{1}{\lambda}$ −	
§2227·9	2n	2227·8 T. & S.	2228·4 H. & A.	0·67	13·6	44871·7
§2227·0	3n	2226·9 ,,	2227·3 ,,	,,	,,	44889·9
2225·8	2s	2225·7 ,,	2226·3 ,,	,,	13·7	44914·0
§2224·9	2s	2224·8 ,,		,,	,,	44932·1
§2218·2	6s	2218·2 ,,	2219·6 ,, 2218·8 ,,	,,	,,	45067·9
§2215·4	3s	2215·3 ,,	2216·8 ,, 2216·1 ,,	,,	,,	45124·9
2214·6	3s	2214·4 ,,	2214 4 ,,	,,	13·8	45141·1
2212·9	1s	2213·0 ,,	2211·6 ,,	,,	,,	45175·8
§2210·4	5s	2210·3 ,,	2211·1 ,, 2209·1 ,,	,,	,,	45226·9
§2200·7	1s	2200·6 ,,	2200·6 ,,	,,	13·9	45426·2
2199·8	3s	2199·8 ,,	2200·1 ,,	,,	,,	45444·8
§2195·9	3s	2195·9 ,,	2196·8 ,,	,,	,,	45525·5
§2192·4	5s	2192·4 ,,	2192·3 ,, 2191·5 ,,	,,	14·0	45598·1
§2189·8	5s	2189·9 ,,	2189·9 ,, 2188·8 ,,	,,	,,	45652·3
2183·0	1s			,,	,,	45794·5
2181·8	1s	2181·8 ,,	2181·3 ,,	,,	,,	45819·7
§2179·45	5s	2175·5 ,,	2179·3 ,, 2178·3 ,,	0·66	14·1	45869·0
2175·15	3s	2175·2 ,,	2174·8 ,,	,,	,,	45959·7
2165·2	1s			,,	14·2	46170·9
§2161·6	1s			,,	,,	46247·8
2157·5	2s			,,	14·3	46335·6
§2152·0	3s			,,	,,	46454·1
§2149·05	4s	2149·2 ,,	2149·1 ,,	,,	,,	46517·9
2147·2	2n			,,	14·4	46557·9
2145·7	2n			,,	,,	46590·4
2144·9	1n			,,	,,	46607·8
§2136·1	3s	2136·1 ,,	2136·1 ,,	,,	14·5	46799·8
§2134·6	2s	2134·6 ,,	2134·5 ,,	,,	,,	46832·7
2130·2	1n			0·65	,,	46929·5
§2126·1	3s	2126·2 ,,		,,	14·6	47019·9
2125·3	3s	2125·3 ,,	2124·7 ,, 2124·3 ,,	,,	,,	47037·6
§2123·06	3s	2122·4 ,,	2122 4 ,, 2121·8 ,,	,,	,,	47087·2
§2117·4	2s	2117·5 ,,	2116·3 ,,	,,	,,	47213·1
§2112·20	2s	2112·2 ,,	2112·5 ,,	,,	14·7	47329·3
§2104·88	2s	2104·9 ,,	2103·3 ,,	,,	14·8	47493·8
2098·7	2b	2098·6 ,,		,,	,,	47633·7
2093·1	1s	2093·9 ,,		,,	1·49	47761·1
2088·2	2s	2088·1 ,,		,,	,,	47873·2
2085·4	3s	2085·5 ,,		,,	1·50	47937·4
2079·0	2s	2078·8 ,,		,,	,,	48085·0
2070·4	1n			0·64	15·1	48284·7
2066·5	1n	2067·0 ,,		,,	,,	48375·9
2062·7	1n	2062·7 ,,		,,	15·2	48465·0
2055·1	2s	2055·1 ,,		,,	15·3	48644·1
2044·0	2s	2044·0 ,,		,,	15·4	48908·3
2037·28	2s	2037·3 ,,		,,	,,	49069·7
2036·0	2s	2036·0 ,,		,,	15·5	49100·4

COPPER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
2031·3	2b	2030·9 T. & S.	0·64	15·5	49214·1
2025·7	2s	2025·7 „	0·63	15·6	49350·1
2017·3	2s		„	1·57	49555·5
2016·0	2s	{ 2016·0 „ 2015·8 „	„	„	49587·5
2014·2	1s		„	„	49631·8
2013·19	1n	2013·2 „	„	„	49656·7
1999·68	2s	1999·9 „	„	15·8	49992·2
1989·24	2s	1989·4 „	„	16·0	50254·5
1979·26	2s	1979·4 „	„	16·1	50507·8
1970·5	1s	1970·4 „	„	16·2	50732·3
1943·88	1s	1944·1 „	„	16·5	51427·0

§ Observed also by Exner and Haschek, who give also the following lines: **4590·2, 4552·5, 4525·5, 4520·3, 4513·5, 4494·6, 4485·7, 4458·2, 4437·5, 4420·8, 4396·2, 4384·6, 4355·5, 4348·2, 4329·0, 4253·8, 4182·9, 4144·2, 4057·1, 4003·1, 3973·3, 3964·6, 3940·6, 3928·6, 3925·3, 3921·3, 3907·6, 3866·1, 3851·1, 3848·1, 3842·8, 3825·3, 3820·9, 3810·3, 3759·6, 3711·9, 3695·4, 3684·8, 3681·5, 3677·0, 3676·8, 3671·8, 3665·8, 3664·2, 3655 9, 3652·3, 3648·4, 3629·8, 3589·1, 3546·4, 3545·0, 3529·3, 3514·6, 3500·3, 3498·3, 3492·1, 3487·8, 3465·8, 3459·7, 3440·8, 3422·3, 3420·4, 3395·4, 3384·9, 3375·6, 3344·7, 3342·6, 3327·2, 3324·2, 3322·9, 3321·9, 3318·8, 3315·6, 3301·2, 3293·9, 3288·4, 3284·5, 3282·7, 3277·4, 3276·4, 3268·4, 3262·7, 3238·9, 3234·1, 3228·2, 3220·9, 3211·7, 3207·4, 3201·8, 3192·2, 3189·4, 3187·8, 3186·2, 3184·7, 3181·7, 3176·0, 3171·4, 3168·4, 3165·5, 3160·2, 3158·9, 3157·5, 3156·9, 3154·7, 3151·6, 3149·7, 3147·9, 3144·9, 3138·4, 3135·2, 3132·4, 3128·9, 3120·6, 3118·3, 3113·6, 3105·1, 3103·7, 3100·1, 3094·1, 3082·7, 3081·8, 3065·9, 3055·9, 3053·9, 3047·1, 3038·5, 3025·0, 3023·5, 3022·7, 3021·7, 3015·0, 3012·0, 2989·2, 2983·9, 2978·4, 2874·4, 2858·2, 2762·9, 2735·6, 2731·9, 2725·7, 2647·7, 2646·4, 2621·0, 2602·8, 2388·3, 2387·3, 2365·7, 2279·8, 2273·3, 2269·1, 2250·3, 2246·0, 2176·5.**

NOTE.—The spark employed by Eder and Valenta was of extraordinary power from a large Ruhmkorff coil, actuated by a current of 8 amperes at 110 volts in combination with a large condenser.

The number of lines observed is thus greatly in excess of the number of those observed by Thalén and other observers.

SILVER (SPARK SPECTRUM).

Eder and Valenta: 'Denkschr. kaiserl. Akad. Wissensch. zu. Wien.,' 1896.
Exner and Haschek: 'Sitzber. kaiserl. Akad. Wissensch. Wien.,' civ. (1895), cv. (1896).

* Observed by Kayser and Runge in the Arc spectrum.

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
6037·3	2n	6037·4 Thalén	1·64	4·5	16559·2
5678·7	1n		1·55	4·8	17604·9
*5667·9	1n		„	„	17638·4
5656·99	1b		1·54	„	17672·4
5646·50	1n	5646·3 „	„	„	17705·3
5628·40	2n	5627·2 „	„	„	17762·2

SILVER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
5623·34	4b	5624·0 Thalén	1·53	4·8	17778·2
5621·25	2n		,,	,,	17784·8
5611·85	2b	5612·0 ,,	,,	,,	17814·6
5602·93	1b		,,	4·9	17842·9
5597·99	1b		,,	,,	17858·7
5593·11	3b	} 5591·4 ,,	,,	,,	17874·2
5590·37	2n		1·52	,,	17883·0
5580·89	1n		,,	,,	17913·4
5575·21	1n		,,	,,	17931·6
5570·63	2b	5569·4 ,,	,,	,,	17946·4
5558·98	3b	5557·6 ,,	,,	,,	17984·0
5552·79	4b	5552·6 ,,	1·51	,,	18004·1
*5544·5	1n		,,	,,	18031·0
5535·41	2b		,,	,,	18060·6
5533·48	1b		,,	,,	18066·9
5530·23	1b		,,	,,	18077·5
5528·72	1b		,,	,,	18082·5
5521·25	4b	5523·2 ,,	,,	,,	18106·9
5494·75	1b		1·50	5·0	18194·2
5489·06	3b	5487·6 ,,	,,	,,	18213·1
5480·81	3b		,,	,,	18240·5
5479·34	2s		,,	,,	18245·4
*5471·70	5s	5471·5 ,,	1·49	,,	18270·9
*5465·64	10s	5465·3 ,,	,,	,,	18291·1
5454·41	3s		,,	,,	18328·8
5450·42	3s		,,	,,	18342·2
5424·9	1n	5424·6 ,,	1·48	,,	18428·5
5412·62	1n	5412·2 ,,	,,	,,	18470·3
5404·13	2b		,,	,,	18499·4
5401·10	2b	5402·7 ,,	1·47	5·1	18509·6
*5209·19	8s	5209·8 ,,	1·42	5·2	19191·6
*4874·42	2s	4874·9 ,,	1·33	5·6	20509·7
4678·23	4b		1·28	5·9	21369·7
4678·04	2b		,,	,,	21370·6
§*4668·58	2s	4667·6 ,,	,,	,,	21413·9
4630·10	3s		1·27	6·0	21591·8
4620·57	2s		,,	,,	21636·4
4620·08	2s		,,	,,	21638·6
*4616·0	1n		1·26	,,	21657·8
*4556·09	2b		1·25	6·1	21942·5
4552·41	1b		,,	,,	21960·3
4511·39	1s		1·24	,,	22120·8
§4509·84	1s		,,	,,	22167·6
§*4476·31	5s		1·23	6·2	22333·6
4447·08	2s		1·22	,,	22480·5
§*4396·30	1n	4396·8 Lecoq de B.	1·21	6·3	22740·1
4394·11	2s		,,	,,	22751·4
§4385·16	4s		1·20	,,	22797·9
4363·46	2s		,,	6·4	22911·2
4358·14	1s		,,	,,	22939·2
§*4311·35	4n		1·18	,,	23188·2
§4226·55	4s		1·16	6·6	23653·4
§*4212·76	2s	4212·0 L. & D.	,,	,,	23730·8
4210·87	8s	4208·5 Lecoq de B.	,,	,,	23741·5
§4085·92	2s		1·12	6·9	24467·4

SILVER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
§*4055·46	6s	4053·9 L. & D.	1·12	6·9	24651·2
4046·45	2s		1·11	7·0	24706·0
3994·96	1s		1·10	7·1	25024·4
§3985·18	3s		,,	,,	25085·9
§*3981·35	2s		,,	,,	25110·0
§3968·34	5s		1·09	,,	25192·4
3961·27	2s		,,	,,	25237·3
§3933·60	5s		1·08	7·2	25414·8
§3919·95	1s		,,	,,	25503·3
3918·41	1n		,,	,,	25513·4
§*3914·01	1n		,,	,,	25542·0
§*3607·76	2b		,,	7·3	25582·8
§*3840·74	1s		1·06	,,	26029·4
§3838·38	1n		,,	,,	26045·4
§*3810·86	3s		1·05	7·4	26233·4
3714·37	1s		1·03	7·6	26914·9
§3683·40	2s		1·02	7·7	27141·1
*3682·49	1s		,,	,,	27147·8
3649·97	2n		1·01	,,	27389·8
§3616·20	1n		1·00	7·8	27645·5
§3596·38	1s		,,	,,	27797·9
§3580·77	1n		,,	7·9	27919·1
§*3542·65	3s	3542·3 H. & A.	0·99	8·0	28219·5
§3513·44	1n		0·98	,,	28454·1
3503·05	1n		,,	8·1	28538·5
§*3502·02	2s		,,	,,	28546·8
§3495·57	1s		0·97	,,	28599·5
§3475·89	3s		,,	,,	28761·5
§3469·52	1s		,,	8·2	28814·2
§3468·0	1n		,,	,,	28826·9
3437·45	1n		0·96	,,	29083·1
§3429·59	2s		,,	8·3	29149·7
3425·56	1n		,,	,,	29184·0
§3421·69	2n		,,	,,	29217·0
3419·43	1n		,,	,,	29236·3
3412·91	1n		0·95	,,	29292·2
§3405·20	3b	3405·2 ,,	,,	,,	29358·6
3401·56	1n		,,	,,	29390·0
3400·34	1n		,,	,,	29400·5
§3397·56	2b		,,	,,	29424·6
3394·05	1n		,,	8·4	29454·9
3392·56	1b		,,	,,	29467·9
3389·44	3s	3391·4 ,,	,,	,,	29495·0
3387·22	1s		,,	,,	29514·3
§*3382·98	10s	3383·5 ,,	,,	,,	29551·3
3376·28	1n		0·94	,,	29610·0
§3373·59	1n		,,	,,	29633·6
§3367·04	2s		,,	,,	29691·3
3864·94	1n		,,	,,	29709·8
3363·69	1n		,,	,,	29720·9
3361·98	1s		,,	,,	29736·0
3361·18	1s		,,	,,	29743·1
3360·36	1s		,,	8·5	29750·2
3358·79	1n		,,	,,	29764·1
3356·90	1n		,,	,,	29780·9

SILVER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3354·41	2n		0·94	8·5	29803·0
3353·45	2n		"	"	29811·5
§3352·16	4s	3353·5 H. & A.	"	"	29823·0
3347·60	1s		"	"	29863·6
§3344·78	2b		"	"	29888·8
3343·28	2s		"	"	29902·2
3341·34	1s		"	"	26919·6
§3339·30	2s		"	"	29937·9
§3433·76	2s		0·93	"	29987·7
§3331·91	3s		"	"	30004·3
3330·69	1s		"	"	30015·3
§3329·84	1s		"	"	30023·0
3325·90	1s		"	"	30058·6
3322·93	1s		"	8·6	30085·3
§3321·81	2s		"	"	30095·5
§3318·26	2		"	"	30127·7
3316·73	2		"	"	30141·6
§3315·54	1n		"	"	30152·4
3313·75	1n		"	"	30168·7
§3312·65	4s	3313·8 ? "	"	"	30178·7
3308·58	2s		"	"	30215·8
3307·31	2s	3308·4 "	"	"	30227·5
*3305·32	1n		"	"	30245·7
3304·75	1n		"	"	30250·9
3304·14	1n		"	"	30256·5
§3301·61	5s	3302·8 "	0·92	"	30279·7
§3299·51	4s		"	"	30298·9
§3297·74	2s		"	"	30315·2
§3295·60	2s		"	"	30334·9
3294·40	2s		"	"	30345·9
§3293·22	3b	3294·1 "	"	8·7	30356·8
§3289·26	3s	3290·4? "	"	"	30393·4
3288·0	1s		"	"	30404·9
§*3280·80	10s	3281·6 "	"	"	30471·7
§3274·40	3s	3274·6 "	"	"	30531·2
3272·16	1n		"	"	30552·2
§3270·05	1n		"	"	30571·9
§3268·43	1s		"	"	30587·0
§3267·40	1s		"	"	30596·7
§3266·0	1s }	3267·0 "	"	" {	30609·8
§3264·20	2s }				30626·7
§3262·75	1s	3262·0 "	"	"	30640·3
3259·80	1n		0·91	"	30668·0
§3258·50	1s		"	"	30680·3
§3257·36	1s		"	"	30691·0
§3256·47	1s		"	"	30699·4
§3254·88	1n		"	"	30714·4
§3253·80	2s	3253·8 "	"	"	30724·6
§3252·65	5s		"	8·8	30735·4
3251·05	1s		"	"	30750·5
§3249·78	1s		"	"	30762·5
§3249·14	2s		"	"	30768·6
§3247·12	3s		"	"	30787·7
§3244·77	4s	3245·3 "	"	"	30810·0
§3241·06	2s double		"	"	30845·3

SILVER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3240·83	2s probably double		0·91	8·8	30847·5
3237·52	1s		,,	,,	30879·0
§3233·69	1s		,,	,,	30915·6
§*3233·07	3s	3233·3 H. & A.	,,	,,	30921·6
§3231·24	2s		,,	,,	30939·1
§3229·90	3s	3230·3 ,,	,,	,,	30951·9
§3228·88	1s		,,	,,	30961·7
§3224·87	1s		,,	,,	31000·2
§3223·37	3s	3223·8 ,,	,,	,,	31014·6
§3221·46	1s		,,	,,	31033·0
§3217·86	1s		0·90	,,	31067·8
§3216·65	4s	3217·5 ,,	,,	,,	31079·4
§3211·86	1n		,,	8·9	31125·7
§3209·92	2s	3209·6 ,,	,,	,,	31144·5
§3208·16	2s				31161·6
§3207·44	2s		,,	,,	31168·6
§3203·63	1s		,,	,,	31205·7
§3200·80	3s	3199·6 ,,	,,	,,	31233·3
§3200·01	1s		,,	,,	31241·0
§3193·34	1s		,,	,,	31306·3
§3191·80	2s	3191·2 ,,	,,	,,	31321·4
§3187·75	2s		,,	,,	31361·2
§3185·08	2s		,,	,,	31387·5
§3184·15	1s	3184·3 ,,	,,	,,	31396·7
§3181·50	2s		0·89	,,	31422·8
§3180·69	2s	3179·7 ,,	,,	9·0	31430·7
§3179·28	2s				31444·7
§3176·22	2n		,,	,,	31475·0
§3173·52	1s	3174·9 ,,	,,	,,	31501·8
§3172·22	1s		,,	,,	31514·7
§3158·73	1s		,,	,,	31649·3
§3153·09	2s		,,	,,	31705·9
§3149·92	1s		,,	,,	31737·8
3142·82	1n		,,	9·1	31809·5
§3142·08	1s		,,	,,	31817·0
§3130·10	2n	§3134·9 ,,	0·88	,,	31938·8
3129·19	1n	3129·2 ,,	,,	,,	31948·1
§3123·97	1n		,,	,,	32001·4
§3117·82	1s		,,	,,	32064·6
3116·93	1s		,,	,,	32073·8
§3115·65	1s		,,	,,	32086·9
§3113·10	1s		,,	9·2	32113·1
§3102·74	1s		,,	,,	32220·4
3098·10	1s		0·87	,,	32268·6
§3096·50	1s		,,	,,	32285·3
§3086·42	2s		,,	,,	32390·8
§3082·95	2s		,,	9·3	32427·2
3081·53	1s		,,	,,	32442·1
§3080·92	1s		,,	,,	32448·5
§3072·76	1n		,,	,,	32534·7
§3064·69	1s		,,	,,	32620·4
§3052·71	1n		0·86	9·4	32748·4

SILVER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
§3047·04	1s		0·86	9·4	32809·3
§3037·82	1n		,,	,,	32908·9
3036·03	1n		,,	,,	32928·4
3035·29	1n		,,	,,	32936·4
3031·75	1n		,,	,,	32974·8
3030·51	1n		,,	,,	32988·3
§3012·85	1s		0·85	9·5	33181·7
3011·89	1s		,,	,,	33192·2
§3000·67	1n		,,	,,	33316·4
2999·67	1n		,,	,,	33327·5
2999·13	1n		,,	,,	33333·5
2986·20	1s		,,	9·6	33477·8
§2982·16	1s		0·84	,,	33523 1
2943·93	1n		,,	9·8	33958·4
2942·06	1n	2938·0 H. & A.	0·83	,,	33980·0
§*2938·53	3b	2934·2 ,,	,,	,,	34020·8
§2934·23	4b	2929·1 ,,	,,	,,	34070·7
§2929·33	5s	2919·9 ,,	,,	,,	34127·7
§2920·0	3s	2902·2 ,,	,,	9·9	34236·7
§2902·08	4s		0·82	,,	34448·1
2886·44	5s		,,	10·0	34634·7
2883·99	2b		,,	,,	34664·2
§2878·88	1n		,,	,,	34725·7
§2873·65	5s	2873·2 ,,	,,	,,	34788·9
§2853·0	1n		0·81	10·1	35040·7
2828·74	1n		,,	10·2	35341·2
§*2824·06	2n		0·80	,,	35399·8
§2815·50	5s	2814·9 ,,	,,	10·3	35507·4
§2802·76	1s		,,	,,	35668·8
2801·69	1n		,,	,,	35682·4
§2799·63	5s	2799·3 ,,	,,	,,	35708·7
2795·60	4s		,,	10·4	35760·1
§2786·53	2n		,,	,,	35876·5
§2767·60	8s	2766·8 ,,	0·79	10·5	36121·9
§2756·46	4s	2755·8 ,,	,,	,,	36267·9
§2753·3	2s		,,	,,	36309·6
§2749·4	4s		,,	10·6	36361·0
§2746·9	3n		,,	,,	36394·1
§2746·6	3n		,,	,,	36398·1
§2744·06	4s		,,	,,	36431·8
2743·3	2s	2743·3 ,,	,,	,,	36441·8
§2740·0	4s		0·78	,,	36485·7
2737·2	1n		,,	,,	36523·1
2727·5	2s		,,	,,	36653·0
§2721·84	3s	2721·2 ,,	,,	10·7	36729·1
2719·1	1s		,,	,,	36766·2
2716·3	1s		,,	,,	36804·1
2714·5	1s		,,	,,	36828·5
§2711·94	8s	2711·8 ,,	,,	,,	36863·3
§2711·34	2s		,,	,,	36871·4
§2688·40	1n		0·77	10·8	37186·0
2684·8	1s		,,	,,	37235·9
§2681·43	5s	2681·1 ,,	,,	,,	37282·7
2666·4	1 Cu?		,,	10·9	37492·9
2664·6	1n		,,	,,	37518·2

SILVER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ +	$\frac{1}{\lambda}$ −	
§2660·52	8s	2660·2 H. & A.	0·77	10·9	37575·7
§2657·0	4b	2656·7 ,,	,,	,,	37625·5
2651·3	1s		0·76	11·1	37992·9
§2628·62	1s	2627·7 ,,	,,	,,	38031·7
§2625·75	3s		,,	,,	38073·3
§2621·6	1s		,,	,,	38133·5
§2617·8	2s		,,	,,	38188·9
§2614·55	6s	2614·3 ,,	,,	,,	38236·4
2613·8	2s		,,	,,	38247·4
§2612·0	2s		,,	,,	38273·7
2607·0	2s		0·75	11·2	38347·1
§2606·20	6s	2605·8 ,,	,,	,,	38358·8
§2599·26	3s		,,	,,	38461·3
§2598·79	2s	2598·8 ,,	,,	,,	38468·3
§2595·60	1s	2595·3 ,,	,,	,,	38515·5
2592·6	1s		,,	,,	38560·1
2591·4	1s		,,	,,	38578·0
§2585·8	2s		,,	11·3	38661·5
2584·2	2n		,,	,,	38685·4
§2580·66	8s	2580·5 ,,	,,	,,	38738·5
§*2575·5	1n		,,	,,	38816·1
§2567·0	2s	2566·1 ,,	,,	11·4	38944·6
§2564·34	3s	2563·5 ,,	0·74	,,	38985·0
2563·5	1s		,,	,,	38997·8
§2562·83	2s	2561·9 ,,	,,	,,	39008·0
§2562·6	1s		,,	,,	39011·5
2556·8	4s		,,	,,	39100·0
§2553·30	2s	2552·4 ,,	,,	,,	39153·6
2538·8	1s		,,	11·5	39377·2
2536·7	2s		,,	,,	39409·8
§2535·50	6s	2534·9 ,,	,,	,,	39428·5
2534·5	1s		,,	,,	39444·0
2533·8	2s		,,	,,	39454·9
2529·7	1s		,,	11·6	39518·8
2526·3	1s		,,	,,	39572·0
2525·5	1s		,,	,,	39584·5
§2523·1	1s		,,	,,	39622·2
2516·2	1s		0·73	,,	39730·9
2514·4	1s		,,	,,	39759·3
2511·9	1s	2506·4 ,,	,,	11·7	39798·8
§2506·74	9s	2506·4 ,,	,,	,,	39880·7
§2504·7	1s		,,	,,	39913·2
2504·1	3s	2504·1 ,,	,,	,,	39922·8
2502·3	1n		,,	,,	39951·5
2498·9	1s		,,	,,	40005·9
2493·2	2s		,,	11·8	40097·3
2490·7	1s		,,	,,	40137·6
2489·9	1s		,,	,,	40150·5
2488·2	1s		,,	,,	40177·9
§2486·6	2s	2486·7 ,,	,,	,,	40203·8
§2485·8	3s	2485·7 ,,	,,	,,	40216·7
2484·3	1n		,,	,,	40241·0
§2483·4	1s		,,	,,	40255·6
§2480·55	5s	2480·1 ,,	,,	,,	40301·8
2478·6	1s		,,	,,	40333·6

SILVER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
§2477·36	6s	2477·2 H. & A.	0·73	11·8	40353·8
§2473·93	8s	2473·7 ,,	,,	11·9	40409·6
§2472·5	1s		,,	,,	40433·0
§2469·7	2s	2469·6 ,,	0·72	,,	40478·9
§2466·8	1s		,,	,,	40526·4
§2462·25	5s	2462·6 ,,	,,	,,	40601·4
§2461·4	2s		,,	,,	40615·4
§2460·4	4s	2460·1 ,,	,,	,,	40631·9
§2458·9	2s		,,	12·0	40656·6
§2453·36	7s	2453·3 ,,	,,	,,	40748·4
§*2447·94	8s	2447·7 ,,	,,	,,	40838·7
§2446·45	5s	2446·0 ,,	,,	,,	40863·6
2445·6	2s		,,	,,	40877·8
§2444·3	5s	2442·2 ,,	,,	,,	40899·5
§2439·6	1n		,,	12·1	40978·2
§*2437·84	10s	2437·7 ,,	,,	,,	41007·8
2436·5	1n		,,	,,	41030·4
2434·7	1s		,,	,,	41060·7
§2433·6	1s		,,	,,	41079·3
§2432·3	1s		,,	,,	41101·3
§2430·25	2s		,,	,,	41135·9
§2429·6	7s	2430·3 ,,	,,	,,	41146·9
§2428·3	5s	2429·3 ,,	,,	,,	41169·0
§2424·2	1s		,,	12·2	41238·5
§2422·4	3s	2423·1 ,,	,,	,,	41269·2
§2420·10	8s	2420·3 ,,	0·71	,,	41308·4
§2415·43	2s	2416·2 ,,	,,	,,	41388·3
§*2413·20	10s	2414·0 ,,	,,	,,	41426·6
§2411·37	8s	2411·6 ,,	,,	12·3	41457·9
§2410·6	1s	2409·7 ,,	,,	,,	41471·2
2410·2	4s		,,	,,	41478·0
§2409·0	2b		,,	,,	41498·7
2406·6	1s	2406·8 ,,	,,	,,	41540·1
§2405·0	4s	2404·9 ,,	,,	,,	41567·7
§2402·6	3s		,,	,,	41609·3
2399·3	1s		,,	,,	41666·5
§2395·64	5s	2395·9 ,,	,,	12·4	41730·1
§2392·94	2b	2393·6 ,,	,,	,,	41777·2
§2390·56	5s	2391·0 ,,	,,	,,	41818·8
§2387·0	2s		,,	,,	41881·2
2386·6	2s	{ 2386·9 ,, 2386·4 ,,	,,	,,	41888·2
§2383·3	4s	2313·8 ,,	,,	,,	41946·2
§2382·2	3s		,,	12·5	41965·5
2380·9	1s		,,	,,	41988·4
2379·4	1s		,,	,,	42014·9
§*2375·3	2b	2375·9 ,,	,,	,,	42087·4
§2373·8	1s		0·70	,,	42114·0
2368·7	1s		,,	12·6	42204·6
§2365·8	3s	2366·3 ,,	,,	,,	42256·4
2364·9	2s	2364·8 ,,	,,	,,	42272·5
§2364·1	4s		,,	,,	42286·8
§2362·3	4s	2362·8 ,,	,,	,,	42319·0
§2360·4	1n		,,	,,	42353·1
§2358·86	6s	2352·6 ,,	,,	,,	42380·8

SILVER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
§2357·94	8s	2358·5 H. & A.	0·70	12·6	42397·3
§2356·8	1n		,,	,,	42417·8
2348·3	2s		,,	12·7	42571·3
§2343·8	1s		,,	,,	42653·1
2343·5	3s	2344·1 ,,	,,	,,	42658·5
§2341·8	2s	2342·5 ,,	,,	,,	42689·5
2340·7	1n		,,	12·8	42709·5
§2339·1	2s	2339·5 ,,	,,	,,	42738·7
2337·9	1s		,,	,,	42760·6
§2332·9	1s		,,	,,	42852·3
*2331·9	2s	2332·8 ,,	,,	,,	42870·7
§2331·34	8s	2332·1 ,,	,,	,,	42881·0
2327·4	1s		,,	12·9	42953·5
§2325·0	4s	2326·3 ,,	0·69	,,	42997·8
§*2324·69	8s	2325·8 ,,	,,	,,	43003·6
2321·6	2s	2322·8 ,,	,,	,,	43060·8
§*2320·24	8s	2321·1 ,,	,,	,,	43086·1
2319·2	1n	2320·0 ,,	,,	,,	43105·4
§2318·6	1s		,,	,,	43116·6
§*2317·03	8s	2317·9 ,,	,,	,,	43145·8
2316·1	1n		,,	,,	43163·1
§*2309·7	4b	2310·5 ,,	,,	13·0	43282·7
§2296·8	2s	} 2297·0 ,,	,,	13·1	43525·7
§2296·1	2s		,,	,,	43539·0
§2291·0	1s		,,	,,	43636·0
§2286·5	3s	2287·0 ,,	,,	13·2	43721·8
§2282·5	2s		,,	,,	43798·4
§2280·0	8s	2281·3 ,,	,,	,,	43846·4
§2278·9	4s	2278·0 ,,	,,	,,	43867·6
§2277·4	2s		0·68	,,	43896·5
§2275·4	5s	2275·8 ,,	,,	13·3	43935·0
§2273·3	2s		,,	,,	43975·6
§2257·3	1s		,,	13·4	44287·3
§2253·5	4s	2254·4 ,,	,,	,,	44362·0
§2250·2	1s		,,	13·5	44427·0
§*2248·80	6s	2250·2 ,,	,,	,,	44454·7
§*2246·46	5s	2247·9 ,,	,,	,,	44501·0
§2243·5	2n		,,	,,	44559·7
§ { 2241·9	1n		,,	,,	44591·5
§ { 2241·4	2n		,,	,,	44601·5
§2240·5	2b		,,	,,	44619·4
§2238·5	2s		,,	13·6	44659·2
§ { 2229·6	5s	2230·9 ,,	0·67	,,	44837·5
{ 2228·7	3s		,,	,,	44855·6
§2226·2	6s		,,	13·7	44905·9
2223·2	1s		,,	,,	44966·5
2220·9	1n		,,	,,	45013·1
§2219·7	1s		,,	,,	45037·4
§2211·3	3s		,,	13·8	45208·5
§2208·6	3s		,,	,,	45263·8
§2206·2	3s	2206·3 ,,	,,	,,	45313·0
§2204·7	1n		,,	,,	45343·8
§2203·7	2s		,,	13·9	45364·3
§2202·3	3n	2202·3 ,,	,,	,,	45393·2
§2192·1	1n		,,	14·0	45604·4

SILVER (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
§2187·0	3s	2186·3 H. & A.	0·67	14·0	45710·7
2173·6	1n		0·66	14·1	45992·5
2171·9	1n		,,	,,	46028·5
§2171·0	1n		,,	,,	46047·6
§2169·6	1n		,,	14·2	46077·2
§2166·6	4s	2166·1 ,,	,,	,,	46141·1
§2162·1	2s	2161·6 ,,	,,	,,	46237·1
§2149·3	1s		,,	14·3	46512·5
§2145·71	3s	2145·7 ,,	,,	14·4	46590·2
2144·9	1s		,,	,,	46607·8
§2129·3	1s		0·65	14·5	46949·3
§2125·5	1b		,,	14·6	47033·2
§2120·5	4s	2119·3 ,,	,,	,,	47144·1
§2113·9	3s	2112·3 ,,	,,	14·7	47291·2
2106·7	2s		,,	,,	47452·9
2084·3	1b		,,	15·0	47962·7
2081·5	1b		,,	,,	48027·3
2075·9	1b		,,	,,	48156·9
2066·2	4s		0·64	15·1	48382·9
2056·9	1		,,	15·2	48601·7
2053·9	1n		,,	15·3	48672·6
2053·2	1n		,,	,,	48689·2
2033·1	2n		,,	15·5	49170·5
2016·1	2s		0·63	15·7	49585·0
2000·6	2s		,,	15·8	49969·2
1999·6	2s		,,	,,	49994·2
1993·5	1s		,,	15·9	50147·1
1975·2	1s		,,	16·1	50611·7

§ Observed also by Exner and Haschek, who give also the following lines: **4443·4, 4411·0, 4355·4, 4326·8, 4209·4, 4182·7, 4159·2, 4113·7, 4081·7, 4057·9, 4054·9, 4045·7, 3973·3, 3949·5, 3943·0, 3863·8, 3860·0, 3856·5, 3851·0, 3848·0, 3843·0, 3830·3, 3825·9, 3820·4, 3815·8, 3759·8, 3758·5, 3745·8, 3740·3, 3737·3, 3735·0, 3732·5, 3720·1, 3709·5, 3674·0, 3655·0, 3623·5, 3619·0, 3570·4, 3557·2, 3519·0, 3505·3, 3499·9, 3471·0, 3445·7, 3390·0, 3245·9, 3236·5, 3227·9, 3216·8, 3198·1, 3196·1, 3185·8, 3177·7, 3175·2, 3170·5, 3167·9, 3166·3, 3157·6, 3155·8, 3155·3, 3146·3, 3142·6, 3122·8, 3114·6, 3101·7, 3099·3, 3094·8, 3093·1, 3092·0, 3067·9, 3067·0, 3051·1, 3047·6, 3038·3, 3034·2, 3028·6, 3024·1, 3021·2, 3020·8, 3010·8, 3009·3, 3002·6, 2994·4, 2990·6, 2983·6, 2973·3, 2967·1, 2949·1, 2930·1, 2896·4, 2885·6, 2882·3, 2877·8, 2872·1, 2870·6, 2863·5, 2862·3, 2857·3, 2852·1, 2849·6, 2848·3, 2845·0, 2844·1, 2840·0, 2837·8, 2837·2, 2820·9, 2775·2, 2761·8, 2735·8, 2732·6, 2708·5, 2707·4, 2704·6, 2675·9, 2659·3, 2637·6, 2620·8, 2619·5, 2617·2, 2602·1, 2560·8, 2559·0, 2557·5, 2505·6, 2501·4, 2499·8, 2497·3, 2471·5, 2470·6, 2468·8, 2465·6, 2463·8, 2456·7, 2449·7, 2431·5, 2422·0, 2408·0, 2394·1, 2392·5, 2374·8, 2367·2, 2361·2, 2355·6, 2355·1, 2354·7, 2328·2, 2323·5, 2313·8, 2312·5, 2289·8, 2283·2, 2281·7, 2277·7, 2272·4, 2265·3, 2256·7, 2252·0, 2233·8, 2233·1, 2232·8, 2219·0, 2196·6, 2190·0, 2181·8, 2164·0, 2163·2, 2148·9, 2147·5, 2143·1, 2138·3.**

GOLD (SPARK SPECTRUM).

Eder and Valenta : 'Denkschr. kaiserl. Akad. Wissench. zu Wien.,' 1896.

* Observed in the Arc Spectrum by Kayser and Runge.

† Observed also by Krüss, 'Untersuchungen über das Atomgewicht des Goldes, Munich,' 1886.

‡ These lines appear only in very powerful sparks.

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
*6278·37	3	6277·8 Thalén, &c.†	1·71	4·3	15923·4
5961·40	2	5961·2 ,, †	1·62	4·6	16770·0
*5957·24	2	5956·7 ,, †	,,	,,	16781·7
5921·43	1n	5920·8 Huggins †	1·61	,,	16883·2
5881·57	1b	5881 ,, †	1·60	,,	16997·7
*5863·23	3s	5863 ,, †	,,	,,	17050·8
*5837·69	6s	5837·7 Thalén, &c.†	1·59	4·7	17125·4
5819·64	1n		,,	,,	17178·5
5789·11	2b	5791 Huggins	1·58	,,	17269·1
5767·46	1n		1·57	,,	17334·0
5762·21	1n		,,	,,	17349·7
5760·14	5s	5759·2 ,,	,,	,,	17356·0
5742·25	2b		,,	,,	17410·1
5732·52	2n		1·56	,,	17439·6
5730·88	1n		,,	,,	17444·6
5727·11	3s	5725·8 L. de B.†	,,	,,	17456·1
5711·14	4b		,,	4·8	17504·8
5692·49	1n		1·55	,,	17562·2
5688·70	3s		,,	,,	17573·9
5679·65	1n		,,	,,	17601·9
5666·82	1n		,,	,,	17641·8
5662·90	1n		1·54	,,	17654·0
*5655·95	6s	5654·2 Huggins †	,,	,,	17675·7
5651·02	1n		,,	,,	17691·1
5649·44	1n		,,	,,	17696·1
5648·11	1b		,,	,,	17700·2
5645·91	3b		,,	,,	17707·1
5644·51	3n		,,	,,	17711·5
5641·61	3s		,,	,,	17720·6
5619·99	1n		1·53	,,	17788·8
5600·36	2b		,,	4·9	17851·1
5598·48	4n		,,	,,	17857·1
5594·50	3b		,,	,,	17869·8
5593·93	3s		,,	,,	17871·6
5591·49	2b		,,	,,	17879·4
5588·08	4b		1·52	,,	17890·3
5585·87	1n		,,	,,	17897·4
5578·72	5b	5581·3 ,, †	,,	,,	17920·4
5576·42	1b		,,	,,	17927·8
5566·92	1n		,,	,,	17958·4
5565·38	2b		,,	,,	17963·3
5559·82	3s		,,	,,	17981·3
5550·47	1s		1·51	,,	18011·6
5543·93	4n		,,	,,	18032·8
5532·69	3s		,,	,,	18069·5
5520·67	3s		,,	,,	18108·8
5514·60	1n		1·50	,,	18128·8
5511·70	1n		,,	,,	18138·3

GOLD (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}-$	
5506·42	1n		1·50	4·9	18155·7
5495·86	1n		,,	5·0	18190·5
5487·87	1n		,,	,,	18217·0
5465·87	1n	†	1·49	,,	18290·3
5428·64	3s		1·48	,,	18415·8
5423·66	1bn		,,	,,	18432·7
5418·77	1bn	5419 L. de B.	,,	,,	18449·4
5413·42	3s		,,	,,	18467·6
5409·80	1s		,,	,,	18480·0
5394·69	3n		1·47	5·1	18531·6
5383·73	1n		,,	,,	18569·4
5381·38	2n		,,	,,	18577·5
5363·63	2n		1·46	,,	18639·0
5355·05	2n		,,	,,	18668·9
5351·36	1n		,,	,,	18681·7
5269·41	1b		1·44	5·2	18972·3
5265·83	1b		,,	,,	18985·2
5262·05	3s	5260 ,,	,,	,,	18998·8
*5230·53	8s	5231·1 Thalén, &c.	1·43	,,	19113·3
5203·21	1s		1·42	5·3	19213·6
5147·76	3s		1·41	,,	19420·6
5142·62	1n	5144 L. de B.	,,	,,	19440·0
5108·20	2n		1·40	5·4	19571·0
5087·87	1b		1·39	,,	19649·2
*5064·76	5s	5067·6 Huggins †	,,	,,	19738·9
5041·83	1n		1·38	,,	19828·7
5016·51	1n		1·37	5·5	19928·7
5005·10	2s		,,	,,	19974·1
5001·39	2s		,,	,,	19988·9
4973·63	1n		1·36	,,	20100·5
4949·05	2n		1·35	,,	20200·4
4920·50	2s		,,	5·6	20317·5
4902·45	4s		1·34	,,	20392·4
4828·70	1s		1·32	5·7	20703·8
4813·58	2n		,,	,,	20768·9
4811·57	5s	4812 ,,	,,	,,	20777·5
*4792·79	8b	4792·7 Thalén	1·31	,,	20859·0
4760·34	2s		1·30	5·8	21001·1
4753·90	3s		,,	,,	21029·6
4715·43	1s		1·29	,,	21201·2
4712·92	2s		,,	,,	21212·5
4701·63	2s		,,	5·9	21263·3
4698·50	3s		,,	,,	21277·5
4696·12	2s		,,	,,	21288·3
4686·96	1s		1·28	,,	21329·9
4684·30	6s		,,	,,	21342·0
4683·84	6s		,,	,,	21344·1
4679·21	1s		,,	,,	21365·2
4673·24	6s		,,	,,	21392·5
4649·96	3b		1·27	,,	21499·7
4646·26	3s		,,	,,	21530·7
4640·72	1s		,,	,,	21542·5
4637·37	3s		,,	,,	21558·0
4633·23	3s		,,	6·0	21577·2
4630·58	3s		,,	,,	21589·6

GOLD (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
4627·98	3s		1·27	6·0	21601·7
4622·02	2b		,,	,,	21629·6
4614·85	2s		1·26	,,	21663·2
4614·19	1s		,,	,,	21666·3
4611·98	1s		,,	,,	21676·7
4607·80	6s	4609 L. de B.†	,,	,,	21696·3
4601·57	2s		,,	,,	21725·7
4587·91	7b		,,	,,	21790·4
4583·87	3s		,,	,,	21809·6
4582·05	4s		,,	,,	21818·3
4577·74	2s		1·25	,,	21838·8
4576·15	2s		,,	,,	21846·4
4573·14	1s		,,	,,	21860·8
4570·85	1s		,,	,,	21871·8
4559·05	6b		,,	6·1	21928·3
4549·64	6b		,,	,,	21973·7
4543·86	3b		,,	,,	22001·6
4541·40	4s		1·24	,,	22013·5
4523·20	4n		,,	,,	22102·1
4492·49	2n		1·23	6·2	22253·2
*4488·43	8s	4489·8 Huggins†	,,	,,	22273·3
*4437·37	4s	4437·7 L. de B.†	1·22	,,	22529·7
4420·69	3s		1·21	6·3	22614·6
4410·55	2n		,,	,,	22666·6
4395·72	3n		,,	,,	22743·1
4382·25	2n		1·20	,,	22813·0
4373·70	2s		,,	,,	22857·6
4370·46	8s		,,	,,	22874·6
4328·65	1s		1·19	6·4	23095·5
4315·34	8s	4315 ,, †	1·18	,,	23166·7
4310·70	1n		,,	,,	23191·7
4309·21	1n		,,	,,	23199·7
4303·15	1n		,,	6·5	23232·3
4292·80	1s		,,	,,	23288·3
4290·20	1n		,,	,,	23302·4
4280·60	1n		1·17	,,	23354·7
4279·24	1n		,,	,,	23362·1
4276·0	1n		,,	,,	23379·8
4260·01	2s		,,	,,	23467·6
4255·0	3n		,,	,,	23495·3
*4241·95	3n		1·16	6·6	23567·5
4221·87	2b		,,	,,	23679·6
4219·11	1b		,,	,,	23695·1
4211·0	2b		,,	,,	23740·7
4199·54	2b		1·15	6·7	23805·4
4186·29	2b		,,	,,	23880·8
4184·65	1b		,,	,,	23890·2
4175·28	3b		,,	,,	23943·8
4172·90	2b		,,	,,	23957·5
4171·42	2b		,,	,,	23966·0
4170·0	1b		,,	,,	23974·1
4142·30	1n		1·14	6·8	24134·4
4128·80	1n		1·13	,,	24213·3
4126·31	2n		,,	,,	24227·9
4118·52	1n		,,	,,	24273·8

GOLD (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	1/λ −	
4089·95	2n		1·12	6·9	24443·3
*4084·31	4s		"	"	24477·0
4076·60	3s		"	"	24523·3
4070·76	1s		"	"	24558·5
*4065·20	10s	4064·6 L. de B.	"	"	24592·1
4053·0	6s		1·11	"	24666·2
*4041·07	4s		"	7·0	24738·9
4028·66	2s		"	"	24815·1
4021·83	1n		"	"	24857·3
4020·86	1n		"	"	24863·3
4016·27	8s		"	"	24891·7
4012·87	2s		1·10	"	24912·8
4010·63	1s	4009 Krüss	"	"	24926·7
4002·57	3s		"	7·1	24976·8
4001·60	3s		"	"	24982·9
3996·96	1s		"	"	25011·9
3991·64	1s		"	"	25045·3
3990·0	1s		"	"	25055·6
3986·48	1n		"	"	25077·7
3986·04	1n		"	"	25080·5
3984·18	1n		"	"	25092·2
3982·87	2n		"	"	25100·4
3979·72	3n		"	"	25120·3
3976·80	3n		"	"	25138·7
3971·80	3n‡		1·09	"	25170·4
3959·35	5s‡		"	"	25249·6
3950·19	2s		"	7·2	25308·0
3945·69	2n		"	"	25336·9
3945·19	1n		1·08	"	25340·1
3937·80	1n		"	"	25387·7
3936·42	1n		"	"	25396·6
3933·16	4s		"	"	25417·6
3927·82	3s		"	"	25452·2
3922·66	1s		"	"	25485·7
3920·28	1s		"	"	25501·2
3919·08	1n‡		"	"	25509·0
3916·15	6s‡		"	"	25528·1
3915·03	2s		"	"	25535·4
*3909·60	3s		"	"	25570·9
3903·47	2s		"	7·3	25610·9
3900·72	2s		"	"	25629·0
*3898·03	10s		"	"	25646·7
3895·65	1n		1·07	"	25662·4
3893·52	1n		"	"	25676·4
3892·65	3s		"	"	25682·1
3889·58	2n		"	"	25702·4
3880·34	3s		"	"	25763·6
3877·45	4s‡		"	"	25782·8
3874·96	4s		"	"	25799·4
3872·81	2s‡		"	"	25813·7
3868·50	2n		"	"	25842·5
3865·70	4s		"	"	25861·2
3859·53	3s‡		"	"	25902·6
3856·60	2n		1·06	"	25922·3
3853·76	6s‡		"	"	25941·4

GOLD (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$ −	
3845·02	4s‡		1·06	7·3	26000·4
3839·60	1s‡		,,	,,	26037·1
3838·66	1s‡		,,	,,	26043·5
3837·70	1n‡		,,	,,	26050·0
3834·42	1n‡		,,	,,	26072·3
3831·31	4s‡		,,	,,	26093·4
3829·52	3s‡		,,	,,	26105·6
3828·56	2s‡		,,	,,	26112·2
3825·87	8s‡		,,	,,	26130·5
3823·20	4s‡		,,	,,	26148·8
3822·11	6s‡		,,	,,	26156·3
3820·45	2s‡		,,	,,	26167·6
3816·50	5s		1·05	7·4	26194·6
3814·30	2n‡		,,	,,	26209·7
3811·60	2n‡		,,	,,	26228·3
3810·41	2n‡		,,	,,	26236·5
3806·95	2b‡		,,	,,	26260·3
3804·22	4s		,,	,,	26277·2
3800·75	3s‡		,,	,,	26303·2
3799·44	2n‡		,,	,,	26312·3
3796·15	3n		,,	,,	26335·1
3787·37	2s‡		,,	,,	26396·2
3783·30	2s‡		,,	,,	26424·6
3780·13	5s‡		,,	,,	26446·7
3777·25	2s‡		,,	,,	26466·9
3773·31	4s‡		1·04	,,	26494·4
3771·12	3s‡		,,	7·5	26509·8
3770·14	4s‡		,,	,,	26516·7
3765·76	4s‡		,,	,,	26547·6
3765·10	3s‡		,,	,,	26552·2
3763·10	2s‡		,,	,,	26566·3
3759·03	3s		,,	,,	26595·1
3754·85	3s		,,	,,	26624·7
3752·90	3s‡		,,	,,	26638·6
3746·5	1n‡		,,	,,	26684·1
3744·54	2s‡		,,	,,	26698·0
3736·82	2s‡		1·03	,,	26753·2
3732·68	2s‡		,,	,,	26782·9
3730·92	2s‡		,,	,,	26795·5
3724·46	2s‡		,,	7·6	26841·9
3718·02	2s		,,	,,	26888·4
3716·89	1s‡		,,	,,	26896·6
3714·96	1s‡		,,	,,	26910·6
3708·30	4s‡		,,	,,	26958·9
3706·99	4s		,,	,,	26968·5
3702·49	3s‡		,,	,,	27001·3
3698·65	2s‡		,,	,,	27029·3
3695·68	2s‡		1·02	,,	27051·0
3694·14	2n‡		,,	,,	27062·3
3691·66	2s‡		,,	,,	27080·5
3690·18	1s‡		,,	,,	27091·3
3687·60	3s‡		,,	,,	27110·3
3686·21	2s‡		,,	,,	27120·5
3684·0	1n‡		,,	,,	27136·8
3681·39	2b‡		,,	7·7	27156·0

GOLD (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$ −	
3677·62	1s‡		1·02	7·7	27183·8
3676·62	1s‡		"	"	27191·2
3675·11	1s‡		"	"	27202·4
3674·0	1s‡		"	"	27210·6
3672.93	2s‡		"	"	27218·5
3671·34	2s‡		"	"	27230·3
3664·61	1s‡		"	"	27280·3
3663·70	1s‡		"	"	27287·1
3662·57	1s‡		"	"	27295·5
3661·79	1s‡		"	"	27301·3
3658·05	1s‡		"	"	27329·3
3657·35	2s‡		1·01	"	27334·5
3654·56	1s‡		"	"	27355·4
3654·22	2s‡		"	"	27357·9
3653·66	3s‡		"	"	27362·1
3653·93	2s		"	"	27382·6
3649·25	4s‡		"	"	27395·2
3647·90	1s‡		"	"	27405·3
3642·66	2n		"	"	27444·8
3637·57	3s		"	7·8	27483·1
3635·21	4s		"	"	27500·9
3633·40	5s		"	"	27514·6
3632·81	2s		"	"	27519·1
3631·02	1s‡		"	"	27532·7
3627·47	1n‡		"	"	27559·6
3625·32	2n‡		"	"	27576·0
3623·73	3s‡		"	"	27588·1
3622·93	6s‡		"	"	27594·2
3620·13	1n		"	"	27615·5
3620·11	2n		"	"	27615·7
3614·17	3s‡		1·00	"	27661·1
3610·95	1s‡		"	"	27685·7
3607·59	3s		"	"	27711·5
3604·94	2s‡		"	"	27731·9
3601·17	4s‡		"	"	27760·9
3598·28	2n		"	"	27783·3
3594·20	2s‡		"	7·9	27814·7
3591·90	2s‡		"	"	27832·5
3586·66	7s		"	"	27873·2
3581·45	4n		"	"	27913·7
3576·11	1s‡		0·99	"	27955·4
3573·94	1n		"	"	27972·4
3565·99	2s		"	"	28034·8
3557·13	2n		"	"	28104·7
3555·58	3s‡		"	"	28116·9
*3553·72	6s‡		"	"	28131·6
3549·26	2s‡		"	8·0	28166·9
3548·26	1s‡		"	"	28174·8
3541·71	3s‡		"	"	28227·0
3539·18	3n‡		"	"	28247·1
3528·25	2n‡		0·98	"	28334·7
3523·42	3s‡		"	"	28373·5
3516·40	1n‡		"	"	28430·2
3515·19	1n‡		"	"	28440·0
3506·17	1n‡		"	8·1	28513·0

GOLD (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3504·62	1n‡		0·98	8·1	28525·7
3501·85	1n‡		,,	,,	28548·2
3496·08	2s‡		0·97	,,	28595·4
3492·99	1s‡		,,	,,	28620·7
3487·34	1s‡		,,	,,	28667·1
3484·60	1s‡		,,	,,	28689·6
3476·58	1n‡		,,	,,	28755·8
3474·36	1n‡		,,	,,	28774·2
3471·76	1s‡		,,	,,	28795·7
3470·47	1s‡		,,	8·2	28806·3
3452·27	2s‡		0·96	,,	28958·2
3437·32	1s‡		,,	,,	29084·2
3410·97	1n‡		0·95	8·3	29308·9
3400·28	2s‡		,,	,,	29401·0
3398·95	2s‡		,,	,,	29412·6
3393·87	1s		,,	8·4	29456·5
3383·05	3s		,,	,,	29550·7
3382·26	1		,,	,,	29557·6
3360·47	2n‡		0·94	8·5	29749·2
3358·61	1s		,,	,,	29765·7
3355·35	1s‡		,,	,,	29794·7
3331·74	1s‡		0·93	,,	30005·8
*3320·32	2b		,,	8·6	30109·0
3310·34	2s‡		,,	,,	30199·8
*3308·36	3s		,,	,,	30217·9
3286·56	2b‡		0·92	8·7	30418·3
3280·72	6s		,,	,,	30472·4
3277·88	2n‡		,,	,,	30498·8
3273·84	4b‡		,,	,,	30536·5
3271·63	2b‡		,,	,,	30557·1
3270·17	2b		,,	,,	30570·0
3266·96	4s		,,	,,	30600·8
*3265·18	4s		,,	,,	30617·5
3253·86	2b‡		0·91	,,	30724·0
3251·73	2b‡		,,	8·8	30744·1
3243·34	2b‡		,,	,,	30823·6
*3230·73	8s		,,	,,	30944·0
3228·0	5s‡		,,	,,	30970·1
3223·03	2n		,,	,,	31017·9
3221·94	4s		,,	,,	31028·4
3219·59	3s		0·90	,,	31051·1
3217·69	2s		,,	,,	31069·4
3216·14	2s		,,	8·9	31084·3
3212·0	1s		,,	,,	31124·4
3211·03	4s		,,	,,	31133·8
*3204·75	8s		,,	,,	31194·8
*3194·90	5s		,,	,,	31291·0
3165·02	2s		0·89	9·0	31586·4
3156·73	5s		,,	,,	31669·4
3146·52	3s		,,	9·1	31772·0
3145·77	1s		,,	,,	31779·6
3138·93	3n		0·88	,,	31848·9
3133·18	2n		,,	,,	31907·4
3131·75	1n		,,	,,	31921·9
3129·86	2n		,,	,,	31941·2

GOLD (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
*3127·24	4s		0·88	9·1	31968·0
*3122·88	10s		,,	,,	32012·6
*3117·20	3s		,,	,,	32071·0
3106·70	1s		,,	9·2	32179·3
3104·09	2s		,,	,,	32206·4
3093·28	3n		0·87	,,	32318·9
3091·47	1s		,,	,,	32337·9
3045·83	2s		0·86	9·4	32822·4
*3033·35	4b		,,	,,	32957·5
*3029·32	6s		,,	,,	33001·3
3015·93	4s		0·85	9·5	33147·8
*3014·50	2n		,,	,,	33163·5
3001·81	2s		,,	,,	33303·7
2995·13	8s		,,	9·6	33377·9
2990·38	6s		,,	,,	33431·0
2982·21	4s		0·84	,,	33522·6
*2973·63	1n		,,	,,	33619·3
*2970·66	1n		,,	9·7	33652·9
*2963·91	1s		,,	,,	33729·5
2959·90	1n		,,	,,	33775·2
2959·11	1n		,,	,,	33784·2
2954·64	6s		,,	,,	33835·4
*2932·33	5s		0·83	9·8	34092·8
2918·48	4s		,,	9·9	34254·5
*2913·63	10s		,,	,,	34311·5
2907·16	5s		,,	,,	34387·9
*2906·07	3b		,,	,,	34400·8
2893·51	5s		0·82	10·0	34550·1
*2892·05	3s		,,	,,	34567·6
2885·69	3s		,,	,,	34643·8
*2883·60	4s		,,	,,	34668·9
2864·67	1n		0·81	10·1	34897·9
2860·92	1n		,,	,,	34943·7
2857·04	3b		,,	,,	34991·2
2852·71	2b		,,	,,	35044·3
2852·30	1n		,,	,,	35049·3
2847·25	5s		,,	10·2	35111·4
2838·15	7s		,,	,,	35224·0
2835·55	2s		,,	,,	35256·3
2833·20	2s		,,	,,	35285·6
2825·59	6s		,,	,,	35380·6
2822·87	4s		0·80	10·3	35414·6
2820·09	10b		,,	,,	35449·6
2805·45	2s		,,	,,	35634·6
2802·39	10s		,,	,,	35673·5
2795·69	3s		,,	10·4	35758·9
2780·95	3s		0·79	,,	35948·5
*2748·35	5s		,,	10·6	36374·9
2732·17	2s		0·78	,,	36590·3
2721·97	2s		,,	10·7	36727·4
2703·42	2s		,,	,,	36979·5
*2700·99	3s		,,	10·8	37012·7
2699·4	1n		,,	,,	37034·5
2697·8	1s		0·77	,,	37056·4
*2694·40	2s		,,	,,	37103·2

GOLD (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			λ+	$\frac{1}{\lambda}$−	
2690·5	1n		0·77	10·8	37151·0
*2688·75	4s		,,	,,	37181·2
2688·24	2s		,,	,,	37188·3
2687·68	4s		,,	,,	37196·0
2686·0	1n		,,	,,	37219·3
2682·3	1n		,,	,,	37270·6
*2676·05	8s		,,	10·9	37357·6
2672·3	1n		,,	,,	37410·1
2670·7	1n		,,	,,	37432·5
2667·07	2s		,,	,,	37483·4
2665·25	3s		,,	,,	37509·0
2651·2	1s		0·76	11·0	37707·8
2645·5	2b		,,	,,	37789·0
2641·70	8s		,,	,,	37843·4
2635·4	1n		,,	,,	37933·9
2634·4	1n		,,	,,	37948·3
2631·7	1n		,,	11·1	37987·2
2627·15	4s		,,	,,	38053·0
2625·65	3s		,,	,,	38074·7
2624·2	2b		,,	,,	38095·8
2622·0	2n		,,	,,	38127·7
2617·60	2s		,,	,,	38191·8
2616·71	4n		,,	,,	38204·8
2612·8	1n		,,	,,	38262·0
2611·9	1n		,,	,,	38275·2
2610·5	1n		,,	,,	38295·7
2609·6	2b		0·75	,,	38309·0
2607·4	1n		,,	11·2	38341·2
2605·0	1n		,,	,,	38376·5
2599·5	2s		,,	,,	38457·7
2592·0	3s		,,	,,	38569·0
*2590·23	6s		,,	,,	38595·4
2583·5	2n		,,	11·3	38695·9
2580·1	1n		,,	,,	38746·9
2579·4	1n		,,	,,	38757·4
2577·7	1n		,,	,,	38783·0
2575·3	1n		,,	,,	38819·1
2571·4	2n		,,	,,	38878·0
2568·3	1n		,,	11·4	38924·9
2565·80	5s		,,	,,	38962·8
2562·7	2s		0·74	,,	39009·9
2561·9	1n		,,	,,	39022·1
2558·0	2n		,,	,,	39081·6
2552·92	3s		,,	,,	39159·4
2553·25	3		,,	,,	39200·4
*2544·30	5		,,	11·5	39292·0
2538·03	4		,,	,,	39389·1
2537·0	2		,,	,,	39405·1
2536·1	3		,,	,,	39419·1
2533·68	6		,,	,,	39456·8
2528·2	2		,,	11·6	39542·2
2522·8	2n		,,	,,	39626·9
2520·7	2s		0·73	,,	39659·9
2517·2	2n		,,	,,	39715·1
2515·2	3s		,,	,,	39746·7

GOLD (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2511·7	1n		0·73	11·7	39802·0
*2510·60	5s		..	..	39819·4
2506·4	2s		..	..	39886·2
2503·42	8s		..	..	39933·7
2495·3	1s		..	..	40063·6
2492·7	3b		..	11·8	40105·3
2491·4	1s		..	..	40126·3
2490·4	2s		..	..	40142·4
2488·3	2s		..	..	40176·3
2483·4	2n		..	..	40255·6
2480·4	4s		..	..	40304·3
2478·6	1s		..	..	40333·6
2477·8	1s		..	..	40346·6
2476·2	3b		..	11·9	40372·6
2468·0	3b		0·72	..	40506·7
2458·1	3s		..	12·0	40669·8
2456·6	2b		..	..	40694·7
2455·3	2b		..	..	40716·2
2452·7	2b		..	..	40759·4
2447·9	2s		..	..	40839 3
2446·6	1n		..	..	40861·0
2445·6	4b		..	..	40877·8
2444·3	1b		..	..	40899·5
2442·3	2b		..	12·1	40932·9
2437·8	3s		..	..	41008·5
2434·5	1n		..	..	41064·1
2433·7	2s		..	..	41077·6
2433·3	2s		..	..	41084·4
*2428·10	10s		..	12·2	41172·3
2423·8	2		..	..	41245·3
2419·4	4n		0·71	..	41320·4
2419·1	1b		..	..	41325·5
2417·4	2b		..	..	41354·6
2416·6	2b		..	..	41368·3
2414·7	1n		..	..	41400·8
2413·4	3s		..	..	41423·1
2411·5	2s		..	12·3	41455·7
2410·7	1s		..	..	41469·4
2408·8	2n		..	..	41502·1
2407·5	2n		..	..	41524·6
2405·2	3s		..	..	41564·3
2402·7	4s		..	..	41607·5
2401·5	2s		..	..	41628·3
2400·2	1s§		..	..	41650·9
2399·3	1s		..	..	41666·5
2395·7	1s		..	12·4	41729·1
2393·7	3s		..	..	41763·9
2391·7	1n		..	..	41798·9
2388·5	2s		..	..	41854·9
*2387·9	4s		..	..	41865·4
2384·3	2s		..	..	41928·6
2382·6	4b		..	12·5	41958·5
2380·5	1n		..	..	41995·5

§ Coincident with a line of copper.

GOLD (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2379·3	1s		0·71	12·5	42016·7
2377·2	1s		,,	,,	42053·8
2376·4	5s		,,	,,	42068·0
2373·4	2n		0·70	,,	42121·1
2371·8	4s		,,	,,	42149·6
2369·5	4n		,,	,,	42190·5
*2364·8	10s.r.		,,	12·6	42274·3
2359·1	1n		,,	,,	42376·4
2357·9	1n		,,	,,	42398·0
2355·5	2s		,,	,,	42441·2
*2352·8	6s		,,	12·7	42489·9
2351·5	3s		,,	,,	42513·3
2348·2	1s		,,	,,	42573·1
2347·0	2s		,,	,,	42594·9
2344·3	2s		,,	,,	42644·0
2343·6	2s		,,	,,	42656·7
2342·6	1s		,,	,,	42674·9
2341·5	1s		,,	,,	42695·0
2340·1	8b		,,	12·8	42720·4
2334·1	2b		,,	,,	42830·3
2332·0	4s		,,	,,	42868·8
2331·5	2s		,,	,,	42878·0
2330·7	1s		,,	,,	42892·8
2326·7	1n		,,	12·9	42966·4
2325·8	3s		0·69	,,	42983·1
2325·3	2s		,,	,,	42992·3
2324·7	1s		,,	,,	43003·4
2322·3	8s		,,	,,	43047·9
2321·4	1s		,,	,,	43064·6
2320·4	2s		,,	,,	43083·1
2318·4	2s		,,	,,	43120·3
2317·5	1s		,,	,,	43127·0
2315·9	7s		,,	,,	43166·9
2314·7	7s		,,	,,	43189·2
2312·2	2s		,,	13·0	43235·9
2309·5	6s		,,	,,	43286·4
2308·2	1s		,,	,,	43310·8
2304·7	8b		,,	,,	43376·6
2301·1	1s		,,	13·1	43444·4
2300·4	1s		,,	,,	43457·6
2298·3	1n		,,	,,	43497·3
2296·9	2s		,,	,,	43523·8
2295·1	2s		,,	,,	43558·0
2294·1	2b		,,	,,	43577·0
2291·5	6b		,,	,,	43626·4
2288·7	2s		,,	,,	43679·8
2287·7	3n		,,	13·2	43698·8
2286·9	1n		,,	,,	43717·9
*2283·4	6s		,,	,,	43781·1
2283·0	3n		,,	,,	43788·8
2279·2	2n		,,	,,	43861·8
2277·6	4n		0·68	,,	43892·7
2273·2	1s		,,	13·3	43977·5
2270·3	3s		,,	,,	44033·7
2267·0	2s		,,	,,	44097·9

GOLD (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2266·0	3b		0·68	13·3	44117·3
2265·3	1n		,,	,,	44131·0
2264·0	3n		,,	,,	44156·3
2262·9	4n		,,	13·4	44177·7
2261·5	2n		,,	,,	44205·0
2260·8	2n		,,	,,	44218·7
2255·8	2n		,,	,,	44316·8
2255·0	1n		,,	,,	44332·5
2253·5	3s		,,	,,	44362·0
2248·9	2n, double ?		,,	13·5	44452·7
2246·7	3n		,,	,,	44496·2
2243·6	1n		,,	,,	44557·7
2242·7	6s		,,	,,	44575·6
2240·4	4n		,,	,,	44621·4
2237·7	2n		,,	13·6	44675·1
2233·8	3n		,,	,,	44753·2
2231·4	4n		,,	,,	44801·3
2229·1	6n		0·67	,,	44847·6
2222·6	2n		,,	13·7	44978·7
2220·5	3s		,,	,,	45019·2
2219·4	2s		,,	,,	45043·5
2215·9	3n		,,	,,	45114·7
2213·2	4s		,,	13·8	45169·6
2210·6	3s		,,	,,	45222·8
2210·3	1s		,,	,,	45228·9
2206·0	3s		,,	,,	45317·1
2201·6	5s		,,	13·9	45407·6
2193·7	1s		,,	,,	45571·2
2192·7	1s		,,	,,	45592·0
2190·7	1s		,,	14·0	45633·5
2189·3	5s		,,	,,	45662·7
2186·9	2s		,,	,,	45712·8
2185·7	2s		,,	,,	45737·9
2184·2	2s		,,	,,	45769·4
2172·3	3s		0·66	14·1	46020·1
2167·7	2s		,,	14·2	46117·6
2160·7	2n		,,	,,	46267·1
2159·2	2n		,,	14·3	46299·2
2157·4	3n		,,	,,	46337·8
2154·4	2n		,,	,,	46402·3
2140·5	1n		,,	14·4	46703·7
2138·0	2b		,,	,,	46758·3
2133·4	1b		,,	14·5	46859·0
2129·7	1b		0·65	,,	46940·5
2126·8	2s		,,	14·6	47004·4
2125·3	5s		,,	,,	47037·6
2113·7	1s		,,	14·7	47295·7
2110·8	9s		,,	,,	47360·7
2098·8	1n		,,	14·8	47631·5
2098·2	1s		,,	,,	47645·1
2095·0	1n		,,	14·9	47717·8
2085·4	1n		,,	15·0	47937·4
2083·1	1s		,,	,,	47990·4
2082·1	8s		,,	,,	48013·4
2071·7	1s		0·64	15·1	48254·4

GOLD (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
			$\lambda+$	$\frac{1}{\lambda}-$	
2064·0	1s		0·64	15·2	48434·4
2059·9	1s		,,	,,	48530·8
2056·6	1s		,,	,,	48608·7
2055·4	1s		,,	15·3	48637·0
2044·7	5s		,,	15·4	48891·5
2012·3	1n		0·63	15·7	49678·7
2000·7	3s		,,	15·8	49966·7
1988·9	1s		,,	16·0	50263·0
1977·3	1s		,,	16·1	50557·9

Proximate Constituents of Coal.—Report of the Committee, consisting of Sir I. LOWTHIAN BELL (*Chairman*), Professor P. PHILLIPS BEDSON (*Secretary*), Professor F. CLOWES, Dr. LUDWIG MOND, Professor VIVIAN B. LEWES, Professor E. HULL, Mr. J. W. THOMAS, *and* Mr. H. BAUERMAN.

ACCORDING to Baltzer[1] coals are mixtures of complex carbon compounds, these forming a genetic and possibly a homologous series. The framework of carbon contained in these compounds is a complex one, the only analogy to which is that presented by the aromatic compounds. The physical properties of coals are such as to render a classification possible, and these different varieties exhibit a similarity in their ultimate composition. Whilst these several varieties form the essential constituents of coal, there are in addition certain accessory constituents, such as the resinous components, the hygroscopic water, and the 'inclosed gases.'

The researches of J. W. Thomas, of E. von Meyer, of Schondorff, of Bedson and McConnell, and others have provided an extensive knowledge of the nature of the gases inclosed in coals from different sources, and also a knowledge of the conditions under which these gases are retained by the coal. The hygroscopic water and the absorptive power for water of different coals have, by reason of their technical importance, received considerable attention.

The remaining group of accessory constituents represented by the resinous bodies, which are distinguished from the coal substance by their solubility, consists of some few hydrocarbons, such as ozokerit, and bodies containing carbon, hydrogen, and oxygen, of which Muck, in his 'Chemie der Steinkohle,' gives the following: i. Middletonite; ii. Pyroretenite; iii. Reussinite; iv. Scleretinite; v. Rosthornite; vi. Anthrakoxen; vii. Guayaquillite; viii. Berengelite.

These mineral substances are of varying solubilities in alcohol, ether, and turpentine. From the description given by the different investigators it would appear probable that several of these substances are mixtures.

[1] *Vierteljahrsschr. d. Zür. Naturf.-Gesellsch.*, 1872; also Muck, *Chem. d. Steink.*, p. 141.

In 1874 Dondorff drew attention to the occurrence in several Westphalian gas coals of a blackish solid, with a reddish brown colour in reflected light, having a brown streak. This substance is found in thin leaflets on this coal, and is almost entirely soluble in ether, forming a light yellow solution, which fluoresces not unlike solutions of the salts of quinine.

By the extraction of a Westphalian gas coal with ether Muck has obtained an ethereal solution of a similar character, and from it obtained a solid of the following percentage composition :—

C=87·22, H=9·20, O=2·29, S=1·29 (nitrogen absent).

This substance, when heated in a platinum crucible, leaves a coke-like residue, amounting to 32·09 per cent. The author considers this substance to be widely diffused in coal, and has shown it to exist in varying amounts in different parts of the same seam. Associated with this investigation is that of P. Siepmann, who has submitted the gas coal of the Pluto mine, Westphalia, to a systematic extraction with chloroform, ether, and alcohol, obtaining the following results :—

The chloroform extract amounted to 1·25 per cent. of the coal ; the solution, dark yellow to brown in colour, possessed a strong green fluorescence ; the composition of the extract was

C=83·46, H=7·93, O=4·27, N=2·71, S=1·63.

The residue, after extraction with chloroform, gave, when treated with ether, a light yellow solution having a bluish green fluorescence, from which a solid was obtained amounting to 0·3 per cent. of the coal, and containing

C=84·82, H=10·51 and O=4·67.

The residue treated with alcohol gave a solution similar in character to the ethereal solution. The amount removed by the alcohol was 0·25 per cent. of the coal, and the composition of the dissolved solid was found to be

C=72·52, H=10·08, O=17·4.

After the above treatment the residual coal was again extracted with chloroform, which removed 0·75 per cent. of the coal, and left on evaporation a dark brown, pitch-like mass, which gave the following results on analysis :—

C=78·82, H=8·56, O=9·97, N (trace), S=2·65.

The last chloroform solution was dark brown in colour and feebly fluorescent.

The composition of the coal before and after this treatment is given below :—

	C	H	O	N
Before treatment	80·31	5·50	12·94	1·25
After treatment	74·00	4·77	20·09	1·14

According to H. Reinsch, alcohol extracts from coal a substance supposed to be altered 'chenopodin,' a body which the author had discovered in the sap of *Melilotus albus*, and to which he attributes the composition $C_{12}H_{13}O_8N$. In 1885 P. Reinsch concluded that coal consists of two classes of substances, one soluble in alkalis, forming coloured solutions, and a second insoluble.

By the use of phenol as a solvent E. Guignet has extracted from 2 to 4 per cent. of a brown solid from coal, which is precipitated from the solution by alcohol. The finely powdered coal treated with nitric acid yields solutions containing oxalic acid and trinitroresorcinol; the insoluble residue contains apparently nitro-compounds, or bodies similar to nitro-cellulose. A portion of this residue is dissolved by caustic alkalis and ammonia, forming brown-coloured solutions.

Guignet, led by the formation of trinitroresorcinol, as mentioned above, attempted to obtain resorcinol by fusion of the coal with caustic soda and distillation in a bath of molten lead, but obtained ammonia and aniline only. The residue after this treatment was, however, found to be partially dissolved by water, forming dark brown solutions, from which acids precipitated out humus-like substances. Guignet concludes these bodies are derived from the cellulose-residues of the coal, and that the trinitro-resorcinol owes its origin to the resinous and wax-like constituents.

During the session 1889–90 Mr. Saville Shaw, Lecturer in Chemistry at the Durham College of Science, Newcastle-upon Tyne, made some experiments on the action of a mixture of concentrated sulphuric and nitric acids on bituminous coal. The coal, in a finely powdered condition, was allowed to remain for three weeks in contact with the mixed acids, and then poured into a large volume of water, filtered and thoroughly washed. The dried residue differs but slightly in appearance from the original coal, but had evidently undergone change in composition, as after this treatment it gave as much as 77 per cent. of 'volatile matter,' whereas the coal contained but 27 per cent.; further when heated in a test-tube it 'puffs' with slight flame, resembling in this respect gun-cotton. A considerable portion of this 'nitro-coal' is soluble in caustic alkalis, yielding very dark brown solutions, from which on acidifying bulky dark brown precipitates are formed. The precipitates, washed and dried, form brilliantly black friable masses, which have lost the semi-explosive properties of the original 'nitro-coal.' Methyl alcohol dissolves some 11 per cent. of the 'nitro-coal,' the solution yielding a black scaly product on evaporation, which, when heated, suddenly decomposes, leaving a very bulky residue of carbon. Attempts to prepare reduction products from this nitro-coal were unsuccessful.

In a note published in the 'Proceedings of the Chemical Society' (1891–92, p. 9) R. J. Friswell described the results obtained by treating finely powdered coal with dilute nitric acid; a considerable portion of the coal is thus converted into a black insoluble acid, which behaves very much as a nitro-compound.

Mention should also be made of the investigations of Mr. Watson Smith, published in 1891, on the soluble and resinoid constituents of bituminous coal. The soluble material extracted by benzene from a Japanese coal Mr. Watson Smith has shown to contain phenols, nitrogenous organic bases, and also some aromatic hydrocarbons.

In a previous report experiments with various solvents on a bituminous coal from the Hutton seam in the county of Durham were referred to, but, owing to the small yields obtained, this method of attacking the problem as to the nature of the proximate constituents of coal has been relinquished.

The oxidation of the finely powdered coal with aqueous solutions of potassium permanganate, in some cases made alkaline with caustic potash, appeared to offer a more promising method of attack. The coal uses up very considerable quantities of the permanganate, and dark brown solutions are obtained. From these solutions it has been attempted, by the aid of the formation of insoluble salts, to isolate some of the acids which result from the oxidation of the coal in this way. The difficulties met with arising from the unsatisfactory properties of many of these salts, which are usually obtained in the form of gelatinous, clayey solids, difficult to wash and obtain in a state of purity suitable for analysis, have led to the abandonment of this reagent.

More promising results have been obtained by acting upon the coal with dilute hydrochloric acid and potassium chlorate. Mr. J. A. Smythe, B.Sc. of the Durham College of Science, Newcastle-upon-Tyne, has undertaken the investigation of this action for the purposes of this committee.

When finely divided coal is boiled for several hours with dilute hydrochloric acid, and potassium chlorate added from time to time, the coal gradually assumes a brown colour, and a brown solid collects on the surface of the yellow liquid. The coal, after lengthened treatment, is filtered off, washed, and dried at 100° C. The product is invariably found to have increased in weight, and when extracted with alcohol or acetone some 30 to 35 per cent. of the material is dissolved out by either of these solvents ; of the two, acetone is the more powerful solvent, leaving a coal-like insoluble residue. The solution obtained in this manner is next distilled, and after removal of the solvent a dark reddish brown resinous mass is left, which, when finely ground, forms a dark brown homogeneous powder. The finely divided powder was extracted with benzene ; the portion insoluble in benzene was treated with alcohol, in which some readily dissolved, leaving a residue sparingly soluble in hot alcohol.

The benzene solution, after removal of the benzene, leaves a dark resinous mass, which, when ground, forms a brown powder, which is dissolved not only by benzene and acetone, but also by ether, chloroform, glacial acetic acid, phenol, and nitrotoluene, but is insoluble in carbon disulphide, petroleum ether, and water. The solutions of this body are all dark brown, almost black, and from these it is always deposited in an amorphous condition. The analysis of this substance gave the following results, from which a formula, $C_{30}H_{22}Cl_8O_{10}$, has been deduced :—

Weight of Substance

(*a*) 0·364 gram gave 0·578 gram CO_2, and 0·086 gram H_2O.
0·293 „ „ 0·411 „ AgCl=34·67 per cent. Cl.
(*b*) 0·357 „ „ 0·571 „ CO_2, and 0·087 gram H_2O.
0·322 „ „ 0·448 „ AgCl=34·29 per cent. Cl.

	a	b	Means	Calculated for $C_{30}H_{22}Cl_8O_{10}$
C.	43·29	43·60	43·44	43·64
H.	2·62	2·70	2·66	2·66
Cl.	34·67	34·42	34·54	34·29
O.	19·42	19·28	—	19·41
	100·00	100·00	—	100·00

From the alcoholic extraction there was obtained, after removal of the alcohol, a brown solid, very similar in appearance to that obtained from the benzene solution. The results of the analysis of this substance most nearly accord with a formula $C_{24}H_{18}Cl_4O_9$.

(*a*)	0·420 gram gave	0·740 gram	CO_2 and 0·114 gram H_2O.
	0·463 „ „	0·451 „	AgCl=24·05 per cent. Cl.
(*b*)	0·386 „ „	0·680 „	CO_2 and 0·104 gram H_2O.
	0·569 „ „	0·550 „	AgCl=23·88 per cent. Cl.

	a	b	Calculated for $C_{24}H_{18}Cl_4O_9$
C.	48·05	48·05	48·66
H.	3·01	2·99	3·04
Cl.	24·05	23·88	23·96
O.	24·89	25·08	24·34
			100·00

From the material left after extraction with benzene and alcohol, which is sparingly soluble in hot alcohol but soluble in acetone, two substances have been obtained which contain a smaller proportion of chlorine than the above, and from the analytical results appear to have the formulæ $C_{22}H_{14}Cl_3O_5$ and $C_{25}H_{20}Cl_3O_8$. The deep yellow acid filtrate from which the oxidised and unoxidised coal had been removed was shaken out with ether; the ethereal solution appears to contain some trichloracetic acid. The aqueous solution, after extraction with ether when concentrated to a small bulk, deposits crystals of potassium chloride, &c., coloured yellow by a colouring matter which is removed by acetone. The acetone solution, on evaporation, gives a reddish viscous liquid, which is dissolved by ether and alcohol, but is insoluble in benzene.

The analysis of the residue left after the evaporation of acetone showed that it contained some mineral matter, which was left as ash when the substance was burnt. Owing to the small amount at disposal, a further purification was not attempted. The determination of the carbon, hydrogen, and chlorine gave the following :—

(*a*)	0·4132 gram gave	0·6460 gram	CO_2 and 0·1414 gram H_2O.
	0·4158 „ „	0·2584 „	AgCl=15·36 per cent. Cl.
(*b*)	0·357 „ „	0·5608 „	CO_2 and 0·125 gram H_2O.
	0·4402 „ „	0·2706 „	AgCl=15·20 per cent. Cl.
	0·426 „ „	0·015 „	Ash=3·52 per cent.

	a	b	
C.	42·61 per cent.	42·82 per cent.	
H.	3·80 „	3·88 „	
Cl.	15·36 „	15·20 „	
Ash	—	—	3·52 per cent.

Calculating the percentage of carbon, hydrogen, chlorine for the substance free from ash, we get amounts corresponding to the formula $C_{33}H_{36}Cl_4O_{20}$, as shown below :—

	a	b	Calculated for $C_{33}H_{36}Cl_4O_{20}$
C. =	44·18	44·39	44·29
H. =	3·94	4·03	4·02
Cl. =	15·92	15·76	15·88
O. =	35·96	35·82	35·81
	100·00	100·00	100·00

Although the action of hydrochloric acid and potassium chlorate on the coal is a slow one, it is much more thorough in its attack than other oxidising agents tried. The coal left after treatment and removal of oxidised product with acetone, when submitted to a second treatment with acid and chlorate of potash, is still further attacked and converted into products similar to those formed in the first instance, and it appears that the proportion of oxidised product increases with each successive oxidation. To study the mode of action, 10 grams of the coal were boiled with dilute acid and 20 grams of chlorate of potash, added in small quantities at a time; the action continued for forty-four hours. The dried product was found to have increased by 21 per cent. in weight, and of this 62·7 per cent. was dissolved by acetone. The residue left after treatment with acetone weighed 5·27 grams, which was again oxidised for forty hours. Of the dried product 74 per cent. was removed by acetone, and the remaining 1·26 gram, after a third and similar treatment, gave a product from which acetone dissolved some 77·8 per cent., leaving 0·32 gram of coal-like insoluble residue.

The analysis of the coal after it had been treated four time with these reagents shows an increased percentage in carbon and hydrogen and the presence of a trace of chlorine.

From the above it is evident that the coal substance is powerfully attacked by hydrochloric acid and potassium chlorate, but the products of this action are for the most part complex substances, from which at present but little information can be derived as to the nature of the materials from which they are formed. These bodies appear to be acidic in properties, and form dark brown solutions with caustic alkalis and ammonia, from which metallic salt solutions, such as barium chloride, lead nitrate, silver nitrate, &c., precipitate out dark coloured gelatinous salts, which are difficult to obtain in a state of sufficient purity for analysis. The attempts to obtain information as to the constitution of these chlorinated compounds have up to the present yielded no satisfactory results.

The composition and physical properties of these chlorinated compounds recall those described by Messrs. Cross and Bevan in their investigations of jute—for example, the substance described by these authors as tetrachlorobastin ($C_{38}H_{36}Cl_8O_{18}$), from which they have obtained protocatechuic acid by fusion with potash.

The treatment of cannel coal with hydrochloric acid and potassium chlorate results in the production of compounds similar to those obtained from the coal of the Hutton seam; the oxidation product soluble in alcohol contained some 24·13 per cent. of chlorine.

A sample of bitumen submitted to a similar treatment gave a product from which ether dissolves about two-thirds, the ethereal solution on evaporation leaving a dark viscous residue, which was found to contain 11·06 per cent. of chlorine.

Whilst postponing for the present the further study of these chlorinated compounds, Mr. Smythe has begun the investigation of the action of hydrochloric acid and potassium chlorate in 'brown coal.' For this purpose samples of brown coal were obtained from Brühl, near Cologne: this variety of coal is much more readily attacked than the coal from Durham. It is also noteworthy that whilst the dry oxidised product from the latter weighs more than the coal, in the case of the brown coal there is a notable decrease in the weight. Further, there is a much larger proportion of the oxidised product soluble in acetone, as the following details of an experiment with 10 grams of finely ground coal show.

Ten grams of brown coal boiled for 12 hours with dilute hydrochloric acid and 20 grams of potassium chlorate; the insoluble mass was filtered off, washed, and dried. The dried solid weighed 6·82 grams: of this 72·4 per cent. was soluble in acetone. The portion insoluble in acetone, viz., 1·88 gram, was treated for 12 hours more with hydrochloric acid and potassium chlorate, giving a solid product of 1·49 gram, of which 79·8 per cent. was dissolved by acetone. The chlorinated compounds formed in this manner are very similar in appearance to those obtained from the Hutton seam coal, and probably of a similar character. The crude solid left after the evaporation of the acetone was found to contain some 22·93 per cent. of chlorine.

The investigation of these substances as also the products formed by the oxidation of brown coal with solutions of potassium permanganate are still in progress.

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CONSIDERABLE progress has been made with the work of this Committee during the past year. The difficulties mentioned in past reports having at length been overcome, a number of experiments are in hand which will it is believed be completed early in 1897. Meanwhile some of the material prepared has been made useful for some subsidiary investigations which also are approaching completion. No further grant is at present necessary. But it is recommended that the Committee be reappointed.

The Action of Light upon Dyed Colours.—Report of Committee, consisting of Professor T. E. THORPE (*Chairman*), Professor J. J. HUMMEL (*Secretary*), Dr. W. H. PERKIN, Professor W. J. RUSSELL, Captain ABNEY, Professor W. STROUD, *and* Professor R. MELDOLA. (*Drawn up by the Secretary.*)

DURING the past year (1895–96) the work of this Committee has been continued, and a large number of wool and silk patterns, dyed with various natural and artificial *blue* and *green* colouring matters, have been examined with respect to their power of resisting the fading action of light.

The general method of preparing the dyed patterns, and the manner of exposing them under glass, with free access of air and moisture, were the same as already adopted in previous years.

The thanks of the Committee are again due to James A. Hirst, Esq., in whose grounds the patterns were exposed at Adel, near Leeds.

Each dyed pattern was divided into six pieces, one of which was protected from the action of light, while the others were exposed for different periods of time. These 'periods of exposure' were made equivalent to those adopted in previous years by exposing, along with the patterns, special series of 'standards,' dyed with the same colouring matters as were then selected for this purpose. The standards were allowed to fade to the same extent as those which marked off the 'fading period' in previous years, before being renewed or before removing a set of dyed patterns from the action of light. The patterns exposed during the past year are therefore comparable, in respect of the amount of fading action to which they have been submitted, with the dyes already reported upon.

The patterns were all put out for exposure on July 19, 1895, certain sets being subsequently removed on the following dates :—August 12, September 3, September 20, 1895 ; April 1, July 9, 1896. Of these five 'periods of exposure' thus marked off, periods 1, 2, 3 were equivalent to each other in fading power, whereas periods 4 and 5 were each equivalent to *four* of the first period in this respect ; hence five patterns of each colour have been submitted respectively to an amount of fading equal to 1, 2, 3, 7, and 11 times that of the first 'fading period' selected—viz., July 19 to August 12, 1895.

The dyed and faded patterns have been entered in pattern-card books in such a manner that they can be readily compared with each other.

The following tables give the general result of the exposure experiments made during the year 1895–96, the colours being divided, according to their behaviour towards light, into the following five classes: Very fugitive, fugitive, moderately fast, fast, very fast.

The initial numbers refer to the order of the patterns in the pattern-books. The S. and J. numbers refer to Schultz and Julius's 'Tabellarische Uebersicht der künstlichen organischen Farbstoffen.'

In the case of colouring matters requiring mordants, the particular mordant employed is indicated in brackets after the name of the dye-stuff.

Class I. Very Fugitive Colours. (Wool.)

Many of the colours of this class have faded so rapidly that at the end of the first 'fading period' (July 19 to August 12, 1895) only a very faint colour remains, and at the end of the fifth period (one year) all traces of the original colour have disappeared, the woollen cloth being either white or of a yellowish or greyish appearance.

Triphenylmethane Colours.

Wool Book IX.

Basic Colours. 10. Victoria Blue R. Constitution not published.
" 11. New Victoria Blue B. Constitution not published.
" 12. Victoria Blue B. Hydrochloride of phenyl-tetra-methyl-triamido-diphenyl-α-naphthyl-carbinol. S. and J. 274.
" 13. Night Blue. Hydrochloride of *p*-tolyl-tetra-ethyl-triamido-diphenyl-α-naphthyl-carbinol. S. and J. 275.
" 14. Victoria Blue 4R. Hydrochloride of phenyl-penta-methyl-triamido-diphenyl-α-naphthyl-carbinol. S. and J. 276.

Safranine Colours.

Basic Colours. 24. Neutral Blue. Phenyl-dimethyl-*p*-amido-pheno-naphthazonium-chloride. S. and J. 354.

Oxazine Colours.

Acid Colours. 9. Gallanilic Indigo PS. Sulphonated product of the action of aniline on gallocyanine-anhydride-anilide.
" 24. Fluorescent Blue. Ammonium salt of tetra-brom-resorufin.
Basic Colours. 5. Capri Blue GON. Dimethyl-tolyl-ammonium-dimethyl-amido-phenoxazine-chloride.
" 7. Cresyl Blue 2BS. Dimethyl-tolyl-ammonium-amido-phenoxazine-chloride.
" 19. Nile Blue. Dimethyl-phenyl-ammonium-α-amido-naphthoxazine-chloride. S. and J. 344.
" 20. New Methylene Blue GG. Dimethyl-phenyl-ammonium-dimethyl-amido-naphthoxazine-chloride.

Thiazine Colours.

Basic Colours. 3. Thionine Blue GO. Zinc double chloride of diethyl-dimethyl-thionine.
" 4. Methylene Blue B. Zinc double chloride of tetra-methyl-thionine.
" 8. Gentianine. Hydrochloride of dimethyl-thionine.
" 9. New Methylene Blue N. Hydrochloride of diethyl-toluthionine.
" — Toluidine Blue. Zinc double chloride of dimethyl-tolu-thionine. S. and J. 351.

Azo Colours.

Wool Book X.
Direct Cotton Colours. 1. Diamine Sky Blue. From diphenitidine and amido-naphthol-disulphonic acid H.
" 2. Chicago Blue 6B. Constitution not published.
" 3. Brilliant Benzo Blue 6B. Constitution not published.
" 8. Diamine Blue 6G. Constitution not published.

NOTES.—Certain colours in this class—*e.g.* Gentianine, &c.—fade during the first period to a grey colour possessing a moderate degree of fastness. Neutral Blue is characterised by fading to a dull reddish colour. Gallanilic Indigo P S and Diamine Blue 6 G, when completely faded, leave the wool of a pronounced yellowish tint.

CLASS II. FUGITIVE COLOURS. (WOOL.)

The colours of this class show very marked fading at the end of the second 'fading period' (August 12 to September 3, 1895), and after a year's exposure they have entirely faded, or only a tint remains.

Triphenylmethane Colours.

Wool Book IX.
Basic Colours. 1. Turquoise Blue. Constitution not published.
" 2. Turquoise Blue 2B. Constitution not published.
" 6. Glacier Blue. Zinc double chloride of dichlor-dimethyl-diamido-ditolyl-phenyl-carbinol.
Acid Colours. 5. Cyanol extra. Sodium salt of *m*-oxy-diethyl-diamido-phenyl-ditolyl-carbinol-disulphonic acid.

Thiazine Colours.

" 10. Thiocarmine. Sodium salt of diethyl-dibenzyl-thionine-disulphonic acid.

Oxazine Colours.

Basic Colours. 27. Muscarin J. Dimethyl-phenyl-*p*-ammonium-β-oxy-naphthoxazine. S. and J. 343.
" 28. Metamine Blue B. Dimethyl-phenyl-*p*-ammonium-β-naphthoxazine. S. and J. 342.
" 29. New Fast Blue H. Constitution not published.
" 30. New Fast Blue F. Constitution not published.
Acid Colour. 27. Azine Blue. Constitution not published.

Safranine and Induline Colours.

Basic Colours. 15. Basle Blue B. Dimethyl-amido-tolyl-amido-tolyl-pheno-naphthazonium chloride.
" 16. Diphene Blue R. An induline colour.
" 17. Indazine M. Tetra-methyl-diamido-diphenazine-phenyl-chloride. S. and J. 364.
" 26. Metaphenylene Blue B. Tetra-methyl-di-*o*-tolyl-diphenazonium chloride.

Natural Colouring Matters.

Acid Colours. 1. Indigo Carmine. Sodium salt of indigotin-disulphonic acid.
" 2. Indigo Purple. Sodium salt of indigotin-mono-sulphonic acid.

Azo Colours.

Wool Book X.
Direct Cotton Colours. 9. Benzo Cyanine 3B. Constitution not published.
11. Indoïn Blue 2B. From Safranine and β-naphthol.

Direct Cotton Colours. 12. Metazurin B. Constitution not published.
" 14. Benzo Blue 3B. Constitution not published.
" 15. Benzo Red Blue G. Constitution not published.
" 16. Columbia Blue G. Constitution not published.
" 17. Chicago Blue R. Constitution not published.
" 18. Naphthazurin. Constitution not published.
" 23. Diamine Blue 2B. From benzidine and amido-naphthol-disulphonic acid H.
" 24. Diamine Blue 3B. From tolidine and amido-naphthol-disulphonic acid H.
" 25. Benzo Cyanine R. Constitution not published.
" 26. Indazurin. Constitution not published.
" 27. Direct Blue B. From dianisidine, dioxy-naphthoïc-sulphonic acid, and α-naphthol-p-sulphonic acid.
" 28. Heligoland Blue 3B. Constitution not published.
" 29. Benzo Azurine G. From dianisidine, and α-naphthol-mono-sulphonic acid NW. S. and J. 210.
" 30. Benzo Red Blue R. Constitution not published.
" 31. Columbia Blue R. Constitution not published.
" 32. Benzo Azurine 3G. From dianisidine, and α-naphthol-mono-sulphonic acid L. S. and J. 213.
" 33. Brilliant Metazurin OOO. Constitution not published.
" 34. Diamine Blue BX. From tolidine, α-naphthol-mono-sulphonic acid NW, and amido-naphthol-disulphonic acid H.
" 35. Diamine Blue B. From ethoxy-benzidine, β-naphthol-δ-disulphonic acid, and α-naphthol-mono-sulphonic acid NW. S. and J. 205.
" 36. Heligoland Blue R. Constitution not published.
" 37. Oxamine Blue 3R. From tolidine, β-amido-α-naphthol-β-sulphonic acid, and α-naphthol-α-sulphonic acid.
" 38. Diamine Blue 3R. From ethoxy-benzidine, and α-naphthol-mono-sulphonic acid NW. S. and J. 206.
" 39. Azo Blue. From tolidine, and α-naphthol-mono-sulphonic acid NW. S. and J. 187.
" 43. Azo Navy Blue. Constitution not published.
" 45. Direct Blue Black B. Constitution not published.
Acid Colours. 23. Azo Acid Blue B. Constitution not published.

Natural Colouring Matters.

Mordant Colours. Logwood (Al). Wood of Hæmatoxylon campechianum.

Notes.—Azo Acid Blue acquires, on fading, a very red shade; Turquoise Blue 2B and Glacier Blue change to a green during the first period. Basle Blue B and Benzo Blue 3B lose their bloom of colour during the first 'fading period,' the remaining dark greyish colour being moderately fast. Direct Cotton Colours, 12, 17, 18, 23, 24, 25, change from blue to grey during the first 'fading period,' and Nos. 15, 16, and 26 to 39 all acquire a marked reddish tint. On this account these colours might almost equally well be placed among the 'very fugitive colours.'

Class III. Moderately Fast Colours. (Wool.)

The colours of this class show distinct fading at the end of the second period (August 12 to September 3, 1895), which becomes more pronounced at the end of the third period (September 3 to September 20, 1895). A pale tint remains at the end of the fourth period (September 20, 1895, to April 7, 1896), and at the end of a year's exposure the colour has entirely faded, or, at most, mere traces of colour remain.

Triphenylmethane Colours.

Wool Book X.
Mordant Colours. 1. Chrome Blue (Cr). Oxy-carboxy-tetra-methyl-diamido-di-phenyl-naphthyl-carbinol.

Wool Book IX.
Acid Colours. 3. Patent Blue A. Calcium salt of *m*-oxy- (or *m*-amido)- tetra-alkyl-diamido-triphenyl-carbinol-sulphonic acid.

" 4. Patent Blue superfine. Ditto.

" 12. Alkali Blue. Sodium salt of mono- and di-phenyl-rosaniline-mono-sulphonic acid.

" 13. Alkali Blue 6B. Sodium salt of tri-phenyl-rosaniline-mono-sulphonic acid.

" 14. Hoechst New Blue. Calcium salts of tri-methyl-tri-phenyl-*p*-rosaniline, di- and tri-sulphonic acids.

" 15. Methyl Blue MBI. Sodium salt of tri-phenyl-*p*-rosaniline-tri-sulphonic acid.

" 16. Water Blue 6B extra. Sodium salt of tri-phenyl-rosaniline-tri-sulphonic acid.

" 17. Bavarian Blue DBF. Sodium salt of diphenylamine blue-tri-sulphonic acid. S. and J. 300.

" 18. Bavarian Blue DSF. Sodium salt of diphenylamine blue-di- and tri-sulphonic acid. S. and J. 299.

" 19. Alkali Blue D. Sodium salt of diphenylamine blue-mono-sulphonic acid. S. and J. 298.

" 20. Alkali Blue R. Sodium salt of mono-phenyl-rosaniline-mono-sulphonic acid.

" 22. Soluble Blue pure. Sodium salt of tri-phenyl-rosaniline-tri-sulphonic acid.

Oxazine Colours.

Wool Book X.
Mordant Colour. 5. Gallocyanine DH (Cr). Chloride of dimethyl-phenyl-ammonium-dioxy-phenoxazine-carboxylic acid. S. and J. 340.

Wool Book IX.
Acid Colour. 35. Gallanilic Blue R. Constitution not published.

Induline Colours.

Wool Book IX.
Acid Colours. 26. Milling Blue. Sodium salt of anilido-iso-naphthyl-rosinduline-mono-sulphonic acid.

" 28. Naphthyl Blue. Sodium salt of anilido-phenyl-naphthinduline-sulphonic acid.

" 29. Naphthazine Blue. Sodium salt of tetra-methyl-diamido-dinaphthyl-diphenazonium-di-sulphonic acid.

" 30. Induline NN. Sodium salt of sulphonic acid of a Spirit Induline. S. and J. 366.

" 31. Indigen F liquid. Sodium salt of sulphonic acid of a Spirit Induline. S. and J. 365.

" 32. Induline 3B. Sodium salt of sulphonic acid of a Spirit Induline. S. and J. 366.

" 37. Fast Blue B. Sodium salt of sulphonic acid of a Spirit Induline. S. and J. 365.

Basic Colours. 22. Toluylene Blue B. Constitution not published.

" 23. Indamine Blue N. Hydrochloride of *p*-amido-phenylamido derivatives of a Spirit Induline.

" 31. Paraphenylene Blue R. Hydrochloride of amido-phenyl-induline.

" 32. Indophenine extra. Constitution not published.

" 33. Indophenine B. Constitution not published.

Azo Colours.

Wool Book IX.
Acid Colours. 38. Blue Black B. From β-naphthylamine-mono-sulphonic-acid azo-α-naphthylamine and β-naphthol-disulphonic acid R. S. and J. 134.

Acid Colours. 39. Indigo Blue powder. From toluene-azo-naphthylamine and β-naphthol-sodium-disulphonate.

Wool Book X.
Direct Cotton Colours. 5. Brilliant Sulphon Azurine R. Constitution not published.
6. Sulphon Cyanine. Constitution not published.
" 7. Sulphon Azurine. From benzidine-sulphon-disulphonic-acid, and phenyl-β-naphthylamine. S. and J. 182.
" 10. Sulphon Cyanine 3R. Constitution not published.
" 13. Brilliant Azurine 5G. From dianisidine and dioxy-naphthalene-α-mono-sulphonic acid. S. and J. 215.
" 19. Naphthyl Blue 2B. From *o*-amido-diphenylic acid, and benzoyl-amido-naphthol.
" 20. Benzo Indigo Blue. From dianisidine, α-naphthylamine, and dioxy-naphthalene-α-mono-sulphonic acid (1 : 8).
" 21. Diamine Blue Black E. From ethoxy-benzidine, β-naphthol-δ-disulphonic acid, and γ-amido-naphthol-sulphonic acid.
" 22. Blue JCR. Constitution not published.
" 40. Benzo Black Blue R. From tolidine-disazo-α-naphthylamine and α-naphthol-mono-sulphonic acid NW. S. and J. 226.
" 41. Congo Fast Blue B. Constitution not published.
" 42. Benzo Black Blue G. From benzidine-disulphonic acid-disazo-naphthylamine, and α-naphthol-mono sulphonic acid NW. S. and J. 225.
" 44. Congo Fast Blue R. Constitution not published.

Natural Colouring Matters.

Wool Book X.
Mordant Colour. Logwood (Cr). Wood of Hæmatoxylon campechianum.

NOTES.—The Patent Blues become darker during the first two fading periods. Brilliant Sulphonazurine R acquires a decided reddish tint during the later stages of fading. The Sulphocyanines and Gallocyanine DH appear to be faster than the rest of the colours placed in this class, and do not change in hue during the fading process. The fastness of the Alkali Blues is probably greater than is usually supposed to be the case. The blue given by logwood with chromium is much faster than that obtained with aluminium mordant.

CLASS IV. FAST COLOURS. (WOOL.)

The colours of this class show comparatively little fading during the first, second, and third periods. At the end of the fourth period a pale shade remains, which at the end of the year's exposure still leaves a pale tint.

Triphenylmethane Colours.

Wool Book X.
Mordant Colour. 9. Galleïn (Cr). Oxidation product of pyrogallol-phthaleïn. S. and J. 335.

Wool Book IX.
Basic Colour. 25. Gentiana Blue 6B. Hydrochloride of tri-phenyl-rosaniline.

Oxazine Colours.

Wool Book X.
Mordant Colour. 7. Gallamine Blue (Cr). Product of action of nitroso-dimethyl-aniline-hydrochloride on gallaminic acid. S. and J. 346.

Azo Colours.

Wool Book IX.
Acid Colour. 36. Naphthol Blue Black. From *p*-nitraniline, aniline, and amido-naphthol-disulphonic acid H (1 : 8).

Induline Colours.

Acid Colour. 33. Fast Blue 6B for wool. A sulphonated induline.

NOTE.—That Gentiana Blue 6B has proved to be fast is very remarkable, since the basic colours, and particularly those of the triphenylmethane group, are usually so fugitive. During the first fading period the bloom of the colour disappears, but the remaining colour fades very little even throughout the period of a whole year.

CLASS V. VERY FAST COLOURS. (WOOL.)

The colours of this class show a very gradual fading during the different periods, and even after a year's exposure a moderately good colour remains.

Oxazine Colours.

Wool Book X.
Mordant Colour. 6. Cœlestine Blue B (Cr). Constitution not published.

Thiazine Colours.

Mordant Colours. 10. Brilliant Alizarin Blue R (Cr). Constitution not published. A derivative of oxy-naphtho-quinone-imide.
" 12. Brilliant Alizarin Blue G (Cr). Constitution not published.

Oxyketone Colours.

Mordant Colours. 2. Alizarin Blue WX (Cr). Di-oxy-anthraquinone-quinoline. S. and J. 255.
" 3. Alizarin Blue S powder (Cr). Sodium bisulphite compound of Alizarin Blue. S. and J. 256.
" 4. Anthracene Blue WR (Cr). Hexa-oxy-anthraquinone.
" 8. Alizarin Cyanine R (Cr). Penta-oxy-anthraquinone. S. and J. 249.
" 11. Alizarin Cyanine G (Cr). Action of ammonia on intermediate product in making Alizarin Cyanine R. S. and J. 250.
" 13. Anthracene Blue WG (Cr). Constitution not published.
" 15. Alizarin Indigo Blue SW (Cr). Sodium bisulphite compound of tetra- and penta-oxy-anthra-quinolin-quinone-sulphonic acid. S. and J. 257.
" 16. Alizarin Cyanine Black G (Cr). Constitution not published.

Natural Colouring Matters.

Direct Colour. 1. Vat Indigo Blue.

Additional Colouring Matters.

Acid Colour. 2. Prussian Blue.

NOTES.—The great fastness of the Brilliant Alizarin Blues is remarkable, since they belong to a group of colouring matters which has not hitherto furnished fast colours. The same remark applies to Cœlestine Blue, although this colour is not so fast as the foregoing. The fastness of the various Alizarin Blues (oxyketone colours) is proverbial, and along with the colours just named they may well be regarded as worthy competitors of indigo for the production of fast blues. The chief difference of behaviour of Indigo Blue and some of the Alizarin Blues is that the latter tend to acquire a reddish tint, whereas the former does not.

The remarkable fastness of Prussian Blue on wool is such that the medium blue colour experimented upon has not perceptibly faded during a whole year's exposure, and it may be justly considered as the fastest blue on wool with which we are at present acquainted; unfortunately it is sensitive to the action of alkalis.

GREEN COLOURING MATTERS.

Class I. Very Fugitive Colours. (Wool.)

Wool Book XI. Basic Colours.	1. Capri Green G. Constitution not published.
„	11. Solid Green 3 B. Zinc double chloride of dichlor-tetra-methyl-diamido-triphenyl-carbinol. S. and J. 265.
„	13. Iodine Green. Zinc double chloride of chlor-methyl-hexa-methyl-rosaniline-hydrochloride. S. and J. 284.
„	15. Methylene Green. Nitro-tetra-methyl-thionine. S. and J. 349 (foot-note).
„	18. Aldehyde Green. Quinoline derivative of rosaniline. (?). S. and J. 377.

Natural Colouring Matters.

Wool Book XI.	Lo-kav (on cotton). Chinese dyestuff derived from Rhamnus utilis.

Class II. Fugitive Colours. (Wool.)

Triphenylmethane Colours.

Wool Book XI. Acid Colours.	1. Light Green SF (yellow shade). Sodium salt of diethyl-dibenzyl-diamido-triphenyl-carbinol-tri-sulphonic acid. S. and J. 268.
„	2. Helvetia Green. Sodium salt of tetra-methyl-diamido-tri-phenyl-carbinol-mono-sulphonic acid. S. and J. 266.
	3. Light Green SF (blue shade). Sodium salt of dimethyl-dibenzyl-diamido-triphenyl-carbinol-tri-sulphonic acid. S. and J. 267.
„	4. Guinea Green BV. Sodium salt of nitro-diethyl-dibenzyl-diamido-triphenyl-carbinol-di-sulphonic acid. S. and J. 270.
„	5. Guinea Green B. Sodium salt of diethyl-dibenzyl-diamido-triphenyl-carbinol-di-sulphonic acid. S. and J. 269.
„	9. Fast Green extra. Sodium salt of tetra-methyl-dibenzyl-pseudo-rosaniline-di-sulphonic acid. S. and J. 286.
Basic Colours.	3. Methyl Green. Zinc double chloride of chlor-methyl-hexa-methyl-*p*-rosaniline-hydrochloride. S. and J. 283.
„	4. China Green cryst. Tetra-methyl-diamido-triphenyl-carbinol-oxalate. S. and J. 263.
„	5. Imperial Green cryst. Zinc double chloride of tetra-methyl-diamido-triphenylcarbinol. S. and J. 263.
„	6. Solid Green GG. Tetra-methyl-diamido-triphenyl-carbinol-sulphate. S. and J. 263.
„	9. Solid Green YYO cryst. Zinc double chloride of tetra-ethyl-diamido-triphenyl-carbinol. S. and J. 264.
„	10. Ethyl Green cryst. Tetra-ethyl-diamido-triphenyl-carbinol-sulphate. S. and J. 264.
Mordant Colours.	2. Chrome Green (Cr). Tetra-methyl-diamido-triphenyl-carbinol-carboxylic acid.

Safranine and Induline Colours.

Wool Book XI. Basic Colours.	17. Azine Green TO. Dimethyl-amido-phenyl-amido-phenyl-pheno-naphthazonium chloride. S. and J. 363.

Azo Colours.

Wool Book XI. Direct Cotton Colours.	2. Columbia Green. Constitution not published.

Class III. Moderately Fast Colours. (Wool.)

Triphenylmethane Colours.

Wool Book IX. Acid Colours.	6. Alkali Green. Sodium salt of diphenyl-diamido-triphenyl-carbinol-mono-sulphonic acid. S. and J. 271.
,,	7. Wool Green S. Sodium salt of tetra-methyl-diamido-β-oxy-naphthyl-carbinol-di-sulphonic acid.
,,	8. Milling Green. Sodium salt of tetra-methyl-dibenzyl-pseudo-rosaniline-disulphonic acid.

Azo Colours.

Wool Book X. Direct Cotton Colours.	1. Diamine Green B. From benzidine, *p*-nitro-benzene-azo-amido-naphthol-di-sulphonic acid, and phenol.
Mordant Colours.	1. Azo Green (Cr). From *m*-amido-tetra-methyl-*p*-diamido-triphenyl-methane, and salicylic acid. S. and J. 273.

Class IV. Fast Colours. (Wool.)

Wool Book X. Direct Cotton Colours.	3. Benzo Olive. Constitution not published.
Mordant Colour.	4. Diamond Green (Cr). Constitution not published.

Class V. Very Fast Colours. (Wool.)

Triphenylmethane Colours.

Wool Book X. Mordant Colours.	3. Cœruleïn (Cr). Product of the action of sulphuric acid on Galleïn. S. and J. 336.

Oxyketone Colours.

Mordant Colours.	5. Alizarin Green SW (Cr). Sodium bisulphite compounds of tri- and tetra-oxyanthraquinone-quinoline-sulphonic acids. S. and J. 258.

Quinoneoxime Colours.

Mordant Colours.	6. Dark Green (Fe). Di-quinoyl-dioxime. S. and J. 232.
,,	7. Gambine Y (Fe). β-naphtho-quinone-α-oxime. S. and J. 234.
,,	8. Gambine B (Fe). Constitution not published.
,,	9. Naphthol Green B (Fe). Ferrous sodium salt of nitroso-β-naphthol-β-mono-sulphonic acid. S. and J. 236.
,,	10. Dioxine (Fe). β-oxy-naphtho-quinone-oxime. S. and J. 235.
,,	11. Gambine R (Fe). Naphtho-quinone-oxime. S. and J. 233.

Notes.—The great fastness of the quinone-oxime colours when fixed with iron mordant is worthy of special notice. The fastness of Cœruleïn green as a Triphenylmethane Colour is also remarkable, but although Cœruleïn is usually classed as a Triphenylmethane Colour, its constitution when fully determined may cause it to be more properly placed in some other class.

Silk Patterns.

Most of the foregoing colours were also dyed on silk, and the patterns were exposed to light along with those on wool. The relative fastness of the various colours was, for the most part, the same as on wool, the differences observed being too unimportant to necessitate a special classification for silk.

The Chinese natural dyestuff Lo-kav fixed on silk with alum mordant is much faster than the same colour fixed on cotton from a soap bath. It was not found possible to apply it satisfactorily to wool.

Vat Indigo Blue is apparently less fast on silk than on wool, and on this fibre some of the Alizarin Blues, and notably the Brilliant Alizarin Blues, are much faster than Indigo Blue. As on wool, so on silk, Prussian Blue is faster to light than all other blues.

Stonesfield Slate.—Third and Final Report of the Committee, consisting of Mr. H. B. WOODWARD (*Chairman*), Mr. E. A. WALFORD (*Secretary*), *the late* Prof. A. H. GREEN, Dr. H. WOODWARD, *and* Mr. J. WINDOES, *appointed to open further sections in the neighbourhood of Stonesfield in order to show the relationship of the Stonesfield slate to the underlying and overlying strata.* (*Drawn up by* Mr. EDWIN A. WALFORD, *Secretary.*)

THE succession from the Great Oolite through the Stonesfield Slate into the Inferior Oolite as shown in the sections made by your Committee may be thus summarised :—

		Ft.	in.
Great Oolite	Surface soil, Limestone fragments with Corals, &c.	0	9
	Limestone and Marls with *Ostrea* (Oyster beds)	17	3
	Slate beds (Stonesfield Slate)	5	3
Fullonian	Fawn-coloured Limestone with lignite of carbonaceous markings (Chipping Norton Limestones) about	18	0
Inferior Oolite Series	Sandy Limestones with some Marl beds; lower limestone with vertical plant-markings (Lower Estuarine series)	11	0
	Clypeus-grit zone of *Ammonites Parkinsoni* .	13	0

(About 12 feet of Inferior Oolite strata can be made out below.)

The faulted state of the bank prevents exact measurement of the series now assumed to be Fullonian. These beds had previously been classed with the Inferior Oolite. Notwithstanding the great care taken in making a practically vertical section, a series of Great Oolite beds was found at a much lower level than the Slate. The error was indicated in the Second Report, and the greater part of beds Nos. 18 to 26 have to be excised from the list.

The additions to our knowledge consist mainly in the discovery of the strata with vertical plant-markings (evidently the equivalent of the Lower Estuarine Series of the Northamptonshire Inferior Oolite), and in the particulars given of the thickness of the higher beds of the Inferior Oolite and the Fullonian strata. Fawler, two miles distant, has been supposed to mark the virtual disappearance of the Inferior Oolite. Sir Joseph Prestwich, however, had grouped with the Inferior Oolite certain beds (14 feet 6 inches thick) which had been proved in the boring at Wytham, near Oxford;[1] and Mr. H. B. Woodward has classed with the Inferior Oolite Series 30 feet of strata proved in a boring at Witney.[2] These correlations were inferential, but the facts now brought forward give them support.

[1] *Geo. Mag.* 1876, p. 238.
[2] *Jurassic Rocks of Britain,* vol. v. 1895, p. 42.

Photographs of Geological interest in the United Kingdom.—Seventh Report of the Committee, consisting of Professor JAMES GEIKIE, (*Chairman*), Professor T. G. BONNEY, Dr. TEMPEST ANDERSON, Mr. J. E. BEDFORD, Professor W. BOYD DAWKINS, Mr. E. J. GARWOOD, Mr. J. G. GOODCHILD, Mr. WILLIAM GRAY, Professor T. M'KENNY HUGHES, Mr. ROBERT KIDSTON, Mr. A. S. REID, Mr. J. J. H. TEALL, Mr. R. H. TIDDEMAN, Mr. H. B. WOODWARD, *with* Mr. OSMOND W. JEFFS *and* Mr. W. W. WATTS (*Secretaries*). (*Drawn up by* Mr. W. W. WATTS.)

THE Committee have the honour to report that during the last year 196 photographs have been received, bringing the total number in the collection up to 1,412. A detailed list is annexed : it shows that the Committee are largely indebted to Mr. Godfrey Bingley and to Mr. W. Whitaker. The latter has sent a considerable number of photographs, many of them old ones, which it would have been difficult to obtain otherwise ; the former, in addition to a set to be specially mentioned later on, has contributed a beautiful series of views taken along the Yorkshire coast, which we trust is a first contribution to the survey of the entire coast suggested by Mr. Woodall some time ago. Mr. Bingley also sends photographs of the remarkable perched blocks about Norber, near Clapham. To these donors and to Miss Andrews, Mr. Armstrong, Mr. Atchison, Mr. Flowers, Mr. Piquet, Mr. Preston, Mr. W. Sinclair, Mr. Small, Mr. Stilgoe, Mr. A. O. Walker, and Mr. H. B. Woodward, to the Yorkshire Naturalists' Union, and to the Leeds Geological Association, the thanks of the Committee are especially due.

A summary of geographical areas represented in this year's collection and in those of former years follows. From this it will be seen that, while some counties have been surveyed by the camera in considerable detail, in others little or nothing has been done. It will be well, therefore, to direct special effort towards having the geological phenomena of these counties photographically registered.

No special attempt has been made this year to obtain prints in order to see how many would be likely to flow in without sending circulars out ; the result is apparent on an analysis of the list. But for the photographs of three contributors the number would be exceptionally small. This shows that constant effort is required to complete the collection, and it must not be relaxed if it is desired that the work should be brought to a satisfactory conclusion. Circulars must be regularly sent to the Field Clubs and Natural History Societies, and to other regular and likely contributors, a constant if small expense being undertaken by the Committee.

Not many of the photographs received this year have yet been mounted, and there are still some of the older ones which require mounting or remounting before it is possible to display the whole collection at its new home in Jermyn Street, to which the whole collection has now been sent ; the bulk of it can, however, be inspected on application at the Library at the Museum of Practical Geology at 28 Jermyn Street, S.W. The method adopted by the Committee, after much consideration, has proved to be an unqualified success, and not the least advantage is that it permits of the periodical rearrangement of the collection, which is so essential. This emphasises the necessity, often urged by the Committee, that prints should, whenever possible, be sent unmounted. The directions sent by the donors with regard to mounting are strictly adhered to, and if donors wish to mount their own prints the standard cards will always be sent them for the purpose.

—	New additions (1896)	Previous collection	Total	—	New additions (1896)	Previous collection	Total
ENGLAND—				Stafford	3	9	12
Bedford	—	—	0	Suffolk	1	—	1
Berks	—	3	3	Surrey	3	5	8
Buckingham	—	—	0	Sussex	—	—	0
Cambridge	—	—	0	Warwick	1	6	7
Cheshire	—	44	44	Westmorland	—	5	5
Cornwall	—	43	43	Wiltshire	—	5	5
Cumberland	—	7	7	Worcester	—	2	2
Derby	2	24	26	Yorkshire	66	228	294
Devon	18	47	65				
Dorset	3	44	47		163	690	53
Durham	—	16	16				
Essex	1	—	1				
Gloucester	1	1	2	WALES—			
Hants	—	5	5	Carnarvon	9	42	51
Hereford	—	—	0	Denbigh	—	18	18
Hertford	—	7	7	Flint	—	1	1
Huntingdon	—	—	0	Glamorgan	—	9	9
Kent	6	33	39	Merioneth	2	10	12
Lancashire	2	40	42	Montgomery	2	4	6
Leicester	49	37	86				
Lincoln	—	—	0		13	84	97
Middlesex	—	3	3				
Monmouth	—	1	1				
Norfolk	1	2	3	CHANNEL ISLANDS	2	9	11
Northampton	—	—	0	ISLE OF MAN	—	23	23
Northumberland	—	28	28	SCOTLAND	14	139	153
Nottingham	—	2	2	IRELAND	1	236	237
Oxford	1	—	1	ROCK-STRUCTURES, &c.	3	35	38
Rutland	—	—	0				
Shropshire	5	21	26				
Somerset	—	22	22		196	1216	1412

A scheme for the rearrangement of the collection according to counties and a catalogue similarly arranged have been drawn up. This system seems the best under the circumstances, and it is hoped that the rearrangement will be an accomplished fact by next year. When once this is completed the clerical work will become much lighter.

The Secretaries venture to ask once again that such explanatory details as can be given with each photograph should be written on the form supplied for the purpose, not only to save the labour of transcription, but to prevent errors which unavoidably creep in.

The work begun last year in giving references to the publications in which any photographs from the collection have been published has not proceeded very far, but one of Mr. Bingley's sets has been reproduced in illustration of a paper by Mr. Tate on the Dry Valleys of Yorkshire; the set of photographs is included in the following list, and the Yorkshire Geological and Polytechnic Society has kindly sent a copy of the number of its 'Proceedings' containing the paper. The Secretaries will be glad to receive not only prints of photographs so reproduced, but, if possible, a copy of the plates or publication containing the reproduction of them.

Since the Committee began their labours a number of bodies, such as the Geologists' Association and the South-Eastern Union of Natural History Societies, have undertaken the acquisition of photographs of geological interest, and in some cases, as in Warwickshire, a complete photographic survey, including that of geological phenomena, is in progress. It is desirable that duplicate prints of such photographs as are of geological interest should find their way into the central and parent collection.

The Committee ask for their reappointment, with a small grant to enable them to make a special effort to reach those localities which have no at present contributed much or at all to the collection.

SEVENTH LIST OF GEOLOGICAL PHOTOGRAPHS.

(TO AUGUST 1896.)

NOTE.—This list contains the subjects of geological photographs, copies of which have been received by the Secretaries of the Committee since the publication of the last report. Photographers are asked to affix the registered numbers, as given below, to their negatives for convenience of future reference. Their own numbers, where given, are added, in the same order, to enable them to do so.

Copies of photographs desired can, in most instances, be obtained from the photographer direct, or from the officers of the Local Society under whose auspices the views were taken.

The price at which copies may be obtained depends on the size of the print and on local circumstances, over which the Committee have no control.

The Committee find it necessary to reiterate the fact that they *do not assume the copyright of any photographs* included in this list. Inquiries respecting photographs, and applications for permission to reproduce them, should *not* be addressed to the Committee, but to the photographers direct.

Copies of photographs should in future be sent to W. W. WATTS, 28 Jermyn Street, London, S.W.

[*E signifies enlargements.*]

ENGLAND.

BERKSHIRE.—*See Surrey, No.* 1325.

DERBYSHIRE.—*Photographed by* Mr. POULTON. (*Per* W. WHITAKER, *F.R.S.*) *Size* $3\frac{1}{4} \times 2\frac{1}{2}$ *inches.*

Regd. No.		
1234	Mam Tor . . .	Face of landslip in Yoredale Beds.

Photographed by E. COOK, *Lynn.* (*Per* W. WHITAKER.)
Size $4\frac{1}{2} \times 3\frac{1}{2}$ *inches.*

Regd. No.		
1235	Eagle Stone, Baslow .	Sandstone on Moorland Plateau 850 feet above sea.

DEVONSHIRE.—*Photographed by* Sir HENRY TRUEMAN WOOD. (*Per* W. WHITAKER.) *Size* $6\frac{1}{2} \times 4\frac{1}{2}$ *inches.*

1236, 1237	White Cliff, Seaton, and Beer Head	Chalk, Upper Greensand, and New Red Marl.
1238	Beer	Chalk.
1239–1242	Beer Quarries . .	Middle Chalk.
1243	Haven Cliff, Mouth of river Axe	Chalk, Greensand, and New Red Marl.
1244–1247	The Dowlands Landslip .	Chalk and Greensand.
1248	The Bindon Landslip .	Chalk.

Photographed by Mr. BRADNEE, *Torquay.* (*Per* W. WHITAKER.)
Size $3\frac{1}{2} \times 2\frac{1}{2}$ *inches.*

1249	Torwood Place, Torquay	Surface creep in slate.

Photographed by W. SHERLOCK, *Budleigh Salterton.* (*Per* W. WHITAKER.)
Size $4 \times 3\frac{1}{2}$ *inches.*

1250, 1251	Cliff W. of Budleigh Salterton	New Red Sandstone and Conglomerate.

Photographed by F. M. GOOD, *London.* (*Per* W. WHITAKER.)
Size $7 \times 4\frac{1}{4}$ *inches.*

1252	Valley of Rocks, Lynton	Weathering of Devonian Rocks.

Photographed by T. TEDRAKE, *Bideford.* (*Per* W. WHITAKER.)
Size $7 \times 4\frac{1}{2}$ *inches.*

1253	Westward Ho! . .	The Pebble Ridge.

DORSETSHIRE.—*Photographed by* A. K. C. SWANNY. (*Per* W. WHITAKER.)
Size 4×3 *inches.*

1254	Cliff at Lyme Regis .	Lias.

(*Per* W. WHITAKER.) *Size* $5 \times 3\frac{1}{2}$ *inches.*

1255	Cliff between Studland and Swanage	Chalk cliff and stacks.

(*Per* H. B. WOODWARD, *F.R.S.*) *Size* $8 \times 4\frac{1}{2}$ *inches.*

1256	Portisham, near Weymouth	Trunk of a fossil tree.

ESSEX.—*Photographed by* H. W. MONCKTON, *F.G.S.*, 10 *King's Bench Walk, Temple.* *Size* $4\frac{1}{4} \times 3\frac{1}{4}$ *inches.*

1257	Walthamstow . .	Pebble with *Ostrea Budleighensis* from gravel.

GLOUCESTERSHIRE.—*Photographed by* P. L. SMITH, *Stonehouse.* (*Per* W. WHITAKER.) *Size* $6\frac{1}{4} \times 4\frac{1}{4}$ *inches.*

1258	Garden Cliff, Westbury-on-Severn	Rhœtic Beds.

KENT.—*Photographed by* G. DOWKER. (*Per* W. WHITAKER.)
Size $4\frac{1}{4} \times 3\frac{1}{4}$ *inches.*

Regd. No.		
1259	Coast W. of Reculvers .	London Clay.
1260	Coast E. from Oldhaven Gap	" "

Photographed by W. T. FLOWERS, 4 *Norfolk Street, Mile End, London.*
Size 6×4 inches.

1226	High Rocks Lane, Tunbridge Wells	Honeycombing in Tunbridge Wells Sand.
1227	Happy Valley, Rusthall Common, Tunbridge Wells	" " " "

Photographed by MR. PERRY, *Folkestone.* (*Per* H. E. STILGOE, *C.E.*, *and* A. R. BOWLES, *M.Inst.C.E.*) *Size* 12×10 *inches.*

1394	(4) Cliffs E. of Folkestone Harbour.	Chalk.
1395	(5) Cliffs E. of Folkestone Harbour (continuation) Copt Point.	Chalk and Gault.

LANCASHIRE.—*Photographed by* R. H. TIDDEMAN, *M.A.*, 28 *Jermyn Street, S.W.* (*Per* W. WHITAKER.) *Size* $6 \times 4\frac{1}{2}$ *inches.*

1261	(A3). Burnley . .	Sands and gravels between Till.
1228		Ripple-marks and worm-tracks in Lancashire Fly-rock.

LEICESTERSHIRE.—*Photographed by* W. W. WATTS, 28 *Jermyn Street, S.W.*
Size $4\frac{1}{4} \times 3\frac{1}{4}$ *inches.*

1262, 1263	(188, 189) Brazil Wood . .	Contact of granite dyke with mica-hornfels.
1264, 1265	(192, 193) Sheet Hedges Quarry, Groby	Syenite overlaid by New Red Marl.
1266, 1267	(194, 195) Groby Quarry . .	" " "
1268, 1269	(196, 197) The Brand, near Woodhouse Eaves	Conglomerates and grits of 'Brand Series.'
1270, 1271	(198, 199) Slate Quarry, north part of Swithland Wood	Ancient valley filled with New Red Marl.
1272–1275	(200–203) Bradgate Park . .	The Slate Agglomerate.
1276	(204) The Hanging Rocks, Woodhouse Eaves	Triassic valley in slate quarry.
1277, 1278	(205, 206) The Hanging Rocks, Woodhouse Eaves	Structures in slate.
1279, 1280	(207, 208) The Hanging Rocks, Woodhouse Eaves	Crags formed by ash beds.
1281	(209) The Hanging Rocks, Woodhouse Eaves	The Slate Agglomerate.
1282	(210) Beacon Hill, Charnwood .	Crag of hornstone.
1283	(212) Broombriggs . . .	'Plagioclinal' crags of hornstone.
1284	(213) Newhurst Quarry, Charnwood	Syenite unconformably covered by New Red Marl.
1285	(214) Newhurst Quarry, Charnwood	Contact of syenite with hornstone.
1286	(217) The Hanging Stone, Charnwood Lodge	Volcanic Agglomerate.

Regd. No.		
1287, 1288	(218, 219) Crags in Drive, Charnwood Lodge	Volcanic Agglomerate.
1289	(221) Crag near Peldar Tor . .	,, ,,
1290	(222) Quarry at Peldar Tor . .	Crush planes in porphyroid.
1291, 1292	(223, 225) Bardon Quarry . .	Trias unconformity.
1293	(224) ,, ,, . .	Nodular rock?
1294, 1295	(226, 227) ,, ,, . .	Crush plane in porphyroid, &c.
1296	(228) Quarry at Rice Rocks, near Shaw Lane	Ripple jointing in hornstone.
1297, 1298	(229, 230) Markfield Quarry .	Structure planes in syenite.
1299–1301	(231–233) Altar Stones, Markfield	The Slate Agglomerate.
1302	(235) Short Buck Hill, near Nanpantan	Coarse and fine ash beds.
1303, 1304	(237, 238) Blackbrook, near Sheepshed	Characteristic scenery in the Blackbrook series.
1305–1308	(241–244) High Sharpley . .	Nodular porphyroid.
1309	(246) Ives Head	Apparent escarpment.
1310	(247) The Pillar Rock, Benscliffe .	The Felsitic Agglomerate.

NORFOLK.—*Photographed by* G. BARROW, *F.G.S.*, 28 *Jermyn Street, S.W.* (*Per* W. WHITAKER.) *Size* 6 × 4 *inches.*

1313	Hunstanton Cliff . .	White Chalk, Red Chalk, and Carstone.

OXFORDSHIRE.—*Photographed by* T. CODRINGTON, *C.E.*, *F.G.S.* (*Per* W. WHITAKER.) *Size* 3 × 3 *inches.*

1314	Railway-cutting, Littlemore	Coral Rag and Calcareous Grit.

SHROPSHIRE.—*Photographed by* H. PRESTON, *Grantham.* *Size* 4¼ × 3¼ *inches.*

1315	The Wrekin . . .	Uriconian Rocks and Carboniferous Limestone escarpment.
1316	Buildwas . . .	Mounds of Glacial Gravel.
1317	Comley, near The Lawley	The *Olenellus* Beds.
1318	Section on the Onny River	Junction of Ordovician and Silurian Rocks.
1319	Weo Edge, near Craven Arms	Escarpment of Aymestry Limestone.

STAFFORDSHIRE.—*Photographed by* A. A. ARMSTONG, M.A., *Denstone College, Staffordshire.* *Size* 6 × 4¼ *inches.*

320-1322	The Peakstones Rock, near Alton Towers	Outlier of Bunter Sandstone partly cemented by sulphate of barium.

SUFFOLK.—*Photographed by* T. C. PARTRIDGE, *Sudbury.* (*Per* W. WHITAKER.) *Size* 6 × 4 *inches.*

1323	Section at Sudbury .	Boulder Clay and contorted Red Crag.

SURREY.—*Photographed by* H. W. MONCKTON, *F.G.S.*, 10 *King's Bench Walk, Temple.* *Size* 4¼ × 3¼ *inches.*

1324	Hills S.E. of Farnham .	Stratified gravel.
1325	Localities in Surrey and Berkshire	Five boulders of quartz and quartzite.

Photographed by G. T. ATCHISON, *Corndon, Sutton, Surrey.* *Size* 4¼ × 3¼ *inches.*

1326	(B 35) Hollow Lane, between Wotton and Abinger	Road cutting in Hythe Beds.

WARWICKSHIRE.—*Photographed for* J. D. PAUL, *F.G.S.*, *Knighton Drive, Leicester.* (*Per* W. WHITAKER.) *Size* 8 × 6 *inches.*

Regd. No.		
1327	Newbold Lime and Cement Works, Rugby	Lias limestone, contorted.

YORKSHIRE.—*Photographed by* E. COOK, *Lynn.* (*Per* W. WHITAKER.) *Size* 6 × 4 *inches.*

1328	Filey	Cliffs of Boulder Clay.

Photographed by GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* (*Per* YORKSHIRE NATURALISTS' UNION AND LEEDS GEOLOGICAL ASSOCIATION.) *Size* $6\frac{1}{4} \times 4\frac{1}{4}$ *inches.*

1329–1331	(3752, 4, 7) Flamborough Head .	Cliff sections of Chalk.
1332	(3761) " " .	Arch rock, Chalk.
1333	(3783) Selwick Bay . . .	Pillar rock of Chalk ('Eve').
1334–1336	(3785, 6, 7) Selwick Bay . .	Caves in Chalk.
1337	(3788) " " . .	Stack of Chalk.
1338, 1339	(3789, 90) " " . .	Cliffs of Chalk.
1340	(3791) " " . .	'High stacks,' Chalk.
1341	(3793) Flamborough Head, North Landing	Cliffs of Chalk.
1342, 1343	(3801, 2) Speeton Cliff . . .	Chalk and Neocomian Rocks.
1344–1347	(3739, 42, 3, 3832) Filey Cliffs .	Boulder Clay on Corallian Rocks.
1348, 1349	(3815, 6) N.E. side of Carr Naze, Filey	Coralline Oolite and Calcareous Grits.
1350, 1351	(3829, 30) Filey Cliffs . . .	" " "
1352	(3746) The Wyke, Gristhorpe Bay	Calcareous Grit and Oxford Clay.
1353, 1354	(3744 and *a*) Gristhorpe Cliff .	" " "
1355–1358	(3822, 5, 6, 7) Carnelian Bay, near Scarborough	Estuarine Series of the Inferior Oolite.
1359, 1360	(3823, 4) Carnelian Bay, near Scarborough	Estuarine Series and Scarborough Limestone.
1361	(3329) Gannister Quarry, Headingley, Leeds	Fault in Coal Measures.
1362	(3491) Kilnsey Crag, Upper Wharfdale	Carboniferous Limestone.
1363	(3737) Banks of river Ure, Ripon Parks	Contorted beds of gypsum.
1364	(3499) Malham Tarn . . .	Carboniferous Limestone on Silurian Rock.
1365	(3500) The Water Sinks, Malham	River passing into underground channel.
1366, 1367	(3501, 2) Comb Scar, Malham .	Gorge in Carboniferous Limestone (dry).
1368, 1369	(3503, 4) " " .	" " "
1370	(3506) Dry Waterfall, Malham	Carboniferous Limestone (dry valley).
1371, 1372	(3507, 8) Looking north from the foot of Comb Scar .	Dry river bed in Carboniferous Limestone.
1373	(3505) From summit of Comb Scar	Dry river bed.
1374	(3509) Cavern at foot of Malham Cove	'Source' of river Aire.

Size 4 × 3 *inches.*

1375–1387	(3502–14) Norber, near Clapham .	Boulders of Silurian Rock perched on Carboniferous Limestone.
1388–1391	(3716–8, 20) " " .	Boulders of Silurian Rock perched on Carboniferous Limestone.
1392	(3715) " " .	Boulder of Carboniferous Limestone.
1393	(3721) " " .	Escarpment and screes of Mountain Limestone.

CHANNEL ISLANDS.—*Photographed by* G. A. PIQUET, 68 *New St. John's Road, Jersey. Size* 8 × 6 *inches.*

Regd. No.		
1406	Portelet, St. Brelade's, Jersey	Raised sea beach.
1407	Cave, near Grand Becquet, Jersey	Sea-worn boulders in cave.

WALES.

CARNARVONSHIRE.—*Photographed by* G. T. ATCHISON, *Corndon, Sutton, Surrey. Size* $4\frac{1}{4} \times 3\frac{1}{4}$ *inches.*

1231	(D. 42) View from near Pen-y-Gwryd, Snowdon	Moel Hebog and Yr Aran in the background; scenery amongst Bala volcanic rocks.
1229	(D. 46) Upper lake in Cwm Glas, Snowdon	Rock barrier.

Size $7\frac{1}{2} \times 5\frac{1}{2}$ *inches.* (*E*)

1230	(D. 45) Clogwyn-y-Person, Cwm Glas, Snowdon	Bala rhyolites and ashes.

Size $6\frac{1}{2} \times 4\frac{1}{2}$ *inches.* (*E*)

1232	(D. 16) The Black Rock E. of Criccieth	Tremadoc Rocks, with sea-caves.

Photographed by A. O. WALKER, *F.G.S., Nant-y-Glyn, Colwyn Bay. Size* 6 × 4 *inches.*

1400–1404	(1, 2, 3, 4, 4*a*) Sand-pit, Coed Pella Road, Colwyn Bay	Drift sand and gravel with fragments of marine shells in them.

MONTGOMERYSHIRE.—*Photographed by* H. PRESTON, *The Waterworks, Grantham. Size* $4\frac{1}{4} \times 3\frac{1}{4}$ *inches.*

1311, 1312	Corndon . . .	The laccolite and its sole.

MERIONETH.—*Photographed by* G. T. ATCHISON, *Corndon, Sutton, Surrey. Size* $4\frac{1}{4} \times 3$ *inches.*

1233	(D. 33) Near Rhinog Fawr	The Harlech Grits.

Photographed by LAURENCE SMALL, B.A., 60 *Brown Road, Bootle. Size* $6 \times 4\frac{1}{2}$ *inches.*

1405	Barmouth, E. of St. John's Church	Glacial grooves.

SCOTLAND.

INVERNESS.—*Photographed by* A. EVELYN BARNARD *and* Miss J. BARNARD, 36 *Hamilton Road, Highbury, London, N.* (*Per* H. B. WOODWARD, *F.R.S.*) *Size* $6 \times 4\frac{1}{4}$ *inches.*

1217	(1) Portree Bay, Skye .	Basalt on Jurassic Rocks.
1218	(2) Quirang, Skye . .	Landslip of Basalt over Oxfordian Strata.
1219	(3) Valtos School House, Skye	Fissure in Basalt caused by landslip.
1220	(4) Valtos School House, Skye	Landslip in Basalt over Great Oolite Series.
1221	(5) Near Valtos, Skye .	Basalt sill in Great Oolite Series.
1222	(6) " " " .	" " "
1223	(7) Longfearn Cliff, Skye	Needle of Basalt.
1224	(8) " " "	" "

Photographed by the REV. H. W. WOODWARD, *Zanzibar.* (*Per* H. B. WOODWARD.) *Size* $5\frac{1}{2} \times 4\frac{1}{2}$ *inches.*

Regd. No.		
1225	(9) Inver Burn, Raasay	Sandstones of Inferior Oolite age.

FIFE.—*Photographed by* GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* (*Per* YORKSHIRE NATURALISTS' UNION AND LEEDS GEOLOGICAL ASSOCIATION.) *Size* $6 \times 4\frac{1}{4}$ *inches.*

1396	(3597) The Spindle Rock, St. Andrew's	Radiating columns of igneous rock.

STIRLING.—*Photographed by* W. SINCLAIR, 61 *Oswald Street, Glasgow.* (*Per* GLASGOW GEOLOGICAL SOCIETY.) *Size* $6 \times 4\frac{1}{2}$ *inches.*

1409 (1), **1410** (2)	The Whaugie .	Landslip fissure in trap rock.
1411 (3), **1412** (4)	Ballagan Glen, near Strathblane	Limestone, sandstone, and shale (Carboniferous).

IRELAND.

ANTRIM.—*Photographed by* Miss M. K. ANDREWS, 12 *College Gardens, Belfast.* *Size* 12×9 *inches.* (*E*)

1408	Quarry, near Templepatrick	Intrusive rhyolite of Tertiary age.

MICROSCOPIC STRUCTURES.—*Photographed by* E. WETHERED, *F.G.S., Stroud.* *Size* $4 \times 2\frac{1}{2}$ *inches.*

1397, **1398**, **1399**	The Streatham boring	Three slides of oolitic rock determined as Cornbrash.

APPENDIX.

REFERENCE LIST OF PHOTOGRAPHS ILLUSTRATING GEOLOGICAL PAPERS AND MEMOIRS.

Yorkshire Geological and Polytechnic Society. 'Proceedings,' Vol. XIII., Part 1, 1895. *Plates VI.–XIV. Illustrating Paper on 'The Malham Dry River Bed,'* by THOMAS TATE, *F.G.S. From Negatives by* GODFREY BINGLEY.

1364	Malham Tarn, Yorkshire	Carboniferous Limestone on Silurian Rock.
1365	The Water Sinks, Malham	River passing into underground channel.
1367	Comb Scar, Malham .	Gorge in Carboniferous Limestone.
1368	,, ,, .	,, ,, ,,
1370	Dry Waterfall, Malham	Dry valley in Carboniferous Limestone.
1372	From foot of Comb Scar	Dry river ,, ,,
1373	From summit of Comb Scar	,, ,, ,,
1109	Malham Cove . . .	Carboniferous Limestone.
1374	Cavern at foot of Malham Cove	'Source' of river Aire.

'*Memoir on the Jurassic Rocks of Great Britain,' Vol. V. By* H. B. WOODWARD, *F.R.S.* (*Fig.* 133.)

1256	Portisham, near Weymouth, Dorset	Trunk of a fossil tree.

Erratic Blocks of the British Isles.—First Report of the Committee, consisting of Professor E. HULL (*Chairman*), Professor T. G. BONNEY, Mr. P. F. KENDALL (*Secretary*), Mr. C. E. DE RANCE, Professor W. J. SOLLAS, Mr. R. H. TIDDEMAN, Rev. S. N. HARRISON, Mr. J. HORNE, *and* Mr. DUGALD BELL. (*Drawn up by the Secretary.*)

THE Committee were reconstituted at the Ipswich meeting of the Association, so that the erratics of the whole of the British Isles now come within their purview. The Scottish Corresponding Societies have been invited to aid in devising a scheme of organisation by which the desired end—the collection of significant facts regarding the distribution of ice-borne blocks—may most speedily and with the least waste of power be attained. Several Societies have made a favourable response, and it is hoped that before the presentation of the next report a considerable body of evidence will have been collected.

In England the work of organisation has been advanced a notable way by the formation of a boulder committee by the Lincolnshire Naturalists' Union on similar lines to that which has done, and is doing, such valuable systematic work in Yorkshire. The Rev. W. Tuckwell has accepted the secretaryship of the new organisation, and his well-known energy and enthusiasm are guarantees that the work will be carried on persistently and thoroughly. The proximity of the active sub-committee working in the East Riding of Yorkshire has been a great advantage to the Lincolnshire Committee, who have had the advantage of the advice and active co-operation in the field of several experienced boulder hunters from Yorkshire.

Mr. Tuckwell's first report records 102 boulders. These include many examples of characteristic Scandinavian rocks, such as the well-known Augite-syenite and Rhomb-porphyry. One example of the former rock, observed near Louth, is the largest specimen yet found in England, and it is satisfactory to learn that Mr. Tuckwell has taken effective measures for its preservation. Another notable record is that of three specimens of Shap granite, the first recorded in Lincolnshire, one of which was found imbedded in undisturbed glacial deposits at South Ferriby, while another was found built into a tenth-century Saxon wall at Irby.

The Yorkshire Boulder Committee have again done most excellent work, the value of which is enhanced by care displayed by the secretary, Mr. Tate, to investigate personally all boulders of more common interest or novelty, and by the petrological knowledge which he brings to the work.

The reports sent in from the East Riding are an enumeration of no fewer than 2,600 boulders, and complete an exhaustive catalogue of all the boulders at present visible in the cliffs or on the beach along the whole coast-line of Holderness from Spurn Point to Bridlington, a distance of 36 miles. Among these were many examples of Augite-syenite and Rhomb-porphyry.

A report by Messrs. Herbert Muff and Thomas Sheppard brings out the extraordinary prevalence of boulders of Shap granite at Robin Hood's Bay where no fewer than 81, varying from a few inches up to

3 feet 6 inches in diameter, were observed. In contrast to this, Messrs. Davis and Stather report that among the 133 large boulders (1 foot and upward in diameter) and thousands of smaller ones observed by them on four miles of coast between Redcar and Saltburn, not a single Shap boulder was seen, nor any Augite-syenite nor Rhomb-porphyry.

A very valuable series of records come from the valley of the Yorkshire Calder, the boulders consisting, as in previous reports, of Lake District igneous rocks and some from the Carboniferous series; but the special interest of those now reported is that the route taken by the stones is now indicated by the completion of a continuous train of erratics over the Walsden Pass at Summit and thence to Todmorden.

The anomalous and isolated group found at Barnsley is reported upon. The constituent boulders include basalts and granites of types not recognised elsewhere in the district, and the group must be regarded with a good deal of suspicion, especially in view of the fact that it is in close proximity to a navigable canal.

Reports are also furnished of the boulders in a remarkable detached patch of Boulder-clay at Balby, near Doncaster. At this place was found a handsome boulder of Shap granite, the most southerly example yet observed on the eastern side of the Pennine Chain.

It is gratifying to learn that, at the request of the Doncaster Natural History and Microscopical Society, this interesting boulder and another of Lake District andesite have been placed by the Corporation of Doncaster in the Free Library. The Yorkshire records conclude with a report upon the stones found in the great crescentic drift-ridges which run across the Vale of York respectively at Escrick and at York itself. In both of these boulders of Shap granite were found.

In Lancashire but little has been done during the past year; but Mr. J. W. Stather, of Hull, found a large pebble of Shap granite on the shores of the Mersey at the Dingle, near Liverpool. Mr. Lomas found at the same place a drusy granite resembling that of Goat Fell, Arran. The latter is the first example found in England; but the Rev. S. N. Harrison sends records of both the granites of Arran and a 'felspar-porphyry' of the same island, from the Isle of Man.

The Belfast Field naturalists continue their work in the north-east of Ireland. It is interesting to observe that *Foraminifera* are found in many of the Boulder-clays of their district. Pebbles of the Riebeckite Eurite of Ailsa Craig are very abundant in the Boulder-clays near Belfast.

ENGLAND.

Cheshire.

Reported by Mr. J. Lomas, *A.R.C.S., per Glacialists' Association.*

Between Raby and Willaston, Mid Wirral—

3 Scottish granites; 3 Silurian grits; 1 Diabase; 1 Lake District andesite; 1 Buttermere grano-phyre.

Near Willaston Mill—

1 Scottish granite; 1 L.D. andesite.

Cross roads near Willaston Hall—

1 Silurian grit.

Striated Surfaces.

On roadside ½ mile from Raby towards Willaston—

Planed surface of sandstones striated from N. 40° W. (true). Two other patches near with the same direction of striation.

Well Lane, Rock Ferry—

On roadside, planed surface covered with boulder-clay, striated from N. 25° W.

LANCASHIRE.

Reported by Mr. J. LOMAS, *A.R.C.S., per Glacialists' Association.*

Liverpool, the Dingle Shore—

1 granite, from Goat Fell, Arran.

Reported by Mr. W. PARKER, *per Glacialists' Association.*

Facit near Rochdale. Out of sewer-excavation opposite Co-operative Stores—

*1 Eskdale granite.

Near Long Acres Farm—

*1 quartz syenite; *2 Buttermere granophyre.
1 local sandstone; 1 sandstone; *1 andesite; 1 rhyolite.

* All these are stated to have lain with their long axes N.W.-S.E.

Robin Hood Clough—

1 rhyolite.

Whitworth. In sewer-cutting, near Whitworth Manufacturing Company's Mills—

1 Carboniferous Limestone with coral (? Syringopora).

LINCOLNSHIRE.[1]

Communicated by the Lincolnshire Boulder Committee.
Reported by the Rev. W. TUCKWELL, *M.A.*

Waltham—

1 basalt (Whin Sill); 1 basalt.

Louth—

The 'Blue Stone' basalt; 1 basalt; 1 light red granite.

Louth, chalkpit north of church—Large heap of boulders, averaging 9 inches diameter, included the following varieties:—

Rhomb-porphyry; augite-syenite; lamprophyre; diorite; gneiss; pink granite; white granite; quartz-porphyry, Carboniferous Limestone, and Lias.

Louth, brickyard on Road to Elkington—Boulders and pebbles in heaps include the following:—

Rhomb-porphyry; augite-syenite; porphyrite (? Fredericsvaarn); halleflinta; mica schist; schist; black flint; green-coated flint; porphyrite; fine-grained white granite; quartz-porphyry; diorite; basalt; vesicular lava; conglomerate (with pebbles of quartz-porphyry); Millstone Grit; Carboniferous Limestone; Carboniferous sandstone (gannister); ironstone (? Liassic); Septarian nodule (? Kimeridge clay).

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[1] This report will be published *in extenso* in the *Naturalist.*

Gate of Thorp Hall close to Louth on Lincoln Road—

1 augite-syenite; 1 basalt.

Roadside nearer to Louth—

1 gannister.

Stream, side of Hubbard's Valley, Louth—

1 Jurassic sandstone.

Ingram's chalk-pit, Louth—

1 basalt.

Mr. Cheetham's lawn, Eastgate, Louth—

1 red granite (taken from railway cutting).

Cemetery, Louth—

1 foliated red granite.

Hallington, rifle range—

Ditch in hollow of hill filled in with pebbles of sandstone and granite.

Benniworth, near carpenter's shop—

1 augite-syenite.

By farmyard gate—

1 Secondary sandstone.

South Elkington, near Old Pinfold—

1 bluish granite.

South Ferriby, from Boulder-clay Cliff—

2 Rhomb-porphyries; 1 quartz-porphyry; 3 basalts; 1 Carboniferous Limestone; 1 black flint: 1 Shap granite.

Side of horse-pond—

2 basalts; 1 gneiss; 1 schist.

Humber Bank, in front of Hall.—A large number of boulders averaging a foot in diameter, amongst which are—

Red granite; Carboniferous Limestone; basalt; sandstone.

Corner of lane opposite Mount Pleasant—

Carboniferous Limestone with encrinite stems; 1 sandstone.

In Mr. Havercroft's stackyard—

2 basalts; 1 basalt with small white amygdules; 2 Secondary sandstones, one with small flakes of white mica; 1 porphyrite (weathered); 1 Primary sandstone; 1 red granite.

In Mr. Havercroft's farmyard—

2 soft limestones (? Oolitic); 2 basalts; 1 basalt (green); 1 basalt, coarse-grained; 1 Carboniferous sandstone (gannister with rootlets); 1 Millstone Grit; 1 porphyrite.

Barton, Mr. Milsom's Mill—

1 Shap granite.

Finger-post, corner of South Ferriby Road—

1 granite (?).

Lamp-post outside Barton Station—

2 basalts.

Corner of Coach and Horses Yard—
1 basalt.

Stewton, conspicuous in a field.
1 basalt.

Ludborough, Mr. Marshall's Farmyard—
1 basalt.

Brigg, Howsham, taken out of Boulder-clay—
1 Spilsby sandstone.

Irby, in Rectory Garden—
1 Shap granite (found built into a Saxon tenth-century wall); 1 basalt; 1 Secondary sandstone; several sandstone blocks from the same old wall, mostly squared for building.

Roadside, opposite Rectory gate—
1 dolerite (?).

Roadside by Schoolroom—
1 basalt (Wesley is supposed to have preached from it).

Corner of road beyond Schoolroom—
1 red granite; 1 Secondary sandstone.

Brocklesby, few yards from Station—
1 Primary sandstone.

Chalk quarry close by Station—
1 basalt.

Gate post two fields off towards Croxton Gravel pits—
1 quartz.

Ulceby, Chase Farmyard—
1 basalt.

Kirmington—
Boulder-clay above brick works gravel-pits.

1 Rhomb-porphyry.

YORKSHIRE.[1]

Communicated by the Yorkshire Boulder Committee.
Reported by Mr. THORNTON COMBER, *M.R.C.S.*

Pickering—
Mr. Comber records in a note the results of a careful examination of the country immediately round Pickering. He found only local limestones and sandstones, which are not far distant from similar rocks *in situ*.

Reported by Mr. E. HAWKESWORTH.

Saltburn—
2 Shap granites; 2 ? Whin Sill.

Skelton Beck—
4 Whin Sill.

[1] This report will be published *in extenso* in the *Naturalist.*

Junction of Saltburn and Skelton Valleys—

1 Whin Sill.

Saltburn. On beach, south of town—

1 Shap granite.

Easington Beck—

2 Shap granites (respectively one and two miles up from coast).

Haselgrove to Marske Old Church (on beach or in Boulder-clay cliffs)—

1 Carboniferous Limestone (in clay).

11 Carboniferous Limestones (3 in cliff); 2 Yoredale Limestones (1 in cliff) 5 basalts (1 in cliff); 1 Whin Sill (in cliff).

Robin Hood's Bay, from Bay Town to South Cheek—

5 Shap granites; 2 mica schists; 4 Mountain Limestones; 1 basalt.

Reported by Mr. Herbert Muff *and* Thomas Sheppard.

Robin Hood's Bay—

81 Shap granites; and a large number of other boulders, including the following rocks:—Pink granite; white granite; gneiss (one being *in situ* in boulder-clay just north of Mill Beck); Augen gneiss; schists; quartz porphyry of Armboth Dyke; Dalbeattie granite; basalt (some were seen *in situ* in Boulder-clay); Rhomb-porphyry (many examples); quartz porphyry; porphyrite, some resembling those of Fredericsvaarn; augite syenite (Laurvikite of Brögger); Carboniferous Limestone (many in Boulder-clay); Millstone Grit (2 in Boulder-clay); Brockram; Magnesian Limestone, including the botryoidal variety from Roker; Triassic Sandstone (in Boulder-clay); gypsum (in Boulder-clay); Liassic shale (in Boulder-clay); Oolitic rocks, chiefly 'Dogger' (in Boulder-clay); black flints (in clay).

Reported by Mr. Robert Law, *F.G.S.*

Calder Valley—Hawks Clough, altitude 300 feet—

1 calcite veinstone; 1 Silurian grit; 1 pink quartzite.

Mytholmroyd, altitude 300 feet—

1 Muncaster (Eskdale) granite; 1 Buttermere granophyre; 1 gneiss (?); 1 rhyolite; 1 quartz andesite; 1 felsite; 1 volcanic tuff.

Brearly—

1 coarse granite; 1 Buttermere granophyre.

Upper Foot—

1 andesite; 1 rhyolite.

Branton—

1 granite.

High Lee, altitude 600 feet.

1 vein quartz (a pebble).

(All the above were collected by Mr. Thomas Broadbent, of Vicarage, Sowerby.)

Long Lee Quarry—

1 Ennerdale granophyre; 2 Buttermere granophyre; 2 volcanic ash; 1 garnetiferous ash; 1 pink rhyolite; 1 Borrowdale andesite; 1 porphyrite; 2 Eskdale granite; 1 Muncaster granite.

Stonehouse Farm—

1 granite (built in a wall).

Far Hollingworth—

1 Buttermere granophyre; 2 granites.

Winter-but Lee—

3 granites; 1 quartzite.

Todmorden, Milwood—

1 Felspar porphyry.

Reported by Mr. HENRY WHITEHEAD.

Blackstone Edge—

1 Borrowdale ash.

Reported by Mr. T. SALTONSTALL.

Mytholmroyd—

Buttermere granophyre; Eskdale granite; old rhyolites; Borrowdale andesites; some local rocks.

Reported by Rev. W. LOWER CARTER, *M.A.*

Battye Ford, Mirfield—

10 Borrowdale andesites; 2 Buttermere granophyres; 5 old rhyolites; 4 Eskdale granites; 3 Ennerdale granophyre; 1 felspar porphyry; 1 granite (not from Lake Country); 1 Carboniferous grit.

Reported by Mr. W. HEMINGWAY.

Dearne Valley, Old Mill Wharf, alt. 170–190 *feet.*

1 gneissose granite; 1 coarse grey granite; 3 felspar porphyries (1 vesicular); 1 old rhyolite; 2 basalts; 1 Mountain Limestone.

Reported by Mr. J. H. HOWARTH, *F.G.S.*

Bowland—

1 Borrowdale andesite ['may be an errant erratic brought by the Preston Waterworks navvies'—R. H. Tiddeman].

Reported by Mr. W. CUDWORTH.

Bradford, Lister Lane, near Peel Park—

Boulder-clay containing Mountain Limestone boulders.

Reported by Mr. J. H. LOFTHOUSE.

Harrogate. Excavation in Station Square—

Boulder of Millstone Grit in clay.

Reported by Mr. H. H. CORBETT *and* Mr. P. F. KENDALL, *F.G.S.*

Doncaster, Balby Brickyard (Doncaster Brick Company)—

In hard, unstratified Boulder-clay the following stones occur in order of prevalence, generally well-striated:—Magnesian Limestone; Coal-measure sandstone, ironstone, and shale with cannel and other coal; Millstone Grit; Carboniferous Limestone, chert, fibrous gypsum; Bunter quartzite; red and green poikilitic sandstone, some with salt pseudomorphs and ripple marks; Lake district andesites and andesitic ashes; 1 quartz-porphyry from Threlkeld; 1 red granite.

Beastall's Sandpit, Balby—

1 Shap granite; 1 andesitic agglomerate.

Bilbrough. In two gravel pits east of the village—

(In order of prevalence.) Carboniferous sandstone, limestone, and chert; Triassic Red Sandstone; Magnesian Limestone; clay-ironstone; dolerite (? Cleveland Dyke); 1 Shap granite.

Fulford. Gravel pit south of Rose Hall—

Sandstones; Carboniferous Limestone, and chert; Lake district andesites.

High Catton. Gravel pit in supposed moraine—

Carboniferous sandstone, limestone, and chert; flints; Carrock Fell diorite; Magnesian Limestone; red Triassic sandstone; Brockram; L.D. andesites; Shap granite.

Some of the stones were highly polished, apparently by wind. 108 stones taken at random proved to comprise 62 sandstones (most, if not all, Carboniferous), and 46 Carboniferous Limestone and chert.

Holtby. In railway-cutting through ridge of Boulder-clay—

Carboniferous sandstone, limestone, and chert; Carboniferous basement bed (? from Vale of Eden); Keuper marl with salt-pseudomorphs; fibrous gypsum; Red Triassic Sandstone; Lias, with Gryphæa; L.D. andesites; basalt (? Whin Sill); Magnesian Limestone; 3 Shap granite; 1 Scottish granite (? Loch Doone).

Reported by the Hull Geological Society.

All the boulders tabulated (p. 374) were *in situ* in the clay or were close to the cliffs from which they had recently fallen. For convenience of comparison the 36 miles of coast are divided into Sections A, B, C, &c., usually indicated by some well-marked natural feature or landmark. The figures in heavy type indicate the actual number of boulders noted, in each Section. The lighter figures give the relative percentage.

Reported by Mr. J. W. Stather.

North Ferriby.—In the Boulder-clay cliff on the Humber shore near North Ferriby, and on the adjacent beach, 373 boulders noted, of 8 inches and upwards in diameter, the classification of which yields the following results:—

		Per cent.
69	Carboniferous Limestones	18·5
104	Sandstones, grits, conglomerate, &c. (probably nearly all from Carboniferous or other Palæozoic rocks)	27·9
49	Sandstones, &c. (probably nearly all of Mesozoic age)	13·1
21	Lias	5·9
10	Chalk (including 4 black flints)	2·6
88	Basaltic and other eruptive rocks	23·5
32	Granites, schist, gneiss, &c.	8·5
373		100·0

Reported by Mr. Paul Davis *and* Mr. J. W. S. Stather, *F.G.S.*

Redcar to Saltburn (4 miles).—In the Boulder-clay cliffs 133 boulders a foot and upwards in diameter were observed.

Boulders noted on the Holderness Coast between Bridlington and Spurn Point.

Boulders 1 foot and upwards in diameter	A	B	C	D	E	F	G	H to O	P	Q	R	S	T	U	V		
	Spurn (Warren) to Kilnsea. J. W. Stather	Kilnsea to Easingson Lane End. J. W. Stather	Easington Lane to Cliff House. J. W. Stather	Cliff House to Out Newton. J. W. Stather	Out Newton to Nevill's Dyke. J. W. Stather	Nevill's Dyke to Hollym Mill. J. Sheppard and J. W. Stather	Hollyn Mill to Withernsea, J. Sheppard and F. F. Walton	See 1895 Report for details	Hornsea to Atwick Gap. J. W. Stather	Atwick Gap to first gap north of Atwick. J. W. Stather	First gap north of Atwick to Skipsea (Peat-bed). W. H. Crofts and T. Sheppard	Peat-bed to Skipsea Brough. W. H. Crofts and T. Sheppard	Skipsea Brough to Barmston Outfall. T. Sheppard	Barmston Outfall to Earl's Dyke. T. Sheppard	Earl's Dyke to Bridlington. T. Sheppard	Totals	Mean percentages
Origin	1 Mile	2 Miles	1½ Mile	2 Miles	1½ Mile	1 Mile	1½ Mile	14 Miles	1½ Mile	1½ Mile	1½ Mile	1½ Mile	2 Miles	2 Miles	3 Miles	36 Miles	
Carboniferous limestone	2	23	21	101	12	31	17	534	11	7	21	1	10	1	1	793	
	13·3	32·0	36·8	37·8	40·1	37·8	30·3	25·8	18·6	12·2	27·3	2·8	6·1	4·0	2·7	—	25 5
Sandstones, grits, &c., chiefly Carboniferous	1	11	3	33	6	10	5	275	12	14	29	28	95	17	26	565	—
	6·7	15·2	5·2	12·2	20·0	12·2	9·0	13·3	20·3	24·5	37·6	77·7	58·3	68·0	70·3	—	20·7
Lias	1	1	6	15	1	3	2	345	1	—	—	1	6	2	2	386	—
	6·7	1·4	10·6	5·6	3·3	3·6	3·5	16·8	1·7	—	—	2·8	3·7	8·0	5·5	—	10·4
Chalk	1	10	2	5	1	10	5	187	6	21	20	5	29	1	—	303	—
	6·7	13·9	3·5	1·9	3·3	12·2	9·0	9·0	10·2	36·8	26·0	13·9	17·8	4·0	—	—	10·1
Other Mesozoic rocks, chiefly sandstones	1	9	2	10	3	9	5	104	5	8	—	—	5	1	1	163	—
	6·7	12·5	3·5	3·7	10·0	11·0	9·0	5·0	8·5	14·3	—	—	3·1	4·0	2·7	—	5·3
Basalts and other eruptive rocks	6	15	16	77	6	19	21	554	16	6	6	1	15	1	6	765	—
	40·0	20·8	28·1	28·8	20·0	23·2	37·5	26·7	27·2	10·5	7·8	2·8	9·2	4·0	16·2	—	23·6
Granites, schist, gneiss, &c.	3	3	7	26	1	—	1	71	8	1	1	—	3	2	1	128	—
	19·9	4·2	12·3	9·1	3·3	—	1·7	3 4	13·5	1·7	1·3	—	1·8	8·0	2·7	—	4·4
Totals	15	72	57	267	30	82	56	2070	59	57	77	36	163	25	37	3103	—
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	—	100·0

NOTES.—In Sections A and B several small boulders of Augite-syenite (Lauroikite of Brögger) were observed sticking in the clay cliff; while two blocks each 15 inches in diameter, and 30 small boulders of the same rock occurred on the shore.

In Section D a boulder of Shap granite occurs on the beach, along with a fine sample of Augite-syenite 2 feet in diameter.

In Sections P and Q many crushed-out chalk boulders in the cliff. A boulder of Augite-syenite on the shore (2 ft. × 1½ ft. × 1 ft.) and several smaller specimens. Here also Rhomb-porphyry was found *in situ* in the cliff.

The relative scarcity of the harder rocks in some of the sections north of Hornsea is due, in part at any rate, to the efforts of the local road-menders.

		Per cent.
50	Carboniferous Limestones	37·6
28	Sandstones and grits of undoubtedly Carboniferous age	21·1
12	Sandstones, origin doubtful, but probably in part Carboniferous	9·0
7	Magnesian Limestone	5·2
15	Lias	11·3
21	Basaltic rocks	15·8
133		100·0

Only 3 small pebbles of granite were observed on the beach; no augite-syenite, Rhomb-porphyry, nor garnetiferous schist was observed here.

Guisbro. In Abbey Gardens—

2 Shap granite.

Sneaton, altitude 400 *feet.*

1 Shap granite.

Reported by Mr. W. S. Parrish.

Swanland, altitude 265 feet.

Red granite; basalt; gritty sandstone.

Reported by Mr. F. F. Walton, *F.G.S.*

Coniston, Holderness—

1 Fine-grained white granite.

Skirlauyh—

2 Basalts.

Preston in Holderness—

5 Basalts; 1 dolerite. The main street is paved with boulders of which the majority (75 per cent.) are basalts, and the remainder mostly Carboniferous sandstones.

Reported by Mr. W. H. Crofts.

Atwick—

1 Shap granite.

Reported by Mr. J. Nicholson.

Hornsea—

2 Carboniferous Limestones; 2 basalts; 1 dolerite.

Flinton—

1 Sandstone.

Isle of Man.

Reported by Rev. S. N. Harrison, *per Glacialists' Association.*

Bride, on the shore—

The two granites and a 'felspar-porphyry' of Arran.

IRELAND.

Reported by the Belfast Naturalists' Field Club.[1]

Further occurrences of the Ailsa Craig eurite are recorded at Kenbane Head, White Park Bay, Ballylesson, on the flanks of the Spinkwee Mountain, and in the Belfast brickyards.

Co. Down.

Ballyholme, near Bangor—

100 stones from the Boulder-clay included 55 Ordovician grit; 10 vein quartz; 12 chalk; 2 quartzite; 2 flint; 1 Riebeckite eurite; 3 Tertiary volcanic rocks from dykes in co. Down; grits from the Cantyre area; felsite, eurite, and diorite from the Clyde area; Lower Silurian (with fossils), Girvan district; metamorphosed grit, quartzite, and Old Red Sandstone from N. Antrim or Cantyre; syenite either from Pomeroy (co. Tyrone) or Scotland; granite either from co. Down or S. Scotland; flint from Ordovician rocks of co. Down; and porphyrite, co. Down. Foraminifera and shell fragments also occur.

Co. Antrim.

Divis Mountain, 1,400 *feet O.D.—*

100 stones from Boulder-clay include 52 chalk; 10 flint; 38 basalt. Foraminifera and shells also occur.

Belfast—Brickfields A, Limestone Road, near Alexandra Park—

100 stones from Boulder-clay include 77 basalt; 6 chalk; 4 flint; 3 mica schist; 3 rocks from Cushendun; 2 Upper Greensand with Belemnites; 2 Lower Lias with fossils; 2 Riebeckite eurite of Ailsa Craig; 1 white quartz. Other stones observed were:—Pegmatite vein from Girvan area; diorite and Crinoidal limestone from Clyde area.

Old Park—

From Boulder-clay: 2 Old Red Sandstone pebbles from co. Antrim; Sherd shale; Carboniferous Limestone; 2 altered Chalk; eurite from Annalong; Riebeckite eurite from Ailsa Craig; dykes (Tertiary), co. Down; felsite, N. Antrim or Clyde; 'porphyry,' Cushendall; Metamorphic rocks, N. Antrim or Derry.

Springfield—

From Boulder-clay: Ailsa Craig eurite; Mica-schist, Lias, Metamorphic rocks, co. Antrim; Old Red Sandstone, N. Antrim; Greensand, Tornamoney; gneiss, Carboniferous conglomerate, eurite, of Cultra; 'porphyry,' Cushendun; eurite, Mourne Mountains; 'Neck' dolerite and other volcanic rocks of Antrim; quartz rock, Down or Scotland.

Woodvale—

From Boulder-clay: Belemnites and Micraster from Cretaceous rocks; and rocks from Clyde area or Cantyre.

Ardoyne—

From Boulder-clay: Micraster from Cretaceous; fossiliferous Lias; Old Red Sandstone from Cushendun; quartz, Ordovician shale, and porphyrite from N. Antrim; rock from Cushleake, N. Antrim.

Annadale—

From Boulder-clay: Magnesian Limestone and Carboniferous rocks of Cultra. Pebbly quartzite; Ordovician shale; 'porphyry' of Cushendun; porphyrite and quartzite of N. Antrim or Clyde; eurite of Ailsa Craig; granite and porphyrite, Mournes or S. Scotland; 'porphyry' and felstone porphyry, Cushendall; Metamorphosed grit, N. Antrim or Cantyre.

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[1] Printed in greater detail, though unfortunately not *in extenso*, in the *Annual Report and Proceedings of the Belfast Naturalists' Field Club*, 1895–96.

Gleno, near Larne, 300 *feet O.D.*—

100 stones from Boulder-clay include 81 basalts; 6 chalk; 4 flint; 2 basalts with zeolites. An underlying bed of Boulder-clay contained large fragments of fossiliferous Lower Lias.

Ballyvoy, near Balycastle—

72 stones from Boulder-clay at Ballypatrick Glen include 33 chalk; 7 flints; 5 quartzite; 7 basalt; 19 schist. Other rock found at Ballyvoy are Carboniferous shale and chert, Ordovician shale; eurite from Tornamoney Point; 3 different rocks from Cushleake; porphyrite, Cushendun; Carboniferous conglomerate, felsite, and metamorphosed grit, N. Antrim or Cantyre; Ailsa Craig eurite.

Structure of a Coral Reef.—Interim Report of the Committee, consisting of Professor T. G. BONNEY (*Chairman*), Professor W. J. SOLLAS (*Secretary*), Sir ARCHIBALD GEIKIE, Professors A. H. GREEN, J. W. JUDD, C. LAPWORTH, A. C. HADDON, BOYD DAWKINS, G. H. DARWIN, S. J. HICKSON, *and* A. STEWART, Admiral W. J. L. WHARTON, Drs. H. HICKS, J. MURRAY, W. T. BLANFORD, LE NEVE FOSTER, J. W. GREGORY, *and* H. B. GUPPY, Messrs. F. DARWIN, H. O. FORBES, G. C. BOURNE, A. R. BINNIE, J. C. HAWKSHAW, *and* Hon. P. FAWCETT, *appointed to consider a project for investigating the Structure of a Coral Reef by Boring and Sounding.*

As mentioned in the report presented to the Ipswich meeting, the Council of the Royal Society had inquired from the Admiralty whether the Government would be able to assist an expedition by putting a surveying vessel at its disposal. In the course of the autumn a reply to this inquiry was received to the effect that My Lords would be willing to convey the members of the expedition and their apparatus, as far as possible, to Funafuti, which had been already suggested as a favourable spot for the investigation. A grant of 800*l.* was made from the fund placed by Government at the disposal of the Royal Society, and a further grant was made from funds administered by the Council, with the result that Professor Sollas, with Mr. Stanley Gardner, of Cambridge, as naturalist, and assistants from Sydney, sailed from that harbour in H.M.S. 'Penguin,' commanded by Captain Field, on May 1. But, even with the above assistance, the expedition could not have been sent had it not been for the great help given in Sydney by Professors Stuart and David, by Mr. W. H. S. Slee, Chief Inspector of Mines, and by the Department of Mines of New South Wales. It is due to them that boring tools and workmen have been lent by that Department, with the result that the cost of the undertaking has been practically halved.

News has been already received from Professor Sollas. The first attempts unfortunately proved unsuccessful, as a quicksand was struck, at a depth of about 65 feet, which choked the machine; but fresh apparatus was on its way from Sydney, and it was hoped that more favourable results would attend the next trial. The news of that is expected shortly.

The grant of 10*l.* was drawn and applied towards the necessary expenses preliminary to the expedition. As the cost of the undertaking is almost certain to exceed the sum granted by the Royal Society, the Committee suggest that a liberal grant be made in aid of the boring, and that it be placed in the hands of a small committee.

P.S.—During the meeting news was received from Professor Sollas that the second attempt had been defeated, at a slightly greater depth, by a similar cause, the difficulty being increased by the presence of hard lumps of coral, like boulders, in the loose stuff. Thus the attempt to obtain a boring deep enough to throw much light on the structure had been a failure. Still the expedition had succeeded in ascertaining many facts which it was hoped would be interesting and valuable.

The Character of the High-level Shell-bearing Deposits in Kintyre.—Report of the Committee, consisting of Mr. J. HORNE (*Chairman*), Dr. DAVID ROBERTSON, Dr. T. F. JAMIESON, Mr. JAMES FRASER, Mr. P. F. KENDALL, *and* Mr. DUGALD BELL (*Secretary*). (*Drawn up by* Mr. BELL, Mr. FRASER, *and* Mr. HORNE; *with Special Reports on the Organic Remains by* Dr. ROBERTSON.)

CONTENTS.

I. *Introduction.*

SINCE the presentation of their interim Report last year on the investigation of the shell-bearing deposits in Kintyre, the members of the Committee have carried out boring operations with the view of proving the extension of the shelly clay near Cleongart. The grant from the British Association having been insufficient for the work, the Committee cordially acknowledge a grant in aid from the Council of the Royal Society of London, obtained through the courtesy and kindly interest of Sir Archibald Geikie.

II. *Geographical Position.*

The shell-bearing deposits in Kintyre, investigated by the Committee during 1895–6, occur at three localities on the west side of the peninsula and to the north of Machrihanish Bay (see maps, figs. 1 and 4). They are exposed in three stream sections: (1) in Tangy Burn; (2) in Drumore Burn; (3) in a stream near Cleongart, which run more or less parallel with each other in a westerly direction towards the Atlantic.

III. *Previous Observations regarding the Shelly Clay, &c.*

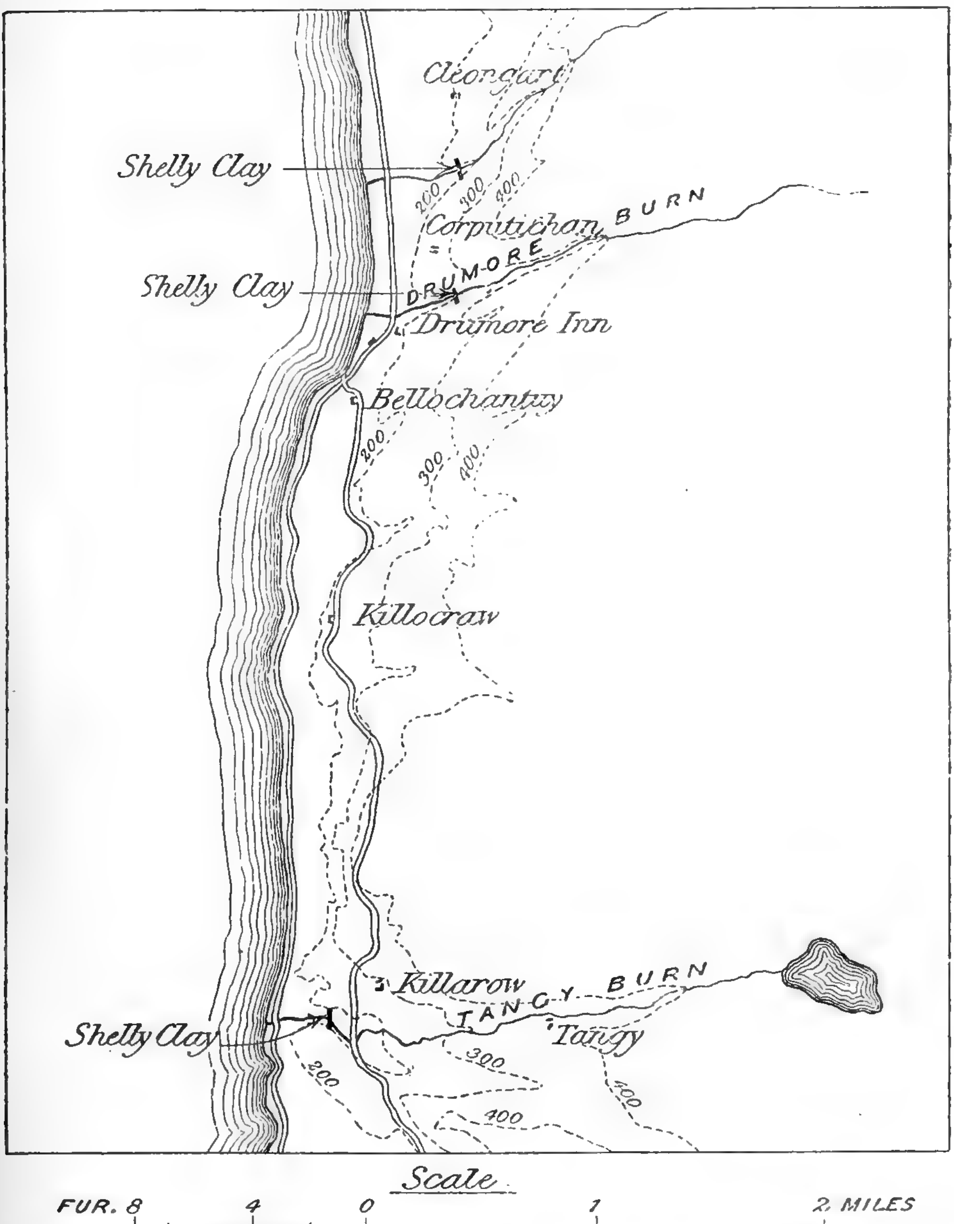
In 1852 Professor James Nicol, of Aberdeen,[1] chronicled the important fact that 'many of the striated boulders in the clays of Kintyre are apparently derived from a distance, and some detached travelled stones are seen on the surface.' He further observed near Macharioch several large boulders of white granite, 'resembling the granite of Arran, which is the nearest place where this rock occurs *in situ*, though at the distance of 23 miles across the deep hollow of Kilbrennan Sound.' Striated rocks were noted at several localities, and he gives a few instances from the

[1] *Quart. Journ. Geol. Soc.*, vol. viii. p. 406.

southern portion of the peninsula, viz. S. 55° E., S. 55° W., E. 10° N., and nearly N. and S.

Tangy Glen.—In 1873 Messrs. Robertson and Crosskey described the section of shelly clay in Tangy Glen[1] at a height of about 130 feet above the sea-level, in a paper from which the following extracts are taken :—

FIG. 1.—Map showing the localities of Shelly Clay where exposed at Cleongart, Drumore Burn, and Tangy Burn, in Kintyre.



'The chief interest of this section consists in the fact that, contrary to the usual position of the boulder-clay in the west of Scotland, it here

[1] *Trans. Geol. Soc. Glasgow*, vol. iv. p. 134.

overlies shell-bearing clay. The latter is dark grey in colour, and contrasts strongly with the overlying boulder-clay, which is of a dull reddish brown. The two clays are equally distinct in composition.

Boulder-clay.	*Shell-bearing Clay.*
50 per cent. fine mud.	80 per cent. fine mud.
27 „ sand, 21 fine and 6 coarse.	14 „ fine sand.
23 „ gravel.	6 „ gravel.

'The shell-bearing clay as exposed in this section is seen standing up in the boulder clay like a boss or knoll. . . . At the greatest part visible it is 13 feet high, and it can be traced as it thins down, along the edge of the streamlet for a distance of 60 or 70 yards. Its exact depth could not be ascertained, but as the rock is seen at a short distance on either hand, it is probably not more than a few feet deeper than what is exposed.

'The fossils in this deposit are but thinly met with—molluscs in particular are rare—*Leda pygmæa* being the prevailing shell, with an occasional *Leda pernula*, *Venus ovata*, and a few fragments of other species. These were submitted to Mr. J. G. Jeffreys, and at least two of them have proved to be of much interest, viz., *Pecten Groenlandicus* and *Montacuta elevata*.

'*Pecten Groenlandicus* has been met with on the east coast at Montrose, Errol and Elie, but not before in the west of Scotland. . . . *Montacuta elevata* is an Arctic species, and new to the glacial clays of Britain.

'Ostracoda and Foraminifera are more numerously represented in this deposit, eighteen species of the former and twenty-three of the latter having been obtained.'

A list of the organic remains from the shelly clay of Tangy Glen is appended to the foregoing paper.

Drumore Burn.—Another exposure of shelly clay was observed by Mr. Symes, of H.M. Geological Survey, in the course of his detailed survey of the peninsula of Kintyre. In the Drumore Burn 3 miles N. of Tangy Glen the shelly clay appears to underlie reddish boulder-clay, and yields broken fragments of shells.

Cleongart.—By far the best section of shelly clay yet observed in Kintyre was discovered by Mr. Alex. Gray, of Campbelton, in a stream near Cleongart, about 4 miles N. of Tangy Glen, where it is overlaid by a great thickness of boulder-clay. A large collection of organic remains was obtained by Mr. Gray from this deposit, which were named by Dr. Robertson, and appear in the list appended to this Report.

The Committee desire to acknowledge the valuable services rendered by Mr. Gray in the course of their investigations during 1895–96. He not only placed at their disposal his knowledge of the locality and his observations on this deposit, but he also superintended for several days continuously the boring operations at Cleongart. These services the Committee feel they cannot overestimate, and in other respects also Mr. Gray did much to assist the Committee in their work.

IV. *Detailed Examination of the Shell-bearing Deposits by the Committee.*

Tangy Glen.—The lower part of this glen forms, for a distance of about half a mile, a deep rocky gorge carved out of mica-schist. Further up the glen the shelly clay appears on the left or south bank of the stream, overlaid by boulder-clay. During the visit of the Committee it was observed that the section described by Dr. Robertson in 1873 had become overgrown with herbage and bushes, and was also partly concealed by a low breast wall. Several artificial cuttings were made on the face of the bank, and samples of the clay were taken for examination. The observations of the Committee, so far as they went, confirmed those of Messrs. Robertson and Crosskey in the paper referred to.

The shelly clay is a stiff, fine, bluish grey clay, upwards of 5 feet of the deposit being laid bare. The upper portion seemed to be affected by exposure to the weather, and the darkish-blue colour was chiefly apparent in the lower part. About 30 feet of reddish boulder-clay with numerous boulders lie above the shelly clay, rising to a greater height further back from the stream.

At this point there is evidence of land-slips on the face of the bank, so that the two deposits are sometimes intermingled.

The top of the shelly clay as exposed in the trench made by the Committee was found by Mr. Fraser, C.E., to be 135¼ feet above the level of the sea.

Drumore Glen.—The lower part of this glen shows prominent cliffs of red sandstone (Upper Old Red Sandstone), the strata dipping at angles of about 8° down stream. Overlying the sandstone is a considerable thickness of grey boulder-clay, full of boulders of crystalline schists. The sides of the glen are in some places masked by the boulder-clay slipping down over them. Resting apparently on the sandstone, however, and under the boulder-clay, there are occasional patches of gravel and sand and brown sandy clay, in the upper part of which some shells and shelly fragments have been found.

The top of the brown shelly clay here was found by Mr. Fraser to be 199 feet above the level of the sea.

Cleongart Burn.—As this is the most important section of shelly clay hitherto observed in Kintyre, the Committee confined their detailed observations chiefly to it.

As in Drumore, the lower part of the glen is occupied by red sandstone (Upper Old Red), which in places forms prominent cliffs, rising to a height of 20 feet or 30 feet. The sandstone is nearly horizontal, or inclined westwards at an angle of 8° to 10°, resting unconformably on the crystalline schists.

About 44 yards eastwards from the unconformable junction of the red sandstone and the schist visible in the bed of the stream, the main section of the shelly clay occurs on the south bank of the Burn, where it is overlaid by a great thickness of boulder-clay. The shelly clay is a stiff, dark, bluish clay, comparatively free from stones in the upper part, though here and there throughout the section well-rounded stones are met with. An examination of the included blocks, the average size of which varies from 1 inch to 3 inches across, shows that they are chiefly of local origin, being composed mainly of mica-schist with granular quartz-schist, and hornblende-schist. No fragment of red sandstone was observed in this deposit in the main section. No striations were observed on any of the stones.

Shells were found in abundance during the first visit of the Committee in 1895, a feature which was probably due to long exposure of the materials to the action of the weather, and the removal of the clay from the surface by the rain.

Some of the species were particularly abundant—as, for example, *Turritella*, *Cyprina*, *Astarte*, *Leda*, &c. Many were in excellent preservation, but others were broken and fragmentary. Some of the smallest shells, *Ledas* and others, were entire.

The lower part of the shelly clay near the level of the stream being concealed by a talus, the Committee resolved to cut a trench to show a vertical section of the deposits down to the level of the stream. The clay was found to rest upon a bed of compact coarse sand and gravel, cut open to a depth of 3 feet 10 inches, no shell fragments being visible. The boundary between the compact shelly clay above and the sand and gravel below was sharply defined, and to all appearance horizontal. Fine shelly mud immediately overlay the sand and gravel. Higher up, the clay contained abundance of shells and a very few small water-worn stones; one stone, the largest found in the trench, appeared to be finely striated.

Owing to the percolation of water from the stream, the cutting was not continued downward to the solid rock; but the mica-schist is visible in the bed of the Burn a few yards further down or west of the main section.

As will be seen from the section (fig. 2), the visible thickness of shelly clay, resting on coarse sand and gravel, is $27\frac{1}{2}$ feet; and the thickness of boulder-clay to the top of the bank is 74 feet.

This overlying boulder-clay is of a reddish-brown colour, charged abundantly with boulders, some of which are striated. These consist mainly of crystalline schists of local origin, with a marked absence of fragments of red sandstone. Though boulders of Arran granite were not observed in the boulder-clay of the main section, they occur in considerable numbers in the immediate neighbourhood, both on the surface and in the ground-moraine.

The shelly clay is also visible at one or two points on the north bank of the Cleongart Burn, where it is in like manner overlaid by reddish-brown boulder-clay. It has not proved so fossiliferous there as in the section on the southern bank which has just been described, but a few shells have been found in it.

With the view of proving the extension of the shelly clay along the stream course in an easterly direction, the Committee put down a series of shallow bores as represented in the accompanying ground-plan (fig. 3).[1] Blue clay, resembling the shelly clay, was recognised in the samples obtained from the three bores Nos. 1, 2, and 3, 22 yards, 44 yards, and 66 yards respectively east of the main section.

No shells or other organic remains, except one or two fresh-water Foraminifera, were found in the materials from these bores.

A small exposure of a similar clay was visible still further east, or 88 yards distant from the main section. This contained some small fragments of shells, and a few Ostracoda and Foraminifera.

Seeing that the shelly clay had been found in each of these three glens at nearly the same elevation, the Committee next considered it of importance to test its extension southward from Cleongart, in the direction of Drumore Glen. For this purpose a trench was first cut along the top of the shelly clay in the main section at Cleongart, extending for about

[1] These shallow bores were about 10 feet above the level of the stream, and respectively 23, 21, and 34 feet back from it.

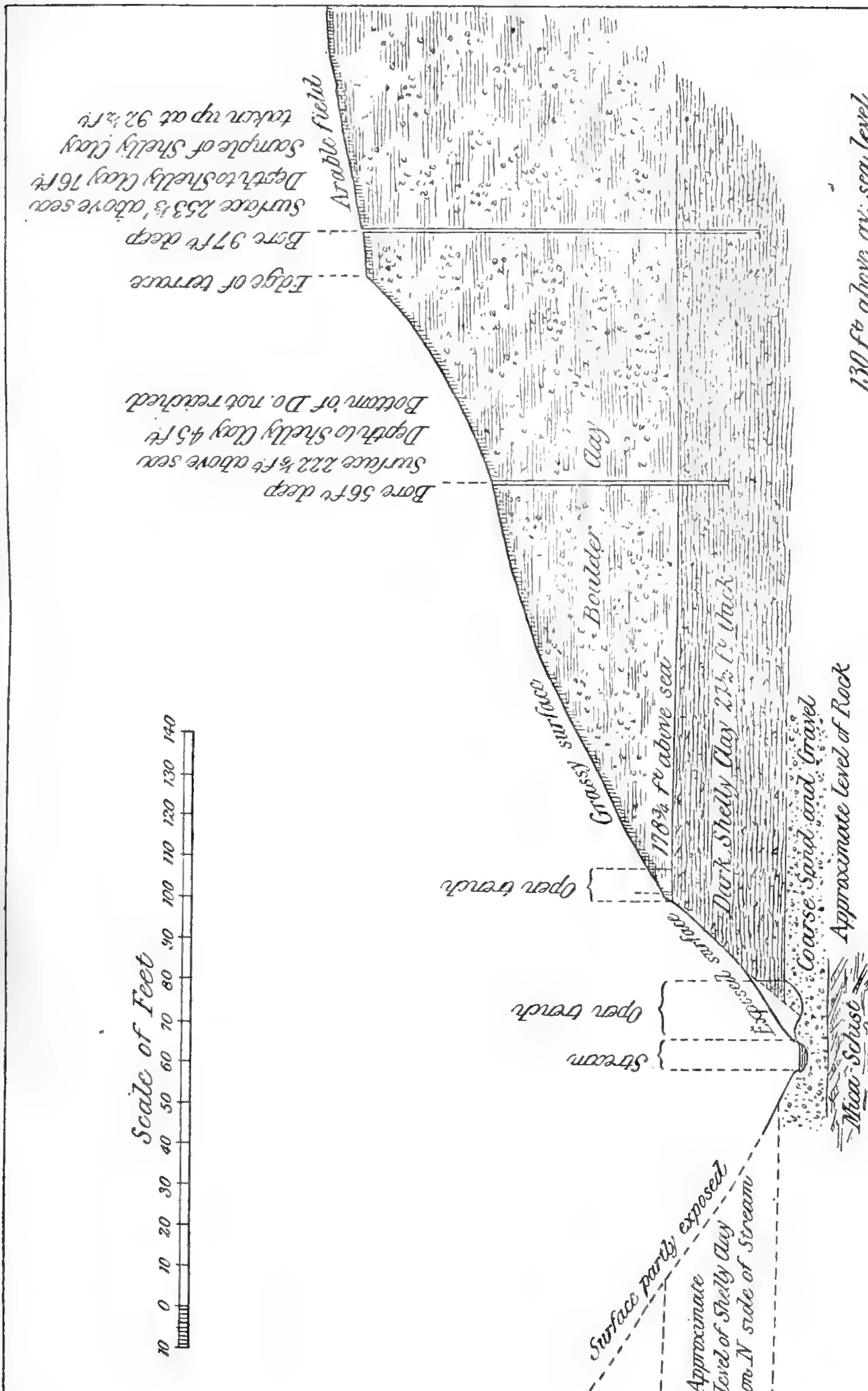


FIG. 2.—Section showing Shelly Clay at Cleongart, Kintyre, 1896.

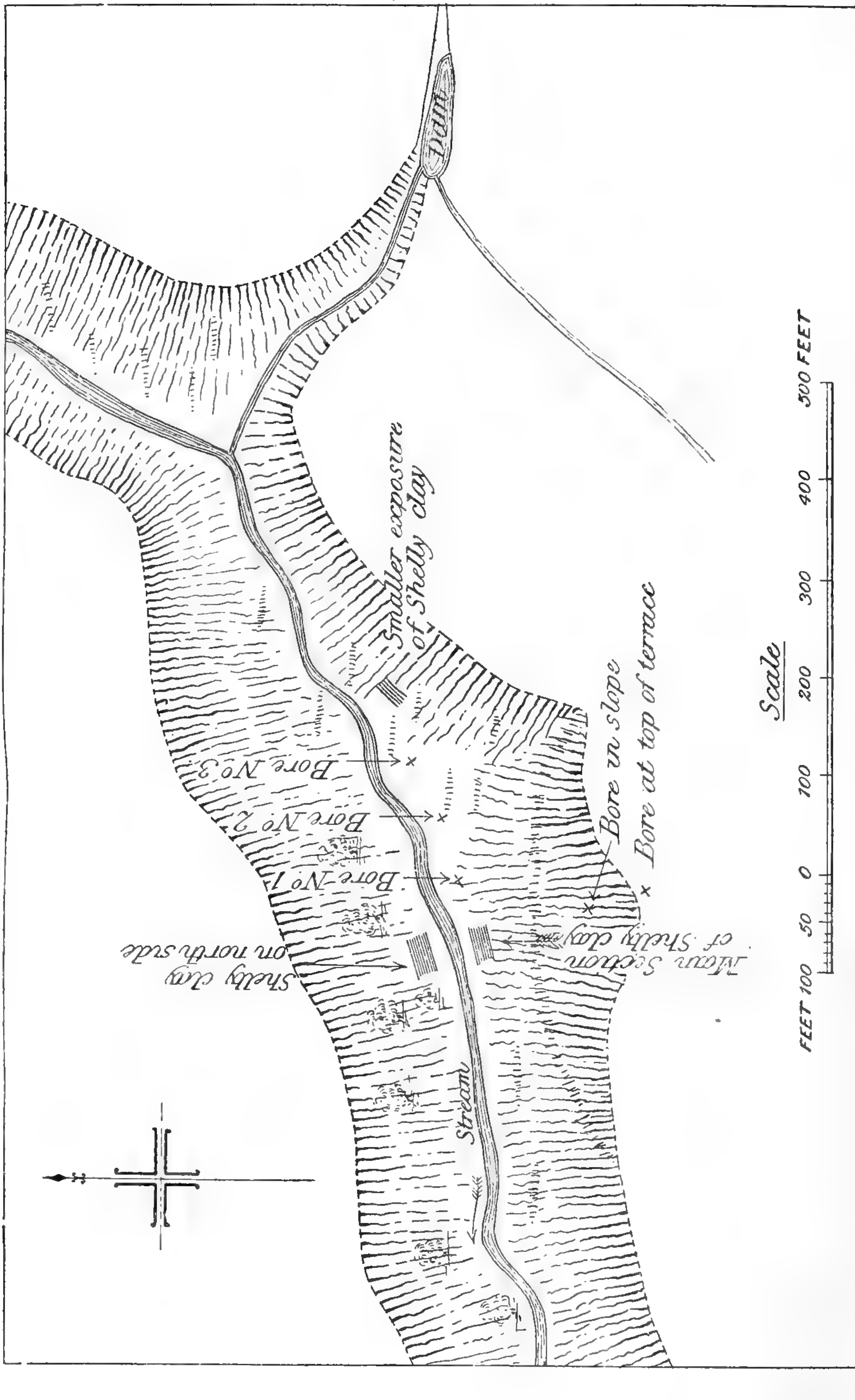


FIG. 3.—Sketch Plan showing positions of Shelly Clay and Borings at Cleongart.

8 feet under the boulder-clay of the south bank. The shelly clay was found to continue in a nearly horizontal position as far as the cutting was carried. It was then deemed advisable to sink bores farther back, in the bank and at the top of it, for the purpose of ascertaining whether the shelly clay still continued in that direction under the boulder-clay. Two points were accordingly marked off, one being in the slope, and the other four yards into the field above, the horizontal distances being respectively 34 and 54 yards from the top of the exposed face of the shelly clay (see sketch-plan of ground, fig. 3, and section, fig. 2).

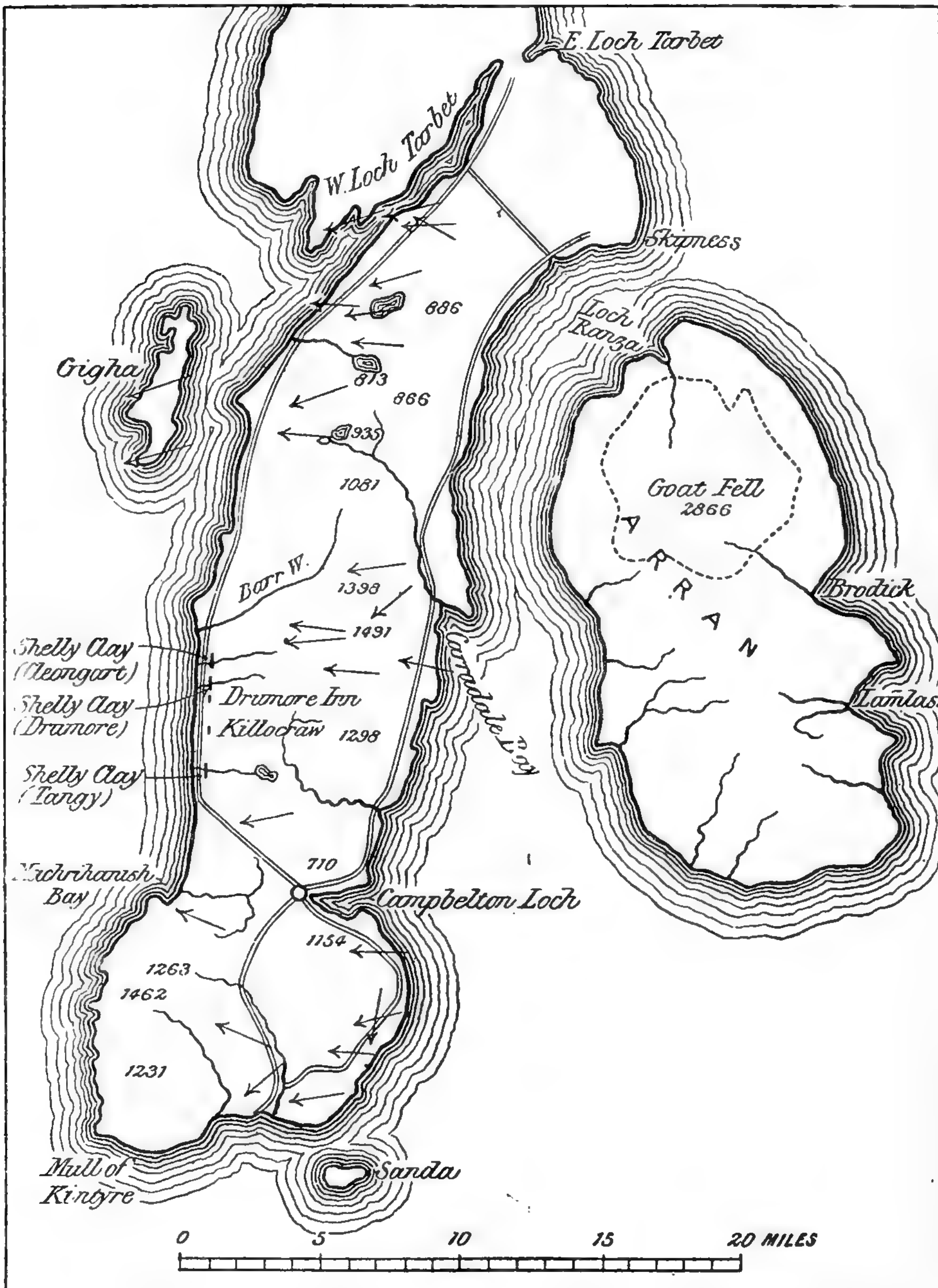
Work was begun first at the bore in the slope, 34 yards distant horizontally, from the top of the exposed face of shelly clay. Here it was estimated that the shelly clay, if it extended so far horizontally, might be met with at a depth of 46 feet from the surface. The boring through the stiff, stony, boulder-clay was attended with considerable difficulties. At the depth of 45 feet, however, the borers actually reached the shelly clay, and after passing downward through 10 feet of it, they struck upon a rock or boulder which arrested their progress. The Committee did not think that they had reached the bottom of the shelly clay. If this were the case, it would seem to show that the deposit was rapidly thinning out, and might be met with only sparingly, if at all, farther back. Till this point was tested, the Committee considered it unnecessary to make any detailed examination of the clay from this bore, it being chiefly important to examine it at the most distant locality where it should be found.

They therefore transferred operations to the upper station, which had been marked off at the top of the south bank. Here, after a good many difficulties and delays, the shelly clay was struck at a depth of 76 feet from the surface, which also corresponded very well with the estimate that had been made beforehand. Mr. Gray was by this time fortunately able to be with the borers, and give them the benefit of his direction and supervision, and also to mark and lay aside samples of the clay from various depths, which were sent on to Dr. Robertson for examination (see Section VI., Dr. Robertson's Report). The clay was found to continue downwards, with some variations in colour and composition, for a depth of about 20 feet from the point where first met with. A good many Ostracoda and Foraminifera were found in it by Dr. Robertson, and a few fragments of shells. The bore was sunk to a depth of 97 feet, the deposit becoming very stony towards the bottom, and finally resembling the hard, compact gravel underlying the shelly clay in the main section. The thickness of the shelly clay here met with seemed to confirm the conclusion of the Committee that the bottom of the deposit had not been reached in the first bore.

The Committee regard the proved extension of the shelly clay thus far, under the boulder-clay, as a point of much interest, and as favouring the conclusion that it may extend more or less continuously, about the same level, from one glen to another. They were desirous of putting down another bore, still further south, to test or confirm this conclusion. But the surface of the ground here consists of great mounds and ridges of boulder-clay, which would render boring operations in that direction tedious and costly, as well as uncertain; and their available means being by this time more than exhausted, they were obliged to stop, and can only state the result of these operations, so far as they have gone.

The Committee beg to record their obligations to His Grace the Duke of Argyll for the interest he manifested throughout in their work, and for permission readily granted to make the necessary excavations and

FIG. 4.—Map of Kintyre and Arran, showing direction of Ice-flow.



NOTE.—The heights of hills are marked in feet. The Arran granite boundary is dotted ....

bores at Cleongart; also to James Hall, Esq., of Tangy, for like favour and assistance in regard to Tangy Glen.

V. *Direction of Ice-flow in Kintyre.*

The direction of the ice-flow in Kintyre is of great importance in relation to the investigations referred to the Committee. A list of localities where striations were observed, based on observations made by Mr. Symes in the course of the geological survey, is here given with the sanction of the Director-General. With the view of presenting these observations in a clearer form, they have prepared a map (fig. 4) of the district extending from West Loch Tarbert in the north to the Mull of Kintyre in the south.

The observations of Mr. Symes have clearly demonstrated that Kintyre has been glaciated by ice which crossed the peninsula in a westerly direction from the Firth of Clyde to the Atlantic. A glance at the appended list and striæ map will show that the average direction in the neighbourhood of West Loch Tarbert is W. 20° S. Proceeding southwards along the watershed between Carradale on the east coast and Cleongart and Drumore on the west, many of the striæ point due W., while some instances trend W. 10°–20° S. Along the transverse hollow at Campbelton the direction varies from W. to W. 20° N. In that portion of the peninsula lying to the south and south-west of Campbelton the trend is variable : along the east coast it varies from W. to S. 25° W. ; in the Cannie Glen from W. 20° N. to W. 43° S. ; while near the west coast it is W. 5° N. It is obvious therefore that throughout Kintyre there must have been a powerful deflection of the ice which enabled it to cross the watershed, ranging in height from 896 feet near West Loch Tarbert to 1,462 feet near the Mull of Kintyre.

List of Ice Striæ.

Going from North to South in one-inch sheets, 12 and 20.

One inch sheet	Direction	Locality
20	W. 20 S.	On north shore of West Lough Tarbert, south of Ferry House
20	W. 25 S.	On north shore of West Lough Tarbert, east of Ardpatrick House
20	W. 25 N.	On south shore of West Lough Tarbert, north of Lough Dughaill
20	W. 25 N.	On road to Tarbert, north of Lough Dughaill
20	E. and W.	Close to road and immediately adjoining last locality
20	W. 20 S.	Not far from shore of West Lough Tarbert and east of Corran farm
20	W. 20 S.	North of Dunskeig farm house
20	W. 30 S.	North of Ballinakill and ½ a mile east of Clachan village
20	W. 15 S.	On Ronachan Hill, N.E. of Ronachon House, about 250 contour, 1 mile west of Clachan village
20	E. and W.	At 300 ft. contour, ½ a mile south of Ronachon House
20	E. and W.	At 250 ft. contour, ½ a mile south east of Ronachon House
20	W. 15 S.	At 500 ft. contour on Cnoc Donn, 1½ miles south of Ronachon House
20	W. 20 S.	At 500 ft. contour south of Ballochroy Glen, 2½ miles south of Ronachon House
20	W. 20 S.	At 700 ft. contour 3¼ miles south of Ronachon House
20	E. and W.	On mountain path from a ¼ to ½ a mile south of Clachan village
20	W. 10 S.	
20	W. 20 S.	
20	W. 10 S.	On south shore of Lough Ciaran 1½ miles S.S.E. of Clachan village

LIST OF ICE STRIÆ—*continued.*

One inch sheet	Direction	Locality
20	E. and W.	At 600 ft. contour $\frac{3}{4}$ of a mile W.S.W. of last locality, $1\frac{3}{4}$ S.S.W. of Clachan village
20	W. 10 S.	
20	E. and W.	$2\frac{1}{2}$ miles S.S.W. of Clachan village and $\frac{3}{4}$ of a mile N.W. of Lough Garasdale
20	E. and W.	$2\frac{3}{4}$ miles S.S.W. of Clachan village and $\frac{1}{2}$ of a mile N.W. of Lough Garasdale
20	W. 20 S.	On west cliff of Gigha Island $\frac{3}{8}$ of a mile S.S.W. of Cnoc Loisgte
20	W. 20 S.	On S.E. shore of Gigha Island.
20	E. and W.	At 600 ft. contour N.E. of Lagloskine, 6 miles S.S.E. of Clachan village
20	E. and W.	At 900 ft. contour, a little over 2 miles E.N.E. of the village of Killean
20	E. and W.	In the Allt a' Bhlair water, 4 miles E.N.E. of Glenbarr village
20	W. 35 S.	At 1,100 ft. contour, 2 miles west of Carradale Bay on E. side of Kintyre
20	W. 10 S.	At 1000 ft. contour, 6 miles E.N.E. of Glenbarr village
20	W. 10 S.	On Bein Bhreac, $5\frac{1}{2}$ miles E.N.E. of Glenbarr village
20	W. 15 S.	
20	E. and W.	East of Blary Hill, $3\frac{1}{4}$ miles E. of Glenbarr village
20	E. and W.	In stream W. of Beinn an Tuire, $4\frac{1}{2}$ miles E. of Glenbarr village
20	E. and W.	In stream W. of Beinn an Tuire, $4\frac{3}{4}$ miles E.S.E. of Glenbarr village
20	W. 5 S.	Bord Mor, 1,250 ft. contour, 4 miles S.W. of Carradale Bay
20	W. 10 N.	On road $2\frac{1}{4}$ miles S.S.W. of Carradale Bay.
12	W. 15 S.	At 700 ft. contour on rock adjoining fort, 3 miles N.W. of Campbelton
12	W. 20 N.	In stream, S. of chapel in ruins, $4\frac{1}{2}$ miles W.S.W. of Campbelton
12	W. 20 N.	At Ballygreggan farm house, 3 miles W.S.W. of Campbelton
12	E. and W.	West of Ballimenach Hill, 3 miles S.E. of Campbelton
12	E. and W.	On road side east of Ballimenach Hill, 3 miles S.E. of Campbelton
12	W. 25 N.	In Crossaig water, $6\frac{1}{2}$ miles S.W. of Campbelton
12	W. 5 N.	E. of Largybaan, $7\frac{1}{2}$ miles S.W. of Campbelton
12	W. 20 N.	In brook at Homeston, $4\frac{1}{4}$ miles S.W. of Campbelton
12	W. 10 N.	In Balnabraid Glen, $3\frac{1}{2}$ miles S.E. of Campbelton
12	W. 20 N.	South of Achinhoan Head, $4\frac{1}{2}$ miles S.E. of Campbelton
12	W. 15 S.	West of Ru Stafnish, $5\frac{1}{2}$ miles S.E. of Campbelton
12	N. 25 E.	$\frac{1}{2}$ of a mile north of last locality
*12	W. 25 S.	In Glen Hervie, 6 miles S.S.E. of Campbelton
12	E. and W.	
12	W. 20 N.	N.W. of Keprigan farm, 6 miles S.S.E. of Campbelton
*12	W. 45 S.	At Machrimore, 8 miles S.S.E. of Campbelton
12	W. 10 S.	1 mile south of east of Southend at the south-east of 1 inch
12	W. 10 S.	$1\frac{1}{8}$ mile S.E. of Southend
12	W. 10 S.	At Kilmashanachan, $1\frac{1}{2}$ miles E. by south of Southend

Remarks.—With the exception of the two localities marked with an *, the general trend of the striæ is about 10° north or south of west, and east and west.

Transport of Boulders.—The distribution of boulders in Kintyre furnishes striking confirmation of the conclusion already given regarding the ice-movement from a consideration of the striæ. Indeed, one of the remarkable features connected with the glaciation of that region is the occurrence of granite boulders derived from the mass in the north of Arran. They are met with in the boulder-clay and on the surface of the ground throughout the peninsula from the Mull of Kintyre to a point several miles north of Carradale Bay. Mr. Symes has noted many examples in the course of his survey of the region, and the members of the Committee who visited Kintyre likewise recorded several instances. The determination of the northern limit of Arran granite boulders is a point of considerable interest in relation to the extent of the deflection of the ice across the peninsula. With the view of obtaining evidence on this question the Secretary of the Committee paid a special visit to Carradale Bay and traced the boulders northwards to Grogport, on the east coast. Mr. B. N. Peach, F.R.S., has noted erratics of quartz-felsite, resembling the quartz-felsite or trachyte of Drumadoon in Arran.

Reference may also be made to the fact that along the west coast between Cleongart and Tangy Glen, where a narrow belt of Upper Old Red Sandstone, resting unconformably on the crystalline schists, fringes the coast, no fragments of red sandstone derived from this patch have been observed in the boulder-clay to the east, while blocks of the local crystalline schists have been carried westwards on to the area occupied by the Upper Old Red Sandstone.

VI. *Report by* Dr. David Robertson, *F.G.S., F.L.S., Mem. Imp. Roy. Zool. Botan. Soc., Vienna.*

In the preparation of the clays for taking the percentage of mud, sand, and gravel of the different deposits, the term 'mud' is that which passes through a sieve of ninety-six meshes to the inch; 'sand' is that which passes through a sieve of twenty-four meshes to the inch; 'gravel' is that which is retained in the same sieve of twenty-four meshes to the inch; and 'floats' is that which is gathered on the surface of the water when the dry clay is put in and stirred up.

I have all the materials parcelled separately, except the muds, which passed away in the washing. I have samples of the sand in small bottles, so that each sample can be compared with the others. The stones and gravels are parcelled up for the same purpose.

The gravels are mostly water-worn; some are angular, the proportions differing more or less in different samples. No striations were noticed on the stones, large or small, with the exception of one stone sent me by Mr. Gray, 2 lb. weight, which is well striated on the line of the longest axis on the under side, and obliquely on the upper. It seems possible, however, that this stone may have got into the shelly clay from the adjoining boulder-clay above.

On our visit to the Cleongart deposit, no whole shells with their valves together could be seen, except one or two of the very smallest. This may be very well accounted for. Our friend, Mr. Gray, the discoverer of this shelly deposit some years ago, had made several visits to the place, and had gathered nearly all the shells worth taking that weathering had exposed, probably for a long time past. These are now to be seen in the Campbelton Museum. Although fragments of shells are still found thickly strewn over the bank, they are but sparsely met with in the dark blue clay underneath. This also may be explained by the action of weathering.

The most remarkable feature of this deposit is the condition of the shells of *Cyprina islandica, Turritella terebra,* and *Fusus contrarius.* In the case of *C. islandica,* which is plentiful in the deposit, it is remarkable that they are all excessively fractured, not through the thinnest portions only, but across the thickest parts of the shell. This is all the more surprising, as there is no visible striation, aqueous action, or abrasion on the fragments of the shells that would account for such destruction. The late Dr. Jeffreys stated :[1] 'In a post-glacial or raised beach at Golspie, Sutherlandshire, close to high-water mark, I noticed that valves were heaped up in extraordinary confusion, generally in fragments. . . . I was told by Mr. Bean, that on pouring boiling water on the living shells (*C. islandica*) a succession of reports ensued as if a volley had been fired. . . . The action of severe frost at the period when the climate and other conditions resembled those of polar regions, might have had the same effect on the shells.' It seems probable that if great heat does splinter the shells, intense frost may do the same. On the other hand, it may be stated that while dredging in the yacht 'Medusa,' in seventy to eighty fathoms, between Brodick and Little Cumbrae, fragments were frequently brought up of *C. islandica* with the fractured edge quite sharp, and showing no rubbing or marks of striation. Whatever the cause may be, it does not seem to be of frequent occurrence in other post-tertiary deposits. In all the Clyde beds that I have examined, the species is generally moderately common, and a broken valve is quite exceptional.

Turritella terebra is another shell that has suffered a great amount of breakage. It is the prevailing shell of the deposit, occurring in great abundance, yet I did not see one perfect specimen. They do not seem to have undergone the same kind of treatment in the breakage as *C. islandica,* having been chiefly, or all, broken transversely at the groove between the whorls, the whorls themselves having nearly all escaped injury. Seeing the great destruction of *C. islandica* in the same deposit, it is difficult to conceive how the prominent whorls of *T. terebra* were not crushed in the same way.

Fusus contrarius is remarkable, being sinistral, which is very rare in our present seas. They are common in the English Crag, but this is the only occurrence I know of having been recorded in British Post-Tertiaries.

TANGY GLEN : *Shelly Clay Deposit.*—Dark blue shelly clay, which consisted of—mud, 74 per cent. ; sand, 12 per cent. ; gravel, 14 per cent.

Mostly water-worn and angular.

List of Organisms from Shelly Clay, Tangy Glen, Kintyre.

I. MOLLUSCA.

Lamellibranchiata :

Corbula gibba, *Olivi.* One valve.
Leda pernula, *Müll.* Rare, mostly fragments, a few of which were more or less water-worn.
Leda pygmæa, *Münst.*

[1] Jeffreys' *British Conchology,* vol. ii. p. 305.

Leda var. *Gouldii*. Common, and in good condition, mostly covered with epidermis.
Montacuta elevata, *Stimp*. One, very young, with the valves together.
Pecten grœnlandicus, *Low*. One fragment.
Venus ovata, *Penn*. Rare in the glacial clays of Scotland.

Gasteropoda.—Fusus antiquus, *Linn*. One very young shell.
Cephalopoda.—Sepia sp. ? Fragments of 'pen.'

II. Annulosa.

Ostracoda.

Cythere pellucida, *Baird*.
,, castanea, *G. O. Sars*.
,, lutea, *Müller*.
,, limicola, *Norman*.
,, globulifera, *Brady*.
,, concinna, *Jones*.
,, dunelmensis, *Norman*.
Cytheridea papillosa, *Bosquet*.
,, Sorbyana, *Jones*.
,, nigrescens, *Baird*.
Cytheridea undata, *G. O. Sars*.
,, clathrata, *G. O. Sars*.
Cytheropteron latissimum, *Norman*.
,, arcuatum, *B. C. & R.*
,, Montrosiense, *B. C. & R.*
Bythocythere constricta, *G. O. Sars*.
Sclerochilus contortus, *Norman*.
Paradoxostoma variabile, *Baird*.

III. Echinodermata.

Echinus fragments of spines, a few.
Amphidotus ? fragments of spines, a few.

IV. Protozoa.

Foraminifera.

Cornuspira foliacea, *Phill*.
Biloculina simplex, *D'Orb*.
,, ringens, *Lamk*.
,, elongata, *D'Orb*.
Miliolina seminulum, *Linn*.
,, subrotunda, *Mont*.
,, circularis, *Bornemann*.
,, Cuvieriana, *D'Orb*.
,, tenuis, *Cyjzck*.
,, oblonga, *Mont*.
Cassidulina lævigata, *D'Orb*.
,, crassa, *D'Orb*.
Lagena costata, *Will*.
,, gracillima, *Seq*.
,, sulcata, *W. & J.*
,, lævis, *Mont*.
,, Jeffreysii, *Brady*.
,, globosa, *Mont*.
,, marginata, *W. & J.*
Lagena squamosa, *Mont*.
Vaginulina legumen, *Linn*.
Polymorphina lactea, *W. & J.*
,, compressa, *D'Orb*.
,, lanceolata, *Reuss*.
Globigerina bulloides, *D'Orb*.
Patellina corrugata, *Will*.
Discorbina rosacea, *D'Orb*.
,, globularis, *D'Orb*.
Truncatulina lobatula, *W. & J.*
Rotalia Beccarii, *Linn*.
Nonionina asterizans, *F. & M.*
,, orbicularis, *Brady*.
,, scapha, *F. & M.*
,, depressula, *W. & J.*
Polystomella striato-punctata, *F. & M.*
,, crispa, *Linn*.

DRUMORE GLEN: *Shelly Clay Deposit.*—The clay in the dry state consisted of—mud, 81 per cent.; sand, 10 per cent.; gravel, 9 per cent. The gravel water-worn. No striations observed.

List of Organisms from Shelly Clay, Drumore Glen, Kintyre.

I. MOLLUSCA.

These are very rare, mostly all broken, none of the fragments larger than half an inch; and, so far as they could be identified, belonged to *Astarte sulcata,* together with two perfect valves of *Leda minuta.*

II. MOLLUSCOIDA.

Tubulipora hispida ?
Cerisia sp. ?

III. ANNULOSA.

Ostracoda.

Cythere pellucida, *Baird.*
" globulifera, *Brady.*
" concinna, *Jones.*
" villosa, *G. O. Sars.*
Cythere dunelmensis, *Norman.*
Cytheridea papillosa, *Bosquet.*
Sclerochelus contortus, *Norman.*

IV. ECHINODERMATA.

Amphidotus cordatus ? Spines were in great abundance, but no part of the test was seen. This may be accounted for by the spines, after death, readily falling off, as they do, and the light test being easily carried by the currents to some distance.

V. PROTOZOA.

Foraminifera.

Biloculina ringens, *Lamk.*
" elongata, *D'Orb.*
" simplex, *D'Orb.*
Miliolina seminulum, *Linn.*
" oblonga, *Mont.*
" Cuvieriana,
" trigonula, *Lamk.*
" Ferussacii, *D'Orb.*
" subrotunda, *D'Orb.*
" tenuis, *Cyjzck.*
Psammosphæra fusca (?), *Schulze.*
Jaculella acuta (?), *Brady* (fragment).
Webbina hemisphærica, *D'Orb.*
Polymorphina lanceolata, *Reuss.*
Uvigerina pygmæa, *D'Orb.*
Rotalia Beccarii, *Linn.*
Nonionina orbicularis, *Brady.*
" depressula, *W. & J.*
" Boneana, *D'Orb.*
" stelligera, *D'Orb.*
Polystomella striato-punctata, *F. & M.*

CLEONGART GLEN: *Shelly Clay Deposit.*—(*a*) Clay taken from the brown weathered surface of the bank consisted of—mud, 83 per cent.; sand 6 per cent.; gravel, 11 per cent.

Stones mostly water-worn; no striation was noticed. It may be stated, however, that few of the stones were of a kind to admit striation being readily seen.

(*b*) A sample of dark blue shelly clay taken from the same deposit underlying the brown weathered clay consisted of—mud, 95 per cent.; sand, 2 per cent.; gravel, 3 per cent.

Stones mostly water-worn, some angular ; no striations observed. This shows a much higher percentage of mud, and a smaller percentage of gravel and sand than the above, which may be accounted for by much of the fine mud and sand being washed away from the overlying weathered surface clay, and a portion of the stones slipping down from the higher boulder-clay and mixing with the surface shelly clay.

Shallow Bores sunk in 1895 *to test the extension of the Shelly Clay Eastwards.*

(*c*) *Shallow Bore, No.* 1.—8 feet from surface ; 22 yards east of main section ; the clay consisted of—mud, 59 per cent. ; sand, 12 per cent. ; gravel, 29 per cent.

Stones mostly water-worn, no striations observed, 2 organisms, might be Deflugi. No other animal remains.

(*d*) *Shallow Bore, No.* 2.—10 feet 9 inches from the surface ; 44 yards east of main section ; the clay consisted of—mud, 54 per cent. ; sand, 18 per cent. ; gravel, 28 per cent.

Stones angular and water-worn in about equal proportions ; no animal remains or striation observed.

(*e*) *Shallow Bore, No.* 3.—9 feet 5 inches from surface ; 66 yards east of main section ; the clay consisted of—mud, 76 per cent. ; sand, 6 per cent. ; gravel, 18 per cent.

Stones mostly angular and water-worn ; no striation or animal remains observed ; one Deflugi sp. ? The 'floats' were full of vegetable fragments that had much of the appearance of being waterlogged.

(*f*) *From the extreme eastern exposure* of shelly clay 88 yards east of main section ; 12 feet 10 inches above level of stream ; 3 lbs. of clay consisted of—fine mud, 96 per cent. ; coarse sand, 3 per cent. ; gravel, 1 per cent.

Stones mostly angular, the others water-worn, no striation detected, a few small fragments of shells. Ostracoda and Foraminifera were present in small numbers.

(*g*) *Gravel at bottom of Shelly Clay.*—From bottom of trench cut into main section 11 feet from surface and 2 inches below level of stream, 14 feet back from stream. This bed of coarse sand and gravel was 3 feet 10 inches thick, very hard ; bottom not reached. The clay consisted of—mud, 28 per cent. ; gravel, 72 per cent.

List of Organisms from Shelly Clay at Cleongart, Kintyre.

(* Signifies Mr. Gray's collection ; † Dr. Robertson's collection.)

Name	Remarks	Distribution	Fossil
		I. MOLLUSCA.	
Lamellibranchiata:			
*† Anomia ephippium, *Linn.*	One small valve, and a large fragment.	British and European seas ; low water to 80 fathoms.	Clyde beds ; coralline crag ; Norway, Sweden.
*† Astarte borealis, *Chem.*	A few valves.	Not in British seas ; Arctic.	Clyde beds, common ; Norway.
*† Astarte compressa, *Mont.*	Many valves, mostly perfect.	British seas, North Atlantic ; low water to 50 fathoms.	Clyde beds, Clava, Norway ; red crag.
*† Astarte sulcata, *Da Costa.*	Many valves, mostly perfect.	British seas, Iceland, Mediterranean ; low water to 85 fathoms.	Clyde beds, Clava, Norway ; red crag.

LIST OF ORGANISMS FROM SHELLY CLAY AT CLEONGART—*continued.*

Name	Remarks	Distribution	Fossil
Lamellibranchiata:			
† Cardium edule, *Linn.*	Fragment of a young shell.	On all European shores, sandy bays; low water to a few fathoms.	Clyde beds, Clava; Norway.
* Cardium exiguum, *Gml.*	One valve.	British and Northern seas; 3 to 15 fathoms.	Clyde beds; Belfast, Sussex deposits.
* Cardium fasciatum, *Mont.*	One valve.	British seas, Norway, Canary Isles; 5 to 90 fathoms.	Clyde beds; coralline crag.
*† Cardium tuberculatum, *Linn.*	Several fragments, and one perfect valve.	Finisterre, Canary Isles; low water to 12 fathoms.	As far as known, Cleongart only.
*† Cyprina islandica, *Linn.*	Many valves, broken in all directions.	British seas, Norway, Faroe Isles; low water to 100 fathoms.	Clyde beds, Clava; most glacial deposits.
*† Dentalium entalis, *Linn.*	Many, mostly imperfect.	British seas, Mediterranean, Adriatic.	Clyde beds. rare; Norway; red crag.
† Dentalium Tarentium, *Lam.*	One fragment.	British seas, Mediterranean, Adriatic; low water to 25 fathoms.	As far as known, Cleongart only.
*† Leda pernula, var. mucilenta, *Steenst.*	Many valves, both broken and perfect.	Arctic seas.	Clyde beds, Clava, Norway.
*† Leda pygmæa, *Münst.*	A few valves, and some attached.	British northern seas. Norway, Naples; 20 to 80 fathoms.	Clyde beds, Clava; coralline crag.
† Montacuta bidentata, *Mont.*	One valve.	Norway to Sicily; 10 to 70 fathoms.	Clyde beds; red crag; coralline crag.
† Mya truncata, *Linn.*	One hinge fragment.	Greenland, Spitzbergen, British seas, Bay of Biscay, Black Sea Littoral.	Clyde beds, Norway.
*† Mytilus edulis, *Linn.*	One small fragment.	Greenland, Norway, British seas, Mediterranean; high water to a few fathoms.	Clyde beds, Clava; coralline crag.
*† Ostrea edulis, *Linn.*	Several perfect and a few fragments.	British seas, North Sea, Mediterranean, Adriatic; low water to 45 fathoms.	Clyde beds, Norway; coralline crag.
*† Pecten islandicus, *Müll.*	Two small fragments.	Arctic seas.	Clyde beds, Uddevalla raised beach.
† Pecten maximus, *Linn.*	One small fragment.	British seas, Norway to Canaries; 7 to 78 fathoms.	Clyde beds, Norway.
† Pecten opercularis, *Linn.*	One small fragment.	British seas, Iceland, Algeria; 6 to 90 fathoms.	Clyde beds (rare), coralline crag.
† Saxicava rugosa, *Linn.*	Two small valves.	British seas, Iceland. Canaries, Mediterranean; low water to 145 fathoms.	Clyde beds, Norway; coralline crag.
*† Tellina calcarea, *Chem.*	Moderately common, broken and perfect.	Now extinct in our seas.	Clyde beds (common), Clava (rare), Norway (common).
*† Venus ovata, *Penn.*	A few valves, perfect and broken.	British seas; low water to 145 fathoms.	Clyde beds (common), Clava (rare), Norway (common).
Gasteropoda:			
*† Buccinum undatum, *Linn.*	Several, large and small, more or less imperfect.	British seas, Iceland, Mediterranean; low water to great depths.	Clyde beds, Clava, Norway.
† Chiton sp.?	One plate much weathered.	—	—
*† Fusus contrarius, *Linn.*	One perfect specimen.	—	—
† Hydrobia ulvæ, *Penn.*	One perfect specimen.	British seas, Finmark, Mediterranean; tidal rivers and oozy sands.	Clyde beds, Norway, Norwich crag.
*† Littorina littorea, *Linn.*	Two perfect and two fragments.	British seas, Greenland, Lisbon; high to low water, common.	Clyde beds, Clava, Norway.
*† Littorina rudis, *Manton.*	Two perfect and one fragment.	British seas, Greenland, Black Sea; between tide-marks, locally common.	England, Scotland, Ireland.
* Natica affinis, *Gml.*	One specimen.	Arctic and northern, no longer British.	Clyde beds.
*† Natica grœnlandica, *Beck.*	Two specimens.	British east coast, Norway, Greenland; 40 to 60 fathoms.	Clyde beds, Clava, England, Ireland, Norway.
† Odostomia sp.?	One specimen, imperfect.	—	—
† Pleurotoma turricula, *Mont.*	One specimen.	British seas, France, Canary Isles; 8 to 30 fathoms.	—
* Purpura lapillus, *Linn.*	One perfect specimen.	British seas, North Atlantic, Arctic, Littoral; to a few fathoms.	Clyde beds (rare), red crag; Norway.
*† Trochus tumidus, *Mont.*	Two imperfect specimens.	Iceland to Ægean Sea.	Clyde beds (common), red crag; Norway.

LIST OF ORGANISMS FROM SHELLY CLAY AT CLEONGART—*continued.*

Name	Remarks	Distribution	Fossil
Gasteropoda:			
*† Trophon truncatus, *Strom.*	Four perfect specimens.	British seas, Norway, Greenland; 50 fathoms.	Clyde beds, coralline crag.
*† Turritella terebra, *Linn.*	Very abundant, scarcely one perfect.	British seas, Norway, Mediterranean; 3 to 100 fathoms.	Clyde beds, Moel Tryfaen, Norway.

(The references are from Jeffreys' 'British Conchology.')

II. MOLLUSCOIDA.

Name	Remarks	Distribution	Fossil
Polyzoa:			
Crisia denticulata ?	One fragment.	—	—

III. ANNULOSA.

Name	Remarks	Distribution	Fossil
Insecta:			
(Beetle)	Wing.	—	—
Crustacea:			
Cirripedia:			
Balanus crenatus.	Many valves.	—	—
Balanus porcatus.	Two valves.	—	—
Balanus balanoides	Two valves.	—	—
Decapoda:			
(Crab)	Fragments of plate of leg and claw.		
Ostracoda:			
Cythere lutea, *Müller.*	A single valve.	British coast, Norway, Mediterranean.	Scotland, Ireland, Norway, Iceland.
Cythere pellucida, *Baird.*	Two valves.	British coast, Norway, Bay of Biscay.	Clyde beds, Clava Cardiff.
Cythere confusa, *Brady.*	A few valves.	British coast, Norway, Bay of Biscay, Mediterranean.	Clyde beds, Clava, Ireland, Norway.
Cythere porcellanea, *Brady.*	One valve.	British coast, Norway, Bay of Biscay.	Clyde beds.
Cythere globulifera, *Brady.*	Valves frequent.	Rare, Norway, Spitzbergen.	Clyde beds, Elie, Errol,, England.
Cythere tuberculata, *G. O. Sars*	Frequent, a few with valves together.	Britain, Greenland, Norway, West Indies.	England, Scotland, Ireland.
Cythere concinna, *Rupert Jones.*	The prevailing Ostracod in the deposit.	Norway, Spitzbergen, Davis Straits.	England, Scotland, Ireland, Norway.
Cythere leioderma, *Norman.*	One valve.	Norway, Shetland, St. Lawrence.	England (Bridlington), Sicily.
Cythere emaciata, *Brady.*	One valve.	Britain, Norway, Spitzbergen, Naples.	Clyde beds, Ireland, Sicily.
Cythere quadridenta, *Baird.*	Two valves.	Britain, Norway, Bay of Biscay.	Clyde beds, Clava.
Cythere dunelmensis, *Norman.*	Common, one with valves together.	Britain.	England, Scotland, Ireland.
Cythere Jonesii, *Baird.*	Two imperfect valves.	Britain, Norway, Spitzbergen, Bay of Biscay.	England, Scotland, Ireland.
Cythere Robertsoni, *Brady.*	One valve, and one with valves together.	Oban, Shetland, England, Ireland.	Scotland (Lochgilp), Norway.
Cythere antiquata, *Baird.*	One valve.	South-west England, Scotland, West of Ireland.	Clyde beds, England, Ireland.
Cythere papillosa, *Bosquet.*	A few valves.	Norway, Davis Straits, St. Lawrence.	Scotland, England, Norway, Canada.
Cytheridea punctillata, *Brady.*	A few valves of different ages.	Britain, Norway, Iceland, Messina.	Britain, Sicily.
Cytheridea Sorbyana, *Jones.*	Two well-marked valves.	Northern seas, rare.	Scotland, Norway, Canada.
Eucythere declivis, *Norman.*	One valve.	British seas, Norway, Bay of Biscay, Naples.	Britain, Norway, Canada.
Loxoconcha impressa, *Baird.*	Two valves.	British seas, Norway, Bay of Biscay, Naples.	Scotland, Ireland, Norway.

LIST OF ORGANISMS FROM SHELLY CLAY AT CLEONGART—*continued.*

Name	Remarks	Distribution	Fossil
Crustacea:			
Ostracoda:			
Cytherura gibba, *Müller.*	One valve.	Scotland, Norway, Holland.	Scotland (Lochgilp), Norway.
Cytherura undata, *G. O. Sars.*	One valve.	British coasts, Norway, Spitzbergen, St. Lawrence.	Scotland, Ireland, Norway, Canada.
Cytherura clathrata, *G. O. Sars.*	One valve.	British coasts, Norway, Davis Straits.	Britain, Norway.
Cytherura cellulosa, *Norman.*	One valve.	British coasts, Norway, Biscay, Naples.	England, Wales, Scotland.
Cytheropteron latissimum, *Norman.*	A few valves.	British coasts, Norway, Baffin's Bay.	England, Scotland, Norway, Canada.
Cytheropteron nodosum, *Brady.*	Three valves.	British coasts, Norway, Biscay, St. Lawrence.	Britain, Norway, Canada.
Bythocythere constricta, *G. O. Sars.*	One imperfect valve.	British coasts, Norway, Biscay, St. Lawrence.	Scotland, Antwerp, Crag.
Bythocythere turgida, *G. O. Sars.*	One valve.	Scotland, England, Norway, St. Lawrence.	Scotland (Cleongart).

(References are to Brady and Norman's Monograph, 'Trans. Royal Society Dublin,' vol. iv.)

IV. PROTOZOA.

NOTE.—C. means common; M.C., moderately common; R., rare; M.R., moderately rare; R.R., very rare.

Foraminifera.

Biloculina ringens, *Lamk.* M.C.
,, elongata, *D'Orb.* M.R.
,, simplex, *D'Orb.* M.R.
Miliolina Cuvieriana ? R.
,, seminulum, *Linn.* M.C.
,, oblonga, *Mont.* M.C.
,, Brongniartii, *D'Orb.* R.
,, Ferussacii, *D'Orb.* R.R.
,, tenuis, *Cyjzck.* M.R.
,, secans, *D'Orb.* R.
,, subrotunda, *Mont.* M.R.
,, circularis, *Bornemann.* R.
,, venusta, *Karrer.* R.
Bulimina marginata, *D'Orb.* M.C.
,, pupoides, *D'Orb.* M.C.
,, elegans, *D'Orb.* M.R.
Bolivina punctata, *D'Orb.* M.C.
,, dilatata, *Reuss.* R.
Cassidulina crassa, *D'Orb.* M.C.
,, lævigata, *D'Orb.*
Lagena lævis, *Mont.* M.R.
,, gracillima, *Seg.* M.C.
,, striata, *D'Orb.* M.C.
,, distoma, *Parker & Jones.* R.
,, Feildeniana, *Brady.* R.
,, costata, *Will.* M.C
,, interrupta. R.
Lagena sulcata, *W. & J.* M.R.
,, semistriata, *Will.* M.R.
,, lucida, *Will.* M.C.
,, fimbriata, *Brady.* R.
,, lineata, *Will.* M.R.
,, lævigata, *Reuss.* M.R.
,, caudata, *D'Orb.* M.R.
,, marginata, *W. & B.* M.C.
,, favoso-punctata, *Brady.* R.
,, globosa, *Mont.* M.R.
,, hexagona, *Will.* M.C.
,, squamosa, *Mont.* R.
,, melo var. R.
,, melo, *D'Orb.* M.R.
,, apiculata, *Reuss.*
,, ovum, *Ehrenberg.*
,, Williamsoni, *Alcock.*
Nodosaria lævigata, *D'Orb.* R.
,, rotundata, *Reuss.* R.
,, pyrula, *D'Orb.* R.
,, pauperata, *D'Orb.*
,, consobrina, *D'Orb.*
,, simplex, *Silvestri.*
,, communis, *D'Orb.* R.
Vaginulina legumen, *Linn.*
Marginulina glabra, *D'Orb.* R.
Cristellaria latifrons, *Brady.* R.

Cristellaria rotulata, *Lam.*
„ cultrata, *D'Orb.* R.
„ gibba, *D'Orb.* M.R.
„ arcuata, *D'Orb.* R.
„ crepidula, *Fech.*
Polymorphina compressa, *D'Orb.*
„ lanceolata, *Reuss.* M.R.
„ sororia, *Reuss.*
„ oblonga, *D'Orb.* M.C.
„ ovata, *D'Orb.*
Urigerina pygmæa, *D'Orb.*
Globigerina bolloides, *D'Orb.* R.
Patellina corrugata, *Will.*
Truncatulina lobatula, *W. & J.* M.R.
Pulvinulina Karsteni, *Reuss.* C.
Rotalia orbicularis, *D'Orb.* M.R.
„ papillosa, *Brady.*
Nonionina orbicularis, *Brady.* M.C.
„ umbilicatula, *Mont.* R.
„ depressula, *W. & J.* M.C.
„ Boneana, *D'Orb.* M.C.
„ stelligera, *D'Orb.* R.
Polystomella macella, *F. & M.* C.
„ striato-punctata, *F. & M.* C.
„ arctica, *P. & J.* R.
Discorbina polystomelloides, *P. & J.*
„ globularis, *D'Orb.* R.
Rhabdamina cornuta (?), *Brady.*
Planospirina exigua, *Brady.* R.
Psammosphæra fusca, *Schulze.* R.

V. Echinodermata.

Ray and disc plates of starfish.
Spines of Spatangus.
„ Echinus.

Remarks.

In some of the parcels from these various depths the gravel was mostly angular; in others, more or less water-worn. A good deal of it might be called a coarse sand, but some of the stones were about the size of ordinary gooseberries. No striation was observed on any of them.

By whatever means the shelly clay was laid down, it will be seen from the following Table that there had been at least three distinct changes in the deposition of the sediment. In the lowest division, including the depths 97 up to 94, the dry clay was of a light brown colour, friable and easily broken. In the next section, including depths 92 feet 9 inches up to 87 feet, the dry clay was of a dark bluish slate colour, hard and difficult to break. The uppermost section, including depths 85 to 76 feet, when dry, was of a light brown. The clay from 76 down to 79½ feet was hard, and disintegrated slowly; from 80 to 85 feet it was less hard, and disintegrated more freely.

It is not without interest to note the variations of the colours and hardness of the clays as they are built up one above another, as well as the number of species of the organisms in the different zones, together with their living distribution.

There are three species of Foraminifera in this deposit that have not been found in Recent deposits in the British Isles, viz., *Discorbina polystomelloides*, *Polystomella macella*, and *Rotalia orbicularis*. All three in the fossil state are, so far as I know, only found in Scotland in the shelly clay deposits of Kintyre, not rarely but frequently; and I may say that *Rotalia orbicularis* is a prevailing species in the deposit.

Their southern widely distributed living habitats are (1) *Discorbina polystomelloides*, at three different stations among the islands south of New Guinea, namely, off Booby Island in 6 to 8 fathoms, off Wednesday Island and Flinders' Passage, and the Australian coral reefs.

(2) *Polystomella macella*, northern temperate zone, the Mediterranean and Adriatic being apparently its northern limit. As fossil it has been

Table of Results of Examination of Material from Deep Bore at top of Bank, south side of Cleongart Glen, Kintyre.

[*Height of Surface 253 feet above the level of the Sea.*]

Depths of Bore =	76 ft.	78½ ft.	79½ ft.	80 ft. 10 in.	82 ft. 10 in.	85 ft.	87½ ft.	91 ft. 5 in.	92 ft. 5 in.	94 ft. 9 in.	95 ft. 9 in.	96 ft. 2 in.	97 ft.
Mud, per cent.	77	92½	73	71	65	80	83	18½	86	73½	75	77	62⅓
Sand „	8	2	6	9	23	9	5	4½	4	17	18	9⅓	24½
Gravel „	15	5½	21	19	12	11	7	6	10	9½	7	13¾	13
Colour of dry clay	Light brown	Light brown	Light brown	Light brown	Light brown	Light brown	Dark bluish	Dark bluish	Dark bluish	Light brown	Light brown	Light brown	Light brown. reddish
MOLLUSCA	—	—	—	—	—	—	A few fragments	—	—	—	—	—	—
ANNULOSA: *Ostracoda*													
Cythere concinna, *Jones*	—	—	1	—	—	—	—	—	—	—	—	—	—
„ dunelmensis, *Norman*	—	1	—	—	—	—	—	—	—	—	—	—	—
„ viridis, *Müller*	1	—	—	—	—	—	—	—	—	—	—	—	—
ECHINODERMATA: *Echinodermata*	—	—	—	—	—	—	A few fragments	—	—	—	—	—	—
PROTOZOA: *Foraminifera*													
Biloculina elongata, *D'Orb.*	—	2	—	—	—	—	—	—	—	—	—	—	—
„ ringens „	—	3	1	—	—	—	—	—	—	—	—	—	—
Bulimina pupoides „	—	—	—	—	—	½	—	—	The only organic remains seen in this parcel was the base end of an *Amphidotus*, and two or three seeds, which have been scarce in any of the parcels	—	—	—	—
Discorbina polystomelloides, *Parker & Jones*	1	—	1	—	1	4	1	—		—	3	1	1
Lagena globosa, *Mont.*	—	—	—	—	—	2	—	—		—	—	—	—
„ lucida, *Will.*	—	1	—	—	—	—	—	—		—	—	—	—
„ caudata	—	—	—	—	—	—	—	1		—	—	—	—
„ squamosa, *Mont.*	—	—	—	—	—	1	—	—		—	—	—	—
„ striata, *D'Orb.*	—	—	—	—	1	—	—	—		—	—	—	—
„ Williamsoni, *Alcock*	—	—	—	—	—	1	—	—		—	—	—	—
„ variata	—	—	—	—	—	1	—	—		—	—	—	—
Miliolina Cuvieriana, *D'Orb.*	—	4	—	—	—	—	—	—		—	—	—	—
„ elongata, *Mont.*	—	1	—	—	—	—	—	—		—	—	—	—
„ Ferussacii, *D'Orb.*	1	—	—	—	—	—	—	—		—	—	—	—
„ semulinum, *Linn.*	—	2	—	—	—	—	4	—		—	—	—	—
„ trigonula, *Lamk.*	—	1	—	—	—	—	—	—		—	—	—	—
„ venusta, *Karrer*	—	—	—	—	1	—	—	—		—	—	—	2
Nonionina depressula, *W. & J.*	—	1	2	—	1	—	—	—		—	1	—	—
„ Boneana, *D'Orb.*	—	—	—	—	—	—	—	3		—	—	—	—
„ orbicularis, *Brady*	—	—	6	2	1	—	—	—		—	—	—	—
„ scapha, *F. & M.*	—	—	—	—	—	—	2	—		—	—	6	—
„ stelligera, *D'Orb.*	2	1	3	1	3	3	3	2		—	2	3	1
Polystomella macella, *F. & M.*	—	—	—	—	4	Many	—	2		—	—	2	—
„ striato-punctata, *F. & M.*	—	1	—	Many	Common	Common	—	4		4	6	Many	4
Pulvinulina Karsteni, *Reuss*	—	—	—	—	3	—	1	—		—	—	—	—
Rotalia orbicularis, *D'Orb.*	1	3	—	8	Common	Common	Common	Common		5	4	1	Common
No. of species of *Foraminifera*	4	11	8	4	10	1	6	6	—	2	5	6	5

found in the Eocene of Paris (*Terquem*), in the Miocene of Vienna (*D'Orbigny*), and in the Tertiaries of Italy (*Reuss*); the Crag of Suffolk (*Jones, Parker and Brady*), and the Post-Pliocene of Calabria (*Seguenza*).

(3) *Rotalia orbicularis*, north and south Atlantic, the Mediterranean and Red Sea; its northern limit appears to be about latitude 60° N. in the Atlantic, and its southern boundary about latitude 43° S. in the southern ocean, in depths from 100 to 2,400 fathoms. Fossil, London Clay (*Jones, Parker and Brady*), and in Post-Tertiary deposits, Norway (*Crosskey and Robertson*).

Their wide southern distribution seems to suggest that their true home had not been in a glacial sea.

Similar evidence was obtained at Clava regarding the occurrence of certain species of Foraminifera, characteristic of warm-temperate and sub-tropical seas (Report on Clava, 1893).

VII. *Conclusion.*

In presenting this report on the shell-bearing deposits of Kintyre, the members of the Committee have endeavoured to give an impartial statement of the evidence bearing on the nature of these deposits; leaving those interested in the question of their origin to draw their own conclusions from the ascertained facts.

The Committee have again had the great benefit of Dr. David Robertson's co-operation in examining the samples of clay taken from the sections and the borings. This he has done with all his wonted care and minuteness, and the value of his Report will be appreciated by all who are interested in these researches.

Mr. P. F. Kendall, another member of Committee, also examined a parcel of the shelly clay from the main section at Cleongart, and his observations so far corresponded with those of Dr. Robertson.

The maps and section exhibited to the Geological Section were carefully prepared by Mr. Fraser, C.E., of Inverness, from measurements taken by him during a visit to the locality in the summer of the present year.

Selangor Caves.—Preliminary Report of the Committee, consisting of Sir W. H. Flower (*Chairman*), Dr. R. Hanitsch, Mr. Clement Reid, Mr. H. N. Ridley (*Secretary*), *and* Mr. A. Russel Wallace, *appointed to explore certain Caves in the Neighbourhood of Singapore, and to collect their living and extinct Fauna.*

Mr. Ridley reports that, being single-handed at the Botanical Gardens, he has been unable yet to explore the Selangor Caves. He expects, however, to be able to run over for a few days at Christmas, so as to arrange a plan of campaign. He could then undertake the work in February or March, when the rainfall is less. Mr. Ridley has now seen the white snake which inhabits the caves, and is said to live on bats; it is not blind, but has large eyes. The Committee ask to be re-appointed, with renewal of the unexpended grant.

The Relation of Palæolithic Man to the Glacial Epoch.—Report of the Committee, consisting of Sir JOHN EVANS (*Chairman*), Miss E. MORSE, Mr. CLEMENT REID (*Secretary*), Mr. E. P. RIDLEY, *and* Mr. H. N. RIDLEY, *appointed to ascertain by excavation at Hoxne the relations of the Palæolithic Deposits to the Boulder Clay, and to the deposits with Arctic and Temperate Plants. (Drawn up by the Secretary.)*

THIS Committee was appointed with the object of clearing up certain doubtful points as to the relation of Palæolithic man to the Glacial epoch. Hoxne, on the borders of Norfolk and Suffolk, was selected as the best locality for the investigation, for Palæolithic implements and various fossiliferous strata were there known to occur in close proximity to undisturbed Boulder Clay, and it was probable that a single excavation would be sufficient to decide several of the disputed questions. A few words as to previous investigations will explain the state of our knowledge when the Committee commenced work.

Previous Observers.

John Frere, in 1797, recorded in a letter the occurrence of abundant Palæolithic implements.[1] These seem to have been obtained from the northern end of the pit, now abandoned and overgrown with oak-trees apparently about ninety years old. Implements seem to have been more plentiful there than in the part now worked, for Frere speaks of the occurrence 'at the rate of five or six in a square yard.' One in about ten square yards is nearer the rate at the present day.

Mr. John Evans was the first of late years to call attention to Frere's discoveries, and he visited Hoxne with Mr. Prestwich. They sank some pits in 1859.[2]

In 1860 and 1864 Professor Prestwich published descriptions of the strata at Hoxne, showing that certain beds with leaves and freshwater shells underlay the Palæolithic deposits, and that these lacustrine strata rested on Boulder Clay.[3]

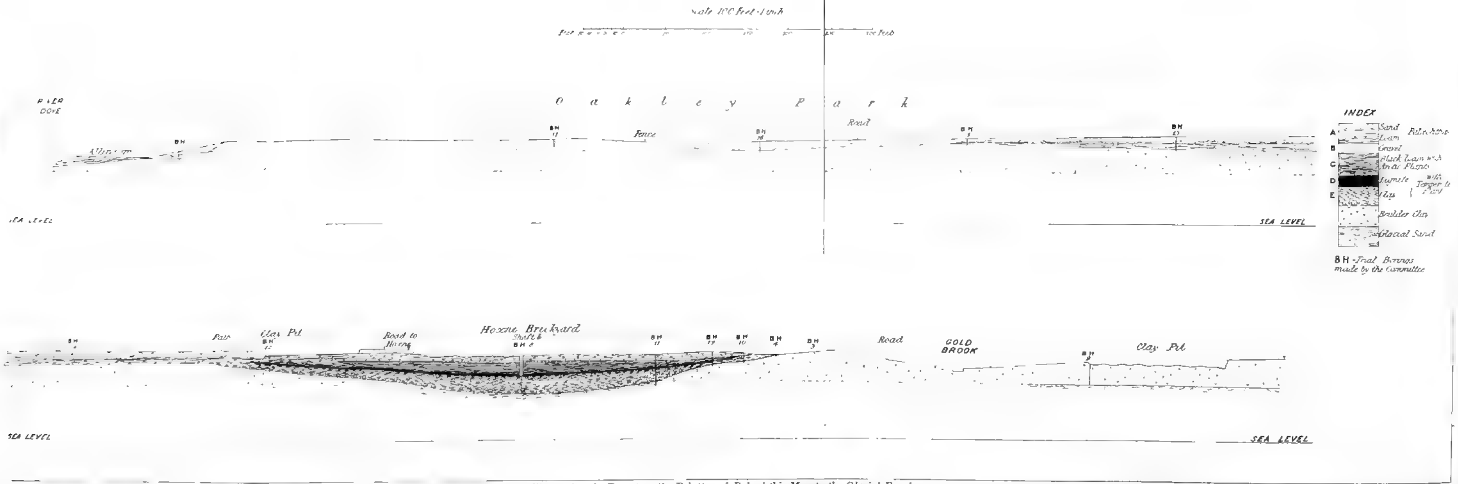
Thomas Belt subsequently (in 1876) tried to prove the interglacial age of the implement-bearing loams, laying special stress on the occurrence in the pit in Oakley Park of a small patch of Chalky Boulder Clay overlying the loam.[4]

A year or two later Mr. H. B. Woodward and Mr. Clement Reid examined a new cut made to drain the brickyard into Gold Brook, and saw Palæolithic deposits resting on Chalky Boulder Clay.

In 1888 Mr. Clement Reid and Mr. H. N. Ridley found that the patch of Boulder Clay noticed by Belt above the Palæolithic deposits was

[1] *Archæologia*, vol. xiii. p. 204, two pp. and two 4to plates of implements.
[2] *Ibid.*, vol. xxxviii. p. 299; Ancient Stone Implements, 1872, p. 517.
[3] *Phil. Trans.*, vol. cl. pp. 304–308, pl. xi., and cliv. p. 283.
[4] *Quart. Journ. Sci.*, n.s., vol. vi. pp. 289–304.

Geological Section through Hoxne Brickyard



Illustrating the Report on the Relation of Palaeolithic Man to the Glacial Epoch.

merely the remains of some clay brought to the pit, and that this Boulder Clay distinctly rested in one place on the recent vegetable soil. They also discovered numerous Arctic plants in the clays, but were unable to ascertain the exact relations of the deposits, for the pit was full of water.[1] They returned, therefore, in 1895, and made a series of borings, which pointed to a succession like that now demonstrated; but, as the results were not conclusive, the manuscript notes[2] were reserved for incorporation in this Report.

Field Work.

The Committee hoped to commence work at Hoxne immediately after the close of the Ipswich meeting; but unexpected difficulty was met with in obtaining permission to make the excavations, so that the most favourable season was thus lost. Nothing could be done during the winter; but as soon as the days became longer and the weather more propitious, renewed application was made, and Mr. Stafford, on behalf of the owners, immediately granted the necessary facilities. On March 23 Mr. Clement Reid went to Hoxne, and remained in charge of the work throughout, Mr. E. P. Ridley, of Ipswich, visiting the place twice during the ten days. During these days a pit was sunk in the brickyard to a depth of 20 feet, and a boring from the bottom of this pit was carried 22 feet lower, till the glacial sands were reached. The Section obtained, and the large samples of the strata taken to London for examination, proved of so great interest that it was thought desirable to complete the investigation by continuing the chain of borings right across the old basin or channel. Permission to bore in Oakley Park was at once given by Mr. Hay, the tenant of the estate, and an application was made by Sir John Evans and Sir Archibald Geikie to the Royal Society, which granted an additional sum of 30*l.* With this grant stronger boring tools were hired from Messrs. Le Grand and Sutcliff, and work was recommenced on May 6, Mr. Reid again taking charge for the fortnight that it lasted. Twelve additional borings were made, and as nine of these reached the base of the lacustrine deposits, we have now sufficient evidence to draw an accurate Section across the ancient silted-up channel (see Plate).

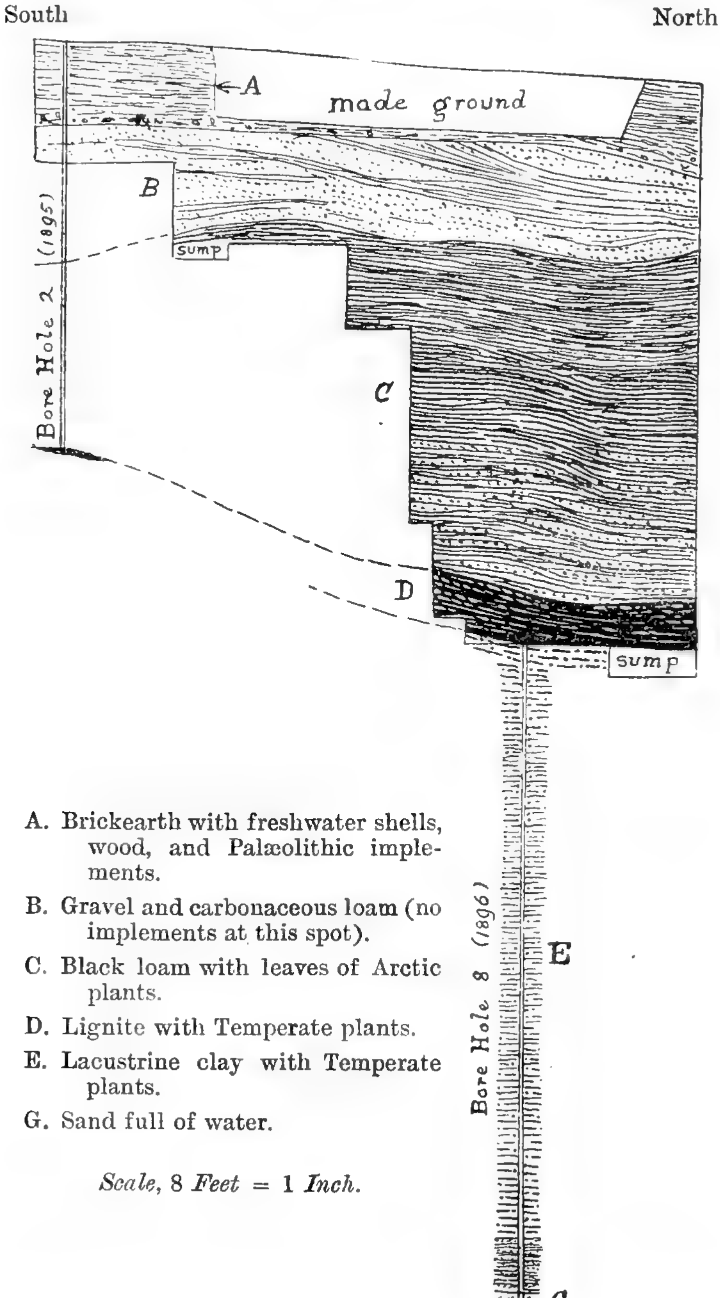
Having the experience of 1888 and 1895 to guide them, they were able at once to select the spot where the buried channel was probably deepest, and where each of the deposits contained in it was fossiliferous. The site selected had, in fact, one of the trial borings of 1895 (BH 2) at its southern end, and it was within 3 or 4 yards of the flooded pit out of which the Arctic plants discovered in 1888 had been thrown. The length of the hole was 23½ feet, and the breadth nearly 4 feet, the intention being to work the clay in steps, as the men are accustomed to do. It was found, however, that the lacustrine deposits were considerably thicker than had been estimated, so after a time the hole was reduced to a vertical shaft, the material and water being removed by a well-sinker's tub and windlass. The Section (fig. 1) will explain the mode of work. The principal, in fact the only real, difficulty met with was due to a spring flowing from the gravel at the south end of the pit. This necessitated constant attention; a sump was made to prevent the lower working being flooded, and the water was baled out from this sump. The lower part of the pit yielded little water, but the spring above filled the pit to within 5 feet of the

[1] *Geol. Mag.*, new ser., dec. iii., vol. v. pp. 441–444.
[2] Read at the Ipswich meeting, 1895.

surface every night, so that much time was occupied each morning in removing this water.

At a depth of 20 feet below the present surface they had sunk through

FIG. 1.—Trial Pit and Borings in Hoxne Brickyard.



A. Brickearth with freshwater shells, wood, and Palæolithic implements.

B. Gravel and carbonaceous loam (no implements at this spot).

C. Black loam with leaves of Arctic plants.

D. Lignite with Temperate plants.

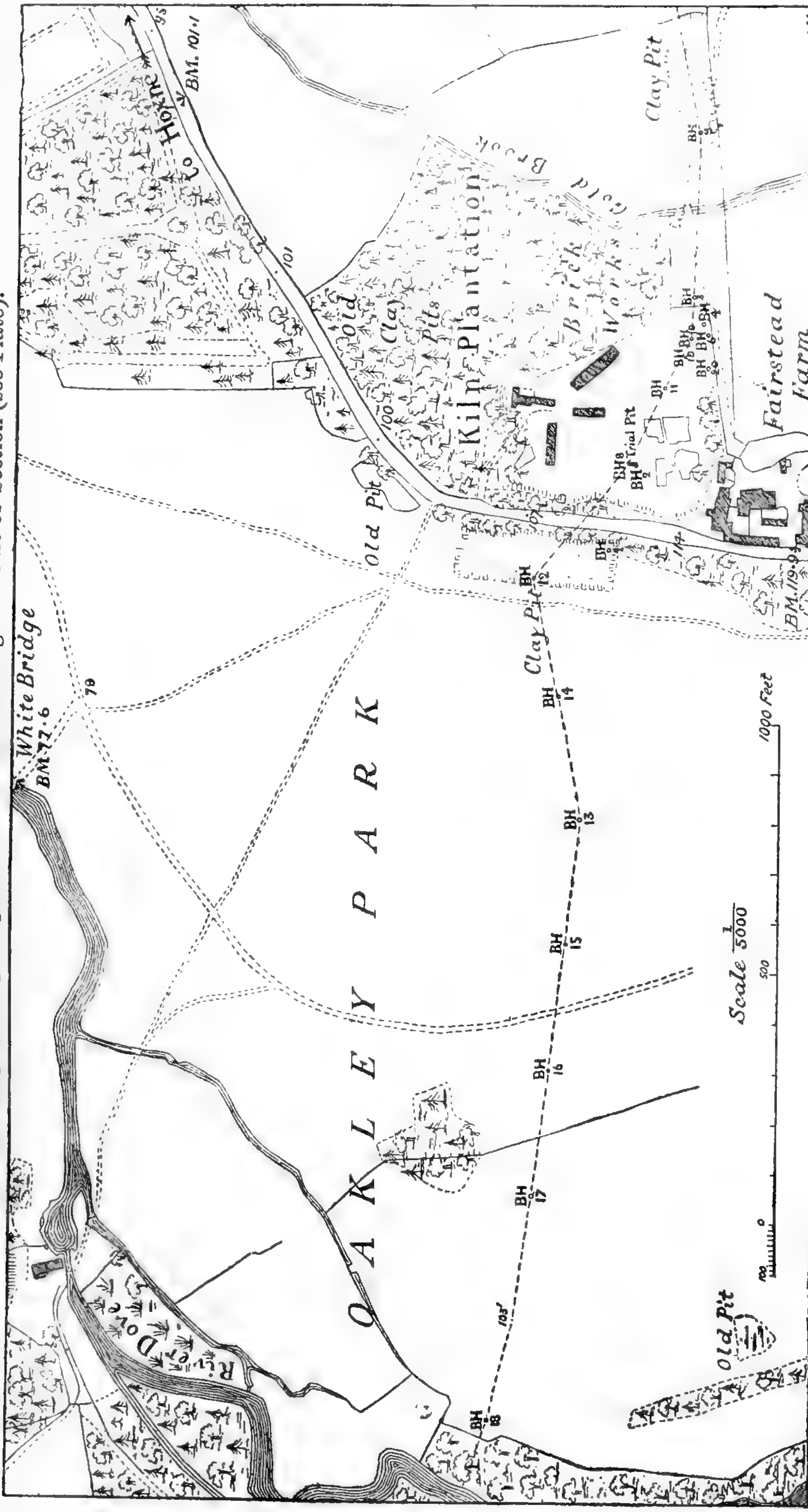
E. Lacustrine clay with Temperate plants.

G. Sand full of water.

Scale, 8 *Feet* = 1 *Inch*.

Palæolithic brickearth and gravel; through beautifully laminated loams with leaves of Arctic plants; through a seam of lignite, and a foot into a hard green lacustrine clay. The lignite and the sandy lower part of the Arctic leaf-bed looked treacherous, and needed careful timbering; it was

FIG. 2.—Map showing the position of the Trial Borings and line of Section (see Plate).

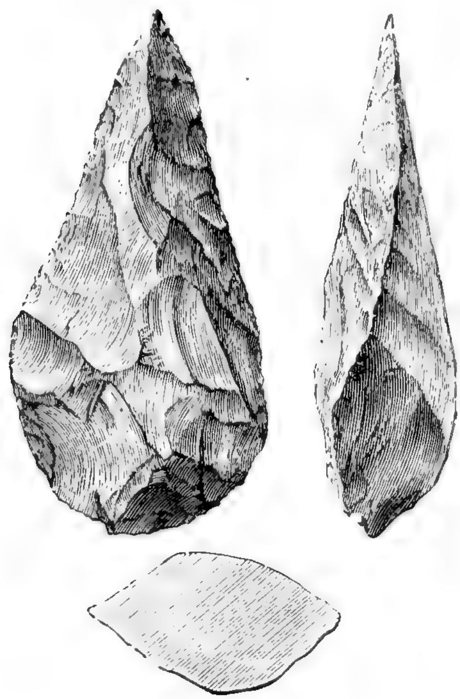


therefore decided to give up sinking and to bore to the base of the lacustrine clay. This was reached at a depth of $41\frac{1}{2}$ feet from the present surface—*i.e.* about 51 feet from the old surface before the brickyard was worked. Directly the auger penetrated the clay and sank into the sand below, water rose so as to stop work ; there was no need, however, to bore further, as the doubtful points were already settled.

As the work progressed large samples were selected from each fossiliferous bed for further examination, and to prevent any chance of mixture the boxes from Bed C were nailed up and sent away before the lignite below was disturbed. These samples have been minutely examined and washed for fossils in London, Miss Morse undertaking part of Bed C, and Mr. Reid superintending the washing of the others.

As Boulder Clay was the only deposit met with in the borings, and

FIG. 3.—Palæolithic Implements from Hoxne
(Sir John Evans, 'Stone Implements,' fig. 450).



not seen in the trial-hole, there is no necessity here to describe each boring in detail ; the particulars will be found in the Appendix, and the position of each is marked on the Map and Section. Suffice it here to say that they show clearly the contour of the ancient channel, prove that it is narrow, and excavated through glacial deposits, and show that the Chalky Boulder Clay (the latest Boulder Clay of Suffolk) lies beneath all of the lacustrine deposits. The chain of borings was carried approximately east and west, so as to cross the old channel nearly at right angles. A few borings out of the line of section seem to indicate that the channel runs nearly north and south. It was out of the question to trace out the course of the channel, for it makes no sign at the surface, and to follow it would need a multitude of borings, most of which would be of little or no interest.

Description of the Deposits and their Fossils.[1]

Bed A.

This is the only deposit usually exposed in the brickyard, and from it the Palæolithic implements (see fig. 3) are obtained. Hoxne Brickyard for many years seems to have been worked mainly for this upper brick-earth, from which are made the red bricks. It thus happens that over an extensive area nearly the whole of Bed A has been removed, and the sides of the pit are so overgrown that it is difficult to obtain detailed measurements. There are clear sections, however, on the opposite side of the road in the new pit in Oakley Park where this brickearth is now worked; the material from which were obtained the fossils given in the list was therefore taken from that pit. The sections in the old yard, as far as they can now be examined, are similar, and fossils and flint implements occur there in the same manner.

Clay Pit in Oakley Park, N. face; surface about 107 feet above the sea level.

	Feet.
Sandy soil	3
Bluish green loam and race (to water)	4
Laminated loams, freshwater shells and cyprids from below water-level	7

During the last two years three implements have been obtained from this spot, usually at a depth of from 5 to 7 feet from the surface. Bones are rare, but we obtained from the men some belonging to horse and deer, and apparently to elephant. Samples of the laminated shelly loams taken in 1896 yielded the species of mollusca and plants mentioned below. The bones were obtained from the workmen in 1888 and 1895.

Mammalia.

Homo (implements)
Equus Caballus, *L.* (teeth)
Cervus (bone)
Bos (bone)
Elephas (fragment of large bone)

Fish.

Indeterminable bones.

Crustacea.

Ostracoda.

Mollusca.

Limnæa glutinosa, *Müll.*
Limnæa peregra, *Müll.*
Planorbis albus, *Müll.*
„ Nautileus, *Linn.*
„ nitidus, *Müll.*
„ spirorbis, *Müll.*
Valvata piscinalis, *Müll.*
Bythinia tentaculata, *Linn.*
„ Leachii, *Shep.*
Pisidium pusillum, *Gmel.*
„ pulchellum, *Jenyns.*
Sphærium corneum, *Linn.*
Unio or Anodon.

Plants.

Alnus? (wood).
Potamogeton.
Chara.

The list contains no species characteristically either northern or southern, and even the assemblage throws little light on the climatic conditions. *Limnæa glutinosa*, not previously recorded as a British fossil, does not extend far north; but the rest of the mollusca range from the Arctic regions to the south of Europe, and all of them are to be found

[1] For convenience of reference the fluviatile and lacustrine strata have been lettered A to E (see Plate and fig. 1).

living within a few miles of Hoxne. The mammals are widely migrating species.

The borings show that the fossiliferous Palæolithic brickearth when traced westward overlaps the other fluviatile deposits, to rest at last immediately on Boulder Clay. They indicate also that the laminated brickearth entirely disappears about the middle of Oakley Park, where it abuts against a slight ridge of Boulder Clay (close to BH 15). West of that point Bed A is represented by a sheet of gravelly sand, perhaps more suggestive of eolian than of fluviatile action (see Plate).

Bed B.

There is commonly to be found at the base of the Palæolithic brickearth a seam of fine gravel mixed with vegetable matter. This gravel was 2 or 3 feet thick in our trial pit, but it contained neither implements nor fossils. As, however, it yielded a small worked flake in one of our trial borings (BH 1 of 1895), it deserves separate notice, especially as Frere appears to have obtained his implements from this gravel, and not from the brickearth above. A good implement found in 1877 by Messrs. H. B. Woodward and Clement Reid, at the east side of the brickyard, seemed also to have come from this horizon.

Bed C.

Immediately beneath the Palæolithic deposits is found the 'black earth' of the brickmakers, though the term is also sometimes applied to carbonaceous parts of the upper deposit. This black earth has only been partly dug over the area already worked for Bed A. It is used for white bricks, which are less in demand than the red ones, and as the pits become flooded when digging ceases sections are seldom visible.

In the trial-pit this black earth was found to be 13 feet in thickness. It consists of alternating thin layers of carbonaceous loam, sand, and vegetable matter, sand and small clay-pebbles becoming very abundant in the lower part. Vegetable remains, such as decayed leaves, twigs, and seams of moss, are so abundant as to render the loam fissile throughout. Scattered freshwater shells occur, though not in great numbers or in much variety. Fish bones also occur ; but no trace of large mammalia was found, and the workmen state that they have never come across any bones below Bed A. The distal end of a small indeterminable mammalian femur was obtained on washing some of the material.

The leaves so abundant in Bed C always belong to three species of dwarf Arctic willow, or, more rarely, to the dwarf Arctic birch. The twigs and stems retaining their bark also belong evidently to the same species. Though fragments of larger wood occur, these are always worn, without bark, and have probably been derived from the destruction of Beds D and E. A single waterworn nut of the hornbeam and one or two broken seeds of yew must be placed in the same category, and several other plants, only represented by woody seeds confined to the gravelly lower part of the deposit, are also in all probability only present as derivatives from the breaking up of the older deposits. An attempt has been made in the following list to distinguish between the derived and the contemporaneous floras ; but it should be understood that this separation is only made on the strength of the state of preservation of the specimens and their occurrence or non-occurrence in other beds than the seams of clay-gravel which undoubtedly contain derivative fossils. It will immediately occur to any botanist looking at the list that several of the plants, besides those marked as derivative, are species not likely to have lived with the dwarf Arctic willows and birch. But as we wish to use the list for the determination of the climatic conditions which reigned when the deposit was being formed, it is clear that we have no right first to reject certain species that seem to contradict the other evidence, and then to argue as though we were dealing with a homogeneous flora. We can say, however, that the fragile specimens, such as leaves, moss, and delicate seeds, which cannot have been washed out of an older deposit, all represent a homogeneous Arctic or high alpine flora. Trees, with the possible exception of the alder, seem to have been entirely absent, and the climate was probably not unlike that of the cold treeless regions of North America and Siberia.

Though so large a quantity of material was removed in our trial-pit, the number of leaves obtained in good preservation was not great; we obtained, in fact, fewer good specimens than in 1888. The reason of the decay of the leaves must be sought in the fact that we struck the centre of the old channel, where the deposits are exceptionally sandy, and the circulation of the water is greatest. We were able to preserve only the smaller tough leaves of *Salix myrsinites*, though larger decayed ones are not uncommon. Of *Betula nana* we have not been able to save a single fragment, although leaves were seen on splitting the wet loam. The following species were obtained on washing the material :—

Ranunculus aquatilis, *L.*
„ sceleratus, *L.*
„ repens, *L.* [derivative ?].
Caltha palustris, *L.*
Viola palustris, *L.*
Stellaria media, *Cyr.*
Montia fontana, *L.*
Rhamnus Frangula, *L.* [worn and derivative].
Rubus Idæus, *L.*
Poterium officinale, *Hook. f.*
Hippuris vulgaris, *L.*
Myriophyllum spicatum, *L.*
Œnanthe Phellandrium, *Lam.* [fruit very small].
Sambucus nigra, *L.* [derivative ?].
Eupatorium cannabinum, *L.*
Bidens tripartita, *L.* [a starved fruit].
Taraxacum officinale, *Web.*
Menyanthes trifoliata, *L.*
Lycopus europæus, *L.*
Ajuga reptans, *L.*
Rumex maritimus, *L.*
Rumex crispus ? *L.*
Urtica dioica ? *L.* [one seed].
Betula nana, *L.*
Alnus glutinosa, *L.* [perhaps derivative].
Carpinus Betulus, *L.* [derivative].
Salix myrsinites, *L.*
„ herbacea, *L.*
„ polaris, *Wahlb.*
Ceratophyllum demersum, *L.*
Taxus baccata, *L.* [derivative].
Sparganium ramosum, *Curtis.*
Alisma Plantago, *L.*
Potamogeton rufescens, *Schrad.*
„ crispus, *L.*
„ pusillus, *L.*
„ trichoides, *Cham.*
„ pectinatus, *L.*
Scirpus pauciflorus, *Lightf.*
„ setaceus, *L.*
„ lacustris, *L.*
Blysmus rufus, *Wahlb.*
Carex incurva ? *Lightf.*
Chara.

Mr. Mitten has kindly examined the mosses from this deposit, and records the following species :—

Amblystegium fluitans, *Mitt.*, fragments of stem with leaves, the leaves as usual varying in form and length of nerve, this last in some unusually long.

Acroceratium sarmentosum, *Mitt.*; fragments of stem with leaves.

Hylocomium squarrosum, *Bruch and Schimp.*; fragments of branches.

Amblystegium stellatum, *Mitt.*; fragments of stems.

Mnium; fragments of stems; species nearly related to *M. serratum*, but remarkable for having single teeth on the leaf margin and not gemminate as usual in European species.

Mnium; species nearly resembling *M. rugicum*.

He writes that 'all these seem to point to an origin in open moorland. *Acroceratium sarmentosum* is not now found on our plains, but is montane or sub-alpine; they are known to go very far into Arctic regions.'

The 1888 list adds the following species, though we cannot be perfectly sure that they are all from Bed C. They also were determined by Mr. Mitten :—

Brachythecium rutabulum, *Bruch and Schimp.*
Acroceratium cuspidatum, *Mitt.*
Philonotis fontana, *Brid.*
Webera albicans, *Schimp.*
Bryum pallens, *Sw.*
Mnium punctatum, *Linn.*

The animal remains associated with these plants are very few. They include only a small indeterminable mammalian bone, some Ostracoda, a few beetles, among which Mr. Waterhouse finds *Hylesinus fraxini?*, some small galls, and six species of freshwater mollusca :—

Limnæa sp.
Valvata piscinalis, *Müll.*
„ cristata, *Müll.*
Bythinia tentaculata, *Müll.*
Sphærium corneum, *L.*
Pisidium pusillum, *Gmel.*

No implements have yet been found in Bed C; but as the pits are in the centre of the channel or lake, and no stone over an inch in diameter was seen, negative evidence is of little value till the margin and gravelly deposits of the same age have been searched.

Bed D.

The character of the deposit changes suddenly immediately beneath the lowest seam containing Arctic willows, though the abruptness of the change is somewhat masked by the inclusion of derived material in the newer strata. Bed C rests on a mass of lignite from 1 to 3 feet in thickness. This lignite, at the spot where the trial-pit was sunk, evidently represents an ancient alder-carr growing in the old channel—just as alder-carrs now grow on the marsh-lands throughout the eastern counties. The bulk of the deposit is composed of alder-wood, retaining its bark, but more or less decayed, mingled with cones, seeds, and leaves of the same tree. The lignite contains also other seeds in profusion, but nearly all belong to a few swamp-loving plants, such as are usually to be found in an alder-carr, or in the pools or sluggish channels that intersect it. There is little or no drifted material, and the few plants that did not live on the spot are, with the exception of the hornbeam, berry-bearing species, the fruits of which are habitually dispersed far and wide by birds. Even the winged seeds of the thistle and dandelion, usually to be found in ancient alluvial deposits, are missing, and we have an extremely restricted flora, every member of which, however, grew in all probability within a few yards of the place where it is now found. The whole of the thirty-seven species of flowering plants now determined are still living in the county.

A few *Valvata piscinalis*, a *Pisidium*, one or two indeterminable fish-bones, and some elytra of beetles are the only animal remains yet met with in the lignite. Mr. Waterhouse observes among the elytra some belonging to *Donacia*, but they are too badly preserved to allow of specific determination.

The plants occurring in Bed D are :—

Ranunculus aquatilis, *L.*
„ sceleratus, *L.*
„ Lingua, *L.*
„ cf. repens, *L.*
Montia fontana, *L.*
Rhamnus Frangula, *L.*
Rubus Idæus, *L.*
Rosa canina, *L.*
Pyrus torminalis ? *Ehrh.*
Œnanthe Phellandrium (fruit very small).
Sambucus nigra, *L.*
Eupatorium cannabinum, *L.*
Bidens tripartita, *L.*
„ „ var. with 4 equal awns (wrongly referred in 1888 to *B. cernua*).
Mentha aquatica, *L.*
Lycopus europæus, *L.*
Stachys ? (1 badly preserved nutlet).
Rumex maritimus, *L.*
Rumex crispus, *L.*
„ Acetosella ? *L.* (1 nut).
Urtica dioica ? *L.* (fruit narrow).
Alnus glutinosa, *L.*
Carpinus Betulus, *L.*
Corylus Avellana, *L.*
Ceratophyllum demersum, *L.*
Taxus baccata, *L.*
Sparganium ramosum, *L.*
Alisma Plantago, *L.* (carpels small).
Potamogeton pusillus, *L.*
„ trichoides, *Cham.*
Eleocharis acicularis, *Sm.*
Scirpus pauciflorus, *Lightf.*
„ setaceus, *L.*
„ lacustris, *L.*
Blysmus rufus, *Wahlb.*
Eriophorum polystachion, *L.*
Carex distans ? *L.*
„ ampullacea ? *Good.*

The oak wood obtained by Professor Prestwich from the workmen may belong to this horizon, though none was met with in the trial-pit. The piece of pine-bark and the seed of cornel, found among disturbed material in 1888 by Messrs. Reid and Ridley, may both belong to recent specimens; these species therefore should not be included in the list without further corroboration. A pit sunk at the margin instead of in the centre of the channel would probably yield many more dry-soil species, and might also yield traces of man.

Mr. Mitten records the following mosses from this horizon, and it may be observed that the conclusions he comes to with regard to the climatic and other conditions under which Beds C and D were deposited agree closely with those arrived at from an examination of the flowering plants :—

Eurynchium striatum, *B. and S.*;	fragments of stem and branches.
Homalothecium sericeum, *B. and S.*;	„ branches.
Brachythecium populeum ? *B. and S.*	„ „
Thuidium tamariscinum, *B. and S.*	„ stem and branches.
Acroceratium cuspidatum, *Mitt.*	„ „ „
Steredon cupressiformis ? *Brid.*	„ branches.
Rhynchostegium, species ?	„ „
Mnium punctatum, *Linn.*	„ stem.
„ sp.	„ „ ; near to M. Seligeri.
Bryum sp.	„ „ ; may be B. ventricosum.
Dicranum scoparium ? *Hedw.*	„ leaves.

'These might be derived from a sylvan country in a temperate region of low elevation.'

Bed E.

The lignite just described rests on a mass of green carbonaceous clay with lacustrine shells, fish-remains, and a few drifted seeds belonging to the same plants as occur in the bed above. This clay is not used in the brickyard ; but our trial-pit was sunk about a foot into it, and then a boring was carried to its base. The upper part of the clay is green, hard, and tough, so that it breaks under the spade instead of cutting ; below it becomes rather softer and more carbonaceous ; at its base it contains an admixture of sand derived from the Glacial or Crag beds beneath. This clay is a most unmanageable deposit from which to obtain fossils. It does not show any tendency to go to pieces in water, even after thorough drying ; and long-continued boiling with soda does not help to disintegrate it. It seems to contain an admixture of animal matter, for in the flame it gives off smoke and smells strongly. The intractable nature of the matrix made it only possible to obtain the fossils by breaking the clay, and thus many of the seeds were destroyed or rendered indeterminable. The fossils obtained from this clay were :—

Fish.

Perca fluviatilis, *L.*
Leuciscus rutilus, *L.*

Mollusca.

Limnæa peregra, *Müll.*
„ glutinosa, *Müll.*
Planorbis albus, *Müll.*
„ Nautileus, *L.*
Valvata piscinalis, *Müll.*
Bythinia tentaculata, *Müll.*
Unio or Anodon
Sphærium corneum, *L.*

Plants.

Ranunculus Lingua, *L.*
„ repens, *L.*
Rubus Idæus, *L.*
Hippuris vulgaris, *L.*
Rumex maritimus, *L.*
Alnus glutinosa, *L.*
Ceratophyllum demersum, *L.*
Sparganium ramosum, *Curtis.*
Potamogeton trichoides, *Cham.*
Zannichellia palustris, *L.*
Scirpus lacustris, *L.*
Carex.

Boulder Clay.

The Boulder Clay at Hoxne calls for no special remark. It is a tough mass principally composed of Jurassic clay and fragments of Chalk, with scattered flints, septaria, and, more rarely, older rocks. Nearly all the stones are striated. This clay is in fact part of the extensive sheet of Chalky Boulder Clay which covers so large a part of our eastern counties. It can be well seen in the Clay-pit on the east side of Gold Brook, near the Brickyard (see Map, fig. 2).

Glacial Sand.

The sand beneath the Boulder Clay was reached at a depth of 24 feet in a boring (BH 9) put down in the Clay-pit just mentioned as occurring east of the Brickyard. Sand, apparently of the same age, was again met with in (BH 11) and in the boring (BH 8) made at the bottom of our trial-pit, where the Boulder Clay seems entirely to have been cut through before the lacustrine deposits were laid down. In this latter case, however, it is possible that Crag may have been reached, for the sandy base of Bed E was full of small derivative valves of *Balanus* such as are so abundant in the Norwich Crag.

Conclusions.

The facts gathered in the course of this inquiry enable us partly to trace the history of this old buried river-channel. It seems never to have been a channel of much importance, but more probably the valley of a small tributary stream than that of a river. Its history seems to have been as follows :—After the disappearance of the ice which deposited the Chalky Boulder Clay—how long after we do not know—the land stood somewhat higher than at present, so that the Hoxne channel could be excavated to a depth slightly below that of the present main channel of the river Waveney. Then gradual subsidence turned this channel into a shallow freshwater lake, in which 20 feet of the lacustrine clay E was deposited. After the lake had silted up it was overgrown by a dense thicket of alders, which by their decay formed the lignite D, containing a Temperate flora like that of bed E. Next a further slight subsidence, or perhaps an irregular silting up of the lower part of the channel, caused lacustrine conditions to reappear, and another 20 feet of lacustrine strata (C) to be deposited ; but the climate had again become colder—in fact it was now an Arctic or sub-Arctic one. Then followed the floods which deposited the Palæolithic Beds B and A, only parts of which seem to be truly fluviatile; and finally the strata became sandy and perhaps of eolian origin. To summarise :—The channel after being scoured to a depth equal to that of the existing valley of the Waveney, and considerably below that of its existing tributaries, the river Dove and Gold Brook, was filled up with fully 50 feet of sediment. It was in fact so completely filled that the streams have since taken quite different courses, and we cannot identify the Pleistocene channel as belonging to any existing valley.

During the excavation and silting up of the channel the climatic conditions seem to have changed at least twice. Of the nature of the transition from the Arctic conditions indicated by the Boulder Clay to the mild period represented by the lacustrine clay E and the lignite D we have at present no evidence. But of the existence of a mild period subsequent to the formation of the Chalky Boulder Clay and previous to the reappearance of Arctic conditions, we can now produce sufficient evidence in the long list of Temperate plants found in Beds D and E. The Palæolithic deposits at Hoxne are therefore not only later than the latest Boulder Clay of East Anglia, but are separated from it by two climatic waves, with corresponding changes of the flora. Such sweeping changes cannot have been local ; they must have affected wide areas.

It may perhaps be advisable before concluding to guard ourselves against any misapprehension as to the exact outcome of this inquiry. It is true that the evidence is now perfectly clear that the well-known Palæolithic implements of Hoxne are much later than the Boulder Clay of that district. But it by no means follows that man did not live in the district while the Arctic leaf-bed C or the lacustrine strata D and E were being deposited, though no implements (or stones of any sort over an inch in diameter) were found in them. It is possible that in other districts man may be inter-Glacial or pre-Glacial, but on this question the Hoxne excavations throw no light ; they only show that a race of men using implements of the Hoxne type certainly inhabited Suffolk long after the latest glaciation of that district. Whether precisely the same form of implement is likely to have been in use in Britain in both pre-Glacial and post-Glacial times is a question into which we need not enter.

APPENDIX.

Borings made in 1895 *by* CLEMENT REID *and* H. N. RIDLEY, *and* 1896 *by the Committee* (*for exact positions see Map, p.* 403. *The heights were obtained with Abney's level and are approximate only*).

BH 1. In the Brick-pit in Oakley Park, about 15 feet from the south face. Surface above 115 feet above O.D., boring commenced at 105 feet.

	Feet.
Made ground	2
A Blue loam	2
B Sandy gravel with flint flakes	4½
C Black loam full of roots	8
D Lignite (not penetrated)	¼
	16¾

BH 2. In Brickyard close to the hole from which Arctic plants were obtained in 1888 and at S.W. corner of trial-pit of 1896. Surface 101 feet above O.D. (about 10 feet of earth already removed).

	Feet.
A Loam and freshwater shells	3
B Whitish sandy gravel and loam, no large stones	5
C Carbonaceous loam	6
D Clay and lignite	½
	14½

BH 3. In Brickyard, about 60 yards west of Gold Brook. Surface 100 feet above O.D.

	Feet.
Soil and made ground	1½
Chalky Boulder Clay	1
	2½

BH 4. In Brickyard, midway between Gold Brook and Fairstead Farm. Surface 103 feet above O.D.

	Feet.
Sandy wash	3
Chalky Boulder Clay	½
	3½

BH 5. In the road midway between Gold Brook and Fairstead Farm. Surface 107 feet above O.D.

	Feet.
Sand and sandy gravel, to large stone (which stopped boring)	5

BH 6. In the bank 5 feet below road from Gold Brook to Fairstead Farm and near gate into Brickyard. Surface 108 feet above O.D.

	Feet.
A Gravelly sand	5
A ? Blue clay with *Valvata* at top	5
Hard blue clay full of Chalk (Boulder Clay)	1
	11

BH 7. In the Brickyard close to the pump. Surface 98 feet above O.D. (boring stopped by rain).

		Feet.
	Made ground	5
C	Black loam with plant remains and *Pisidium*	2
D	Lignite and mud with Alder ? &c.	$3\frac{1}{2}$
E	Hard greenish clay with Fish remains, Ostracoda, *Planorbis albus*, *Bythinia tentaculata*, *Valvata piscinalis*, *Ranunculus repens*, *Carex*	4
		$14\frac{1}{2}$

BH 8. Commences at bottom of trial-pit (see fig. 1).

BH 9. In Clay-pit E. of Gold Brook. Surface 89 feet above O.D.

	Feet.
Chalky Boulder Clay, hard and dry	24
Sand (water rose $6\frac{1}{2}$ feet)	1
	25

BH 10. E. corner of Brickyard. Surface 102 feet above O.D. (7 feet below old surface).

		Feet.
	Made ground (dug about 1884; apparently in part Bed A, though no gravel here separated it from the bed below)	5
E	Black carbonaceous loam, with scattered quartz grains, small splinters of flint, and *Pisidium pusillum*	$3\frac{1}{2}$
	Chalky Boulder Clay (not pierced)	$6\frac{1}{2}$
		15

BH 11. Close to BH 7 of 1895. Surface 98 feet above O.D.

		Feet.
	Made ground	1
C	Black carbonaceous loam with leaves, moss, and small twigs	7
D	Clayey lignite with small roots (?) throughout. Seed of Yew in upper part	$2\frac{1}{2}$
E	Hard green clay, with small freshwater shells, becoming softer and more carbonaceous below	17
E	Carbonaceous clay and seams of sand	$\frac{1}{2}$
	Sand, full of water (glacial ? or base of E ?)	1
		29

BH 12. In Clay-pit in Oakley Park, opposite middle of western face. Surface 104 feet above O.D. (original surface about 113 feet).

		Feet.
	Made ground	5
A ?	Bluish loamy and carbonaceous brickearth	1
D	Black peaty lignite	1
E	Hard green clay with freshwater shells; *Valvata* in the upper part	7
E	Hard clay, greenish and black	4
E	Chalky clay with a little lignite and freshwater shells	1
Boulder Clay	Chalky Boulder Clay with small roots in the top foot	7
Boulder Clay	Lead-coloured marl, no stones	2
Boulder Clay	Chalky Boulder Clay, as above, but hard stones more abundant (not pierced)	8
		36

BH 13. In the middle of Oakley Park. Surface about 110 feet above O.D.

		Feet.
A	Sandy soil	1
	Sand	2
	Sandy loam	2
	Sand and brickearth alternating	5
	Darker carbonaceous loam. *Valvata piscinalis*, *Unio*, Cyprids at 13 ft.; *Pisidium pusillum* and small twigs at 14 ft.	5
	Chalky clay with twigs	$\frac{1}{2}$
	Hard Chalky Boulder Clay	$1\frac{1}{2}$
		17

No trace of Beds B, C, D, or E was met with.

BH 14. In Oakley Park. Surface 118 feet above O.D.

		Feet.
A	Loamy sand with a few scattered stones	$7\frac{1}{2}$
	Bluish carbonaceous clayey loam, with occasional twigs and freshwater shells	7
	Lead-coloured Chalky Boulder Clay	$4\frac{1}{2}$
		19

BH 15. In Oakley Park. Surface 101 feet above O.D.

		Feet.
A	Sand and a few stones	$2\frac{1}{2}$
	Loamy sand and loam	1
	Bluish loam and freshwater shells	$1\frac{1}{2}$
	Clay with Chalk pebbles	$\frac{1}{2}$
	Freshwater shell-marl	$\frac{1}{2}$
Boulder Clay	Chalky Boulder Clay	3
	Gravelly loam and water	$\frac{3}{4}$
	Chalky Boulder Clay	$\frac{1}{4}$
		10

BH 16. In Oakley Park. Surface 97 feet above O.D.

		Feet.
	Sandy soil	3
A	Sand and a few stones	$1\frac{1}{2}$
	Loamy sand and scattered stones	$2\frac{1}{2}$
	Whitish sandy loam	3
	Grey loam	$\frac{1}{2}$
	Chalky Boulder Clay, very tough and hard	$2\frac{1}{2}$
		13

BH 17. In Oakley Park. Surface 101 feet above O.D.

	Feet.
Gravelly sand	$8\frac{1}{2}$
Gravelly loamy sand (boring stopped by a large stone before Boulder Clay was reached)	1
	$9\frac{1}{2}$

BH 18. In Oakley Park, near the river Dove, and 8 feet above the Alluvium level. Surface 86 feet above O.D.

	Feet.
Gravelly sand and a few stones (apparently all rainwash from the slope above)	9
Chalky Boulder Clay (not pierced)	8
	17

BH 19. In Brickyard. Surface 104 feet above O.D. and 8 feet below old surface.

		Feet.
	Made ground	5
A	Light blue brickearth (base of A ?)	2
C	Black loam	3
E	Hard green clay	1
	Green and black clay, quartz grains in lower part	2½
	Carbonaceous clay and Chalk pebbles	½
	Chalky Boulder Clay, penetrated by small roots	1
		15

BH 20 and section in bank, in the Brickyard near the pug-mill. Surface 111 feet above O.D.

		Feet.
A	Gravelly sand } seen in the bank	6
	Sand and sandy loam } seen in the bank	2
	Grey loam	6
C	Carbonaceous loam and plant remains, very black below (perhaps base of A)	1
E	Hard green clay	5
	Green and black clay	1
		21

Life-zones in the British Carboniferous Rocks.—Report of the Committee, consisting of Mr. J. E. MARR (*Chairman*), Mr. E. J. GARWOOD (*Secretary*), *and* Mr. A. H. FOORD, *appointed to study the Life-zones in the British Carboniferous Rocks.* (*Drawn up by* Mr. GARWOOD.)

IN a paper read before the British Association at Ipswich, in 1895, two of us called attention to the work of Dr. Waagen on the Upper Palæozoic rocks of the Salt Range, and gave reasons for supposing that the Carboniferous rocks of Britain might be divided into zones.[1] In that paper it was suggested 'that a Committee be appointed to inquire into the possibility of dividing the Carboniferous rocks into zones, to call the attention of local observers to the desirability of collecting fossils with this view, and, if possible, to retain the services of eminent specialists to whom these fossils may be submitted.' This Committee was appointed, and the members thereof beg leave to submit their report.

The Committee believe that the following districts would furnish good results, and recommend that those whose names are appended to the various districts be asked to take charge of their particular districts and to endeavour to carry out therein the objects of the Committee :—

England and Wales: Northumberland and the Border, Professor G. A. Lebour; Northern part of Pennine chain and adjoining regions, Messrs. Garwood and Marr; Southern part of ditto and adjoining regions, Mr. P. F. Kendall and Dr. Wheelton Hind; North Wales, Mr. G. H.

[1] See *Rept. Brit. Assoc.* 1895, p. 696.

Morton; South Wales, Mr. A. Strahan; Devon, &c., Mr. Howard Fox and Dr. G. J. Hinde.

Isle of Man: Mr. G. W. Lamplugh.

Scotland: Mr. B. N. Peach.

Ireland: Mr. A. H. Foord.

The Committee recommend that the following directions for working be communicated to the various workers:—

1. When possible, a typical measured section should be given of each locality examined, with notes of as many confirmatory sections as possible.

2. Any specimen not actually found *in situ* to be labelled to that effect, with the exact conditions under which it was found noted.

3. All specimens should be labelled with the local name of the bed, giving as many additional details as possible, and in all cases the exact locality, which should further be noted on a large-scale map.

4. All specimens should be labelled *when found*.

5. So far as possible, workers are recommended to collect from one bed at a time, and to pack the specimens from each bed in a separate parcel before commencing to collect from another bed.

6. Attention should be paid to apparently identical forms separated by many feet or yards of deposit, as the forms may be *mutations*; large suites of such specimens should be collected; indeed—

7. As large a number of specimens as possible should be obtained of each species in every bed examined.

8. Absence of fossils in any bed should be noted whenever possible.

9. Attempts should be made to record the relative abundance of fossils, which may be roughly done by recording those which are very rare (*v. r.*), rare (*r.*), common (*c.*), and very common (*v. c.*).

10. In case of beds being obviously rich in micro-organisms, large pieces should be collected for future examination.

11. Considering the importance which cherts have assumed, it is very desirable to collect specimens of cherts.

Specimens may be kept by the discoverers or forwarded to the Secretary of the Committee (E. J. Garwood, Dryden Chambers, 119 Oxford Street, London, W.) on loan or for retention.

The Committee recommend that the names of those whom they have mentioned as likely to undertake the charge of districts be added to the Committee, and that the following palæontologists be asked to co-operate with the other members, and to identify such fossils as may be submitted to them, their names being also added (when not previously mentioned) to those of the Committee:—Dr. G. J. Hinde (radiolaria and sponges), Professor H. A. Nicholson (corals), Mr. J. W. Kirkby (entomostraca), Dr. H. Woodward (other crustacea), Mr. F. A. Bather (echinoderms and brachiopods), Dr. Wheelton Hind and Mr. E. J. Garwood (lamellibranchs and gastropods), Messrs. G. C. Crick and A. H. Foord (cephalopods), Dr. R. H. Traquair (fish), and Mr. R. Kidston (plants).

The Committee recommend that a grant of 15*l.* be applied for in order to pay for the services of collectors, who are to be under the direction of the Secretary of the Committee.

[In bound reprint, pp 1-34

The Marine Zoology, Botany, and Geology of the Irish Sea.—Fourth and Final Report of the Committee, consisting of Professor A. C. HADDON, Professor G. B. HOWES, Mr. W. E. HOYLE, Mr. CLEMENT REID, Mr. G. W. LAMPLUGH, Mr. I. C. THOMPSON, Dr. H. O. FORBES, Mr. A. O. WALKER, Professor F. E. WEISS, *and* Professor W. A. HERDMAN (*Chairman and Reporter*).

THIS Committee have now been at work for four years. It is difficult, however, to dissociate this work from the previous and the contemporaneous work carried on by the Liverpool Marine Biology Committee. Consequently it will probably best serve the interests of science if this final report be made to include references to all the work that has been done of recent years on the marine fauna and flora of the Irish Sea.

HISTORICAL.

A good deal of exploring work in the Irish Sea has been done in the past by Edward Forbes, McAndrew, Price, Byerley, Marrat, Moore, Higgins, Collingwood, and others; but the more modern investigations date from the formation of the Liverpool Marine Biology Committee in March 1885. After a year's work on the investigation of the fauna and flora of Liverpool Bay and the neighbouring seas, the Committee published in January 1886 the first volume of 'Reports upon the Fauna of Liverpool Bay.' In this first volume they recorded all previous speciographic work done in the district, and also the results of their own dredging and other collecting expeditions, amounting in all to 913 species, of which 235 had not been found before in the district (see fig. 1, p. 450).

During the second year's work the Committee felt the need of a biological station near to one of their richer collecting grounds, and so the Puffin Island Station was fitted up and opened in May 1887. At the end of that year the first annual report was issued under the title of 'The Foundation and First Season's Work of the Liverpool Marine Biological Station, Puffin Island.' From this time onwards an annual report on the work of the L.M.B.C. has been published at the end of each year, the ninth appearing in December 1895. The larger publications, the volumes of the 'Fauna,' have appeared at intervals of three years—the first in 1886, the second in 1889, the third in 1892, and the fourth in 1895. The records in the second volume brought the number of known species in the fauna up to 1,456, the third raised it to 1,685, and the fourth to 2,025. The total number to date is 2,133. Volume i. gives the record of the investigations prior to the foundation of the biological station. Volumes ii. and iii. record the observations made at Puffin Island; while volume iv. opens the account of the Port Erin Station.

In 1892 the Committee relinquished Puffin Island and built the new Biological Station at a very much more convenient and richer locality, Port Erin, at the south-west end of the Isle of Man. This establishment was formally opened on June 4, 1892, by his Excellency Dr. Spencer Walpole, Lieut.-Governor of the island. In the following year a second building—the Aquarium—was added, and since then the institution has been constantly in use, and has proved increasingly useful each season, both to members of the Committee and to other naturalists. Since the opening of the Port Erin Station, in 1892, fifty-six biologists have paid over 200 longer or shorter visits for the purpose of working at the marine fauna and flora.

The British Association Committee for the investigation of the Marine Zoology, Botany, and Geology of the Irish Sea were appointed in 1892, and three previous reports have been submitted. The first, laid before the Nottingham meeting in 1893, gave an account of the limits and more prominent physical conditions of the area under investigation, with a brief interim notice of the dredging expeditions undertaken during the year. The second report, at the Oxford meeting in 1894, gave a fuller description of the methods of work on one of the dredging expeditions, and also included an account of the distribution of the submarine deposits of the area, and a notice of the chief results of the year's work, including some new species. The third report, given last year at Ipswich, dealt chiefly with the submarine deposits, the investigation of the surface currents, and with the distribution of animals as shown from dredging statistics. The previous reports have all been provisional only, and in none of them have more than a few of the more prominent of the animals obtained been mentioned. In this final report, consequently, we give for the first time a complete list of all the species we have been able to record from our area of the Irish Sea; and to render this list more useful we append to each name a brief reference to the volume and page of the report or paper in which the species was recorded. First, however, we give a brief account of the work of the past year, so as to complete the record of our collecting expeditions.

THE YEAR'S WORK.

Since September 1895 the Committee have organised eight dredging expeditions, nearly all in steamers, as follows:—

I. October 27, 1895.—Hired steamer 'Rose Ann.' Localities dredged and trawled:—off Port Erin and along S.E. side of Isle of Man, from the Calf Sound to Langness, at depths of 15 to 20 fathoms.

II. November 24, 1895.—Small boats. Localities dredged:—Port Erin Bay, in depths up to 7 fathoms.

III. February 2, 1896.—Hired steamer 'Rose Ann.' Localities dredged and trawled:—through the Calf Sound, and off its eastern and western ends, at depths of 16 to 20 fathoms.

IV. March 14, 1896.—Sea Fisheries steamer 'John Fell.' Off Port Erin.

V. April 5, 1896.—Hired steamer 'Rose Ann.' Localities trawled:—out in the deep channel, 12 miles S.W. of Calf; bottom reamy mud, with many spawning fish; depths 40 to 50 fathoms.

VI. April 21–24, 1896.—Sea Fisheries steamer 'John Fell.' Localities trawled:—deep channel, 12 miles S.W. of Calf, and further north to opposite Port Erin; also west of Dalby, 8 miles off; reamy bottom; depths 20 to 40 fathoms.

VII. May 29 and 30, 1896.—Sea Fisheries steamer 'John Fell.' Localities:—estuary of the Wyre and around Piel Island, in Barrow Channel; shallow water.

VIII. August 31, 1896.—Mr. Woodall's S. Y. 'Vallota.' Localities dredged and trawled :—between Port Erin and Calf Island ; depth 17 to 22 fathoms.

Two of these expeditions—those at Easter in the 'Rose Ann, and at the end of April in the 'John Fell'—were particularly successful, and resulted in the capture of a number of new and interesting species. Amongst these is a large green Gephyrean worm, which is either *Thalassema gigas*, M. Müller, or a new species of *Thalassema* with a remarkable pigment ; and a Cumacean, for which a new genus is necessary.

Additions have been made during the year to most of the groups of invertebrate animals, and these will be found noted in the lists below ; but Mr. A. O. Walker has prepared the following special account of the higher Crustacea obtained on these expeditions:—

The following species of CRUSTACEA MALACOSTRACA have been added to the fauna since the last report. Nearly all were dredged off the S. end of the Isle of Man in the 'John Fell' expedition, from April 22 to 24, 1896.

PODOPHTHALMA :—*Portunus corrugatus* (Pennant).—S.E. of Calf Sound, 26 fathoms.

Nika edulis, Risso.—Co. Down Coast (Ascroft). From stomach of whiting, 12 m. S.W. of Chicken Rock, 33 fathoms.

SCHIZOPODA :—*Erythrops serrata*, G. O. Sars ; 12 m. S.W. of Chicken Rock, 33 fathoms.

Siriella armata (M. Edw.). Port Erin harbour, April 1896.

CUMACEA :—Fam. Leuconidæ.

Leuconopsis, n. gen.

Female with a distinct two-jointed appendage to the fourth pair of feet, not furnished with natatory setæ. Lower antennæ short, with the third joint conical, with a minute one-jointed rudimentary flagellum. Rami of uropoda subequal.

Male with the third pair of feet each provided on the second joint with a pair of curved blade-like processes.

Remaining characters as in *Leucon*.

Leuconopsis ensifer, n. sp.

Female :—Carapace about as long as the free thoracic segments, dorsal crest of fourteen teeth beginning about the middle of the upper margin, and curving down to the base of the rostrum ; a small tooth on the upper and near the posterior margin ; lower margin with the anterior half coarsely toothed, and forming with the anterior margin an acute angle, the upper portion of which is finely toothed. Rostrum about quarter the length of the carapace, obliquely truncate, almost horizontal ; lower margin with two or three teeth near the extremity and two or three near the base.

Fourth pair of legs with an exopodite or imperfect natatory appendage, two-jointed, reaching nearly to the end of the first joint, which is almost as long as the remaining four.

Telson triangular, as in *Leucon*.

Uropoda with peduncle and both rami subequal in length ; peduncle almost spineless, inner ramus with six unequal spines on the inner and two on the outer side of the first joint ; second joint with two very short and slender spines on the inside ; outer ramus obliquely truncate, with five plumose setæ on the inner side and four at the end. Length $5\frac{1}{2}$ mm.

Male :—Upper margin of carapace as long as the free segments ; lower margin with five or six teeth on the anterior half increasing in size anteriorly, forming a right angle with the anterior margin which has five teeth just below the rostrum, the second from the rostrum being the largest; rostrum horizontal, blunt, about one-sixth the length of the carapace, with five small teeth on the lower margin.

First pair of legs with seven teeth on the lower margin of the first joint. Second pair with a large spine at the distal end of the second, and two unequally long spines at the end of the third joint. Third pair with an appendage on the second joint, consisting of two parallel curved blades, twice as long as the succeeding three joints. Length $8\frac{1}{2}$ mm.

The above interesting species has a general resemblance to *Leucon*, from which genus, however, it may be at once distinguished by the appendages on the fourth pair of legs in the female and the third pair in the male. It was taken in the tow net attached to the back of the trawl net on April 22, 12 m. S.W. of Chicken Rock, 33 fathoms.

Eudorella emarginata (Kröyer).—One female. Same locality as last.

Campylaspis glabra, G. O. Sars.—Three specimens, from same locality as last. A Mediterranean species, not previously recorded from British Seas. I have specimens taken by Mr. Ascroft off the Ile d'Yeu.

AMPHIPODA :—*Normanion quadrimanus* (Bate and Westwood).—One small specimen; length 2 mm., 6 miles W.S.W. of Calf, 23 fathoms.

Stenothoë crassicornis, n. sp.—Three males. Same locality as last.

Mandibles without a palp.

Maxillipedes with the basal lobe very small, divided to its base.

Antennæ stout, the flagellum of the lower but little longer than the last joint of the peduncle; its first joint almost as long as the remaining four together.

First gnathopods as in *S. marina*.

Second gnathopods with the palm of the propodos defined near the base by a triangular tooth, the distal extremity expanded and cut into four blunt lobes, of which the proximal is much the largest; dactylus with a prominence on the inner margin, coinciding with the palmar lobus.

Peræopods short and strong, the third (meros) joint in the last three pairs much produced backwards, as in *Probolium calcaratum*, G. O. Sars.

Third uropods with four spines on the upper surface of the peduncle, which is twice as long as the first joint of the ramus.

Telson with three pairs of dorsal spines on its proximal half, the first pair the smallest. Length 2 mm.

In the form of the hand of the second gnathopods this species approaches *S. tenella*, G. O. S., and *S. Dollfusi*, Chevreux; but both these (perhaps identical) species are remarkable for the length and slenderness of their antennæ and peræopods.

Halimedon parvimanus, Sp. Bate.—Five or six specimens, 12 m. S.W. of Chicken Rock, 33 fathoms.

Argissa hamatipes (Norman) = *Syrrhoë hamatipes*, Norman, 'Brit. Ass. Rep.,' 1868 (1869), p. 279.

Same locality as last.—Two females, one with ova, 2 mm. long.

Prof. G. O. Sars, with some hesitation, follows Boeck in placing *Argissa* among the Pontoporeiidæ, but there can be little doubt that Canon A. M. Norman was right in classing it with the Syrrhoidæ.

Gammarus campylops, Leach.—Brackish pond near Colwyn Bay; also Port Erin harbour.

LIST OF THE SPECIES RECORDED FROM THE IRISH SEA AREA.

The species in this list are given in zoological order, commencing with the Algæ and the Protozoa, and each name is followed by a brief reference to the volume and page of the L.M.B.C. publications in which the species was recorded or described. The following contractions have been made use of :—The four published volumes of the 'Fauna of Liverpool Bay' are indicated as i., ii., iii., iv. The L.M.B.C. 'Annual Reports' are indicated as 1st to 10th A.R. The 'Transactions' of the Liverpool Biological Society are referred to as T.L.B.S., I., &c. Species which have been found recently, but of which the record has not yet been published, are followed by 10th A.R. to indicate the Annual Report which will appear in December 1896.

The Committee are indebted to some of the Liverpool Marine Biology Committee and other naturalists, who have worked at Port Erin, and have written reports upon the marine fauna, for compiling or supervising the compilation of the following lists :—

LIST OF THE DIATOMACEA.

[See Report by HENRY STOLTERFOTH, M.D., &c., in 'Fauna,' vol. ii.]

Achnanthes brevipes, Ag.
A. longipes, Ag.
A. subsessilis, Ehr.
Actinocyclus crassus, W. Sm.
A. Ralfsii, W. Sm.
Actinoptychus splendens (Shad), Ralfs.
A. undulatus, Ehr.
Amphiprora alata, Kütz.
A. paludosa, Greg.
A. plicata, Greg.
A. pusilla, Greg.
A. vitrea, Greg.
Amphora affinis, Kütz.
A. binodis, Greg.
A. commutata, Grun.
A. complexa, Greg.
A. hyalina, Kütz.
A. lævis, Greg.
A. litoralis, Dn.
A. membranacea, W. Sm.
A. minutissima, Gray
A. salina, W. Sm.
A. spectabilis, Greg.
A. ventricosa, Greg.
Asterionella Bleakleyii, W. Sm.
A. Ralfsii, W. Sm.
Atheya decora, West.
Bactereastrum varians, Lauder.
Berkleya obtusa, Grev.
Biddulphia aurita, Breb.
B. Baileyii, W. Sm.
B. obtusa, Kütz.
B. granulata, Roper.
B. radiatus, Greg.
B. rhombus, W. Sm.
B. suborbicularis, Grun.
B. turgida, W. Sm.
Campylodiscus bicostatus, W. Sm.
C. cribrosus, W. Sm.
Cestodiscus johnsonianum, Greg.
Chætoceros armatum, West.
C. boreale, Bail.
C. paradoxum, Cleve.
C. Wighamii, Brightw.
Cocconeis scutellum.
C. britannica, Nægeli.
C. eccentrica, Dn.
Coscinodiscus asteromphalus, Grun.
C. concinnus, W. Sm.
C. eccentricus, Ehr.
C. fimbriatus, Ehr.
C. obscurus, Schmidt.
C. radiatus, Ehr.
Cymbella scotica, W. Sm.
Dickeia alvoides, Berk.
Dimeregramma nanum, Greg.
Epithemia constricta, Greg.
E. gibba, Kütz.
E. turgida, W. Sm.
Eucampia zodiacus, Ehr.
E. striata, Stolt.
Eupodiscus argus, Ehr.
Gomphonema marinum, W. Sm.
Grammalophora marina, Kütz.
G. serpentaria, Kütz.
Hantzschia virgata, Grun.
Hyalodiscus stelliger, Bail.
H. scoticus, Grun.
Lauderia delicatula, Peragello.
Licmophora gracilis, Grun.
L. anglica, Grun.
L. dalmatica, Kütz.
Mastogloia lanceolata, Th.
M. Smithii, Th.

Melosira borreri, Grev.
M. nummuloides, Bory.
M. sulcata, Ehr.
M. Westii, W. Sm.
Navicula abrupta, Greg.
N. æstiva, Dn.
N. affinis, Ehr.
N. aspera, Ehr.
N. Boeckii, Herberg.
N. bombus, Ehr.
N. carassius, Ehr.
N. clepsydra, Ehr.
N. crabro, Ehr.
N. cyprinus, Ehr.
N. didyma, Ehr.
N. distans, W. Sm.
N. fortis, Greg.
N. fusca, Greg.
N. fusiformis, Grun.
N. granulata, Breb.
N. interrupta, Kütz.
N. Johnsonii, Greg.
N. litoralis, Dn.
N. lyra, Ehr.
N. marina, Greg.
N. northumbrica, Dn.
N. numerosa, Dn.
N. palpebralis, Breb.
N. peregrina, Dn.
N. pusilla, W. Sm.
N. pygmæa, Kütz.
N. rectangulata, Greg.
N. rostrata, Ehr.
N. semiplena, Greg.
N. suborbicularis, Greg.
N. subsalina, Dn.
N. venata, Kütz.
N. Westii, Greg.
Nitzschia bilobata, W. Sm.
N. birostrata, W. Sm.
N. closterium, W. Sm.
N. distans, Greg.
N. granulata, W. Sm.
N. lanceolata, W. Sm.
N. notabilis, Grun.
N. obtusa, W. Sm.
N. panduriformis, Greg.
N. (*Bacillaria*) *paradoxa*, Gm
N. plana, W. Sm.
N. punctata, Grun.
N. reversa, W. Sm.
N. sigma, W. Sm.
N. scalaris, W. Sm.
N. tænia, W. Sm.
N. tryblionella, Hantz.
Plagiogramma gregorianum, Grev.
Plagiogramma van-Heurckii, Grun.
Pleurosigma æstuarii, W. Sm.
P. angulatum, W. Sm.
P. balticum, W. Sm.
P. delicatulum, W. Sm.
P. distortum, W. Sm.
P. elongatum, W. Sm.
P. fasciola, W. Sm.
P. formosum, W. Sm.
P. hippocampus, W. Sm.
P. litorale, W. Sm.
P. marinum, W. Sm.
P. obscurum, W. Sm.
P. prolongatum, W. Sm.
P. scalprum, W. Sm.
P. strigilis, W. Sm.
P. strigosum, W. Sm.
P. tenuissimum, Greg.
P. transversale, Roper.
Rhabdonema arcuatum, Kütz.
R. minutum, Kütz.
Rhaphoneis amphiceros, Ehr.
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R. setigera, Brightw.
R. styliformis, Brightw.
R. Wighamia, Brightw.
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S. helmintosum, Greg.
S. vulgare, Th.
Scoliopleura latistriata, Breb.
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Skeltonema costatum, Grun.
Stauroneis acuta, W. Sm.
S. salina, W. Sm.
S. linearis, W. Sm.
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Striatella unipunctata, Ag.
Surirella constricta, W. Sm.
S. crumena, Breb.
S. gemma, Ehr.
S. fastuosa, Ehr.
S. salina, W. Sm.
S. splendida, Kütz.
S. striatula, Turp.
Synedra affinis, Kütz., var. *arcus*, Kütz.
S. fulgens, Kütz.
S. Gallionii, Ehr.
S. obtusa, W. Sm.
S. pulchella, var. *acicularis*, Kütz.
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T. insignis, Dn.
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T. favus, Ehr.
T. striolatus, Ehr.

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[See Reports by Professor R. J. HARVEY GIBSON, M.A., F.L.S., in 'Fauna,' vol. ii. p. 1, and vol. iii. p. 65.]

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B. marginata, D'Orb.
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B. elegans, D'Orb.
B. elegantissima, D'Orb.
B. squamigera, D'Orb.
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B. variabilis, Will.
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N. radicula, Linn.
N. Calomorpha, Reuss.
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N. pyrula, D'Orb.
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[See Report on the Alcyonaria of the L.M.B.C. District, by Professor HERDMAN, 'Fauna,' vol. i. p. 120, and also note upon yellow variety of *Sarcodictyon catenata* in 'Fauna,' vol. iv. p. 322.]

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Hoplonyx similis, Sars. Rev.
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Euonyx chelatus, Norm. Rev.
Bathyporeia norvegica, Sars. Rev.
B. pelagica, Bate. Rev.
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S. monoculoides (Mont.) Rev.
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[NOTE.—A few of the marine insects and mites have been identified, but the lists are so far from complete that it would be useless to print them.]

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A. plebeia, Ald. i. 300; ii. 121.
A. depressa, Ald. & H. i. 301; 6th A. R., p. 35.
A. prunum, O. F. M. i. 301.
Corella parallelogramma, O. F. M. i. 301; ii. 126.
Forbesella tessellata, Forbes. 3rd A. R., p. 37.
Styelopsis grossularia, V. Ben. i. 302; ii. 126.
Polycarpa rustica, Linn. (?). i. 303; ii. 127.
P. comata, Ald. i. 303; 8th A. R., p. 11.
P. pomaria, Sav. i. 304; ii. 127.
P. glomerata, Ald. A. R.
P. monensis, Hrdm. i. 305.
Cynthia echinata, Linn. ii. 127.

Cynthia morus, Forb. 7th A. R., p. 19.
Molgula occulta, Kupf. i. 307; ii. 128.
Molgula citrina, A. & H. ii. 128; 6th A. R., p. 35.
M. Hancocki, Hrdm. ii. 130.
Eugyra glutinans, Möll. i. 309; ii. 128.

CEPHALOCHORDA.

Branchiostoma lanceolatum, Pall. 10th A. R.

LIST OF THE FISHES.

[See lists by Mr. P. M. C. KERMODE in 'Zoologist,' 1893, and by Prof. HERDMAN in 'Transactions' Liverpool Biological Society for 1893.]

Labrax lupus, Cuv.
Serranus cabrilla, C. and V.
Mullus barbatus, var. *surmuletus*, Linn.
Cantharus lineatus, Mont.
Pagellus centrodontus, C. and V.
Sebastes norvegicus, Ascan.
Cottus scorpius, Linn.
C. bubalis, Euph.
Trigla hirundo, Linn.
T. cuculus, Linn.
T. lineata, Gm.
T. gurnardus, Linn.
Agonus cataphractus, Bl.
Lophius piscatorius, Linn.
Trachinus draco, Linn.
T. vipera, C. and V.
Scomber scomber, Linn.
S. Colias, Gm.
Orcynus germo, Lac.
Thynnus pelamys, Linn.
Lampris luna, Gm.
Caranx trachurus, Lac.
Zeus faber, Cuv.
Xiphias gladius, Linn.
Sciæna aquila, Risso.
Gobius niger, Linn.
G. Ruthensparri, Euph.
G. minutus, Gm.
G. paganellus, Gm.
G. pictus, Malm.
G. quadrimaculatus, C. and V.
G. Parnelli, Day.
Aphia pellucida, Nard.
Callionymus lyra, Linn.
Cyclopterus lumpus, Linn.
Liparis Montagui, Don.
L. vulgaris, Flem.
Lepadogaster Gouanii, Lac.
L. bimaculatus, Don.
Carelophus Ascanii, Coll.
Blennius pholis, Linn.
B. ocellaris, Linn.
B. galerita, Linn.
B. gattoruginæ, Bl.
Centronotus gunnellus, Bl.
Zoarces viviparus, Linn.
Gasterosteus aculeatus, Linn.
G. spinachia, Linn.
G. pungitius, Linn.
Mugil chelo, Cuv.
Labrus maculatus, Bl.
L. mixtus, Fries and Eks.
Centrolabrus exoletus, Linn.
Crenilabrus melops, Cuv.
Ctenolabrus rupestris, Linn.
Gadus morrhua, Linn.
G. merlangus, Linn.
G. virens, Linn.
G. æglefinus, Linn.
G. luscus, Linn.
G. minutus, Linn.
G. pollachius, Linn.
Merluccius vulgaris, Cuv.
Molva vulgaris, Flem.
Loto vulgaris, Cuv.
Phycis blennoides, Bl.
Motella tricirrata, Nils.
M. cimbria, Linn.
M. mustela, Linn.
Raniceps raninus, Linn.
Ammodytes lanceolatus, Les.
A. tobianus, Linn.
Rhombus maximus, Cuv.
R. lævis, Rond.
Hippoglossus vulgaris, Flem.
Hippoglossoides limandoides, Bloch.
Zeugopterus punctatus, Bl.
Z. unimaculatus, Risso.
Z. norvegicus, Günth.
Arnoglossus megastoma, Don.
A. laterna, Walb.
Pleuronectes platessa, Linn.
P. limanda, Linn.
P. flesus, Linn.
Pleuronectes microcephalus, Don.
P. cynoglossus, Linn.
Solea vulgaris, Quen.
S. lutea, Risso.
S. aurantiaca, Günth.
S. lascaris, Risso.
S. variegata, Don.
Maurolicus Pennantii, Walb.
Argentina sphyræna, Linn.
Salmo salar, Linn.
S. trutta, Linn.
S. fario, Linn.
Osmerus eperlanus, Linn.
Belone vulgaris, Flem.
Engraulis encrasicholus, Linn.
Clupea harengus, Linn.

Clupea sprattus, Linn.
C. finta, Cuv.
Anguilla vulgaris, Turt.
Conger vulgaris, Cuv.
Siphonostoma typhle, Linn.
Syngnathus acus, Linn.
Nerophis æquoreus, Linn.
N. ophidion, Linn.
N. lumbriciformis, Willugh.
Orthagoriscus mola, Linn.
Carcharias glaucus, Cuv.
Acipenser sturio, Linn.
Galeus vulgaris, Flem.
Mustelus vulgaris, Müll.
Lamna cornubica, Gm.
Alopias vulpes, Gm.
Selache maxima, Gunner.
Scyllium canicula, Cuv.
S. catulus, Cuv.
Pristiurus melanostomus, Raf.
Acanthias vulgaris, Risso.
Rhina squatina, Linn.
Torpedo nobiliana, Bonap.
Raia batis, Linn.
R. oxyrhynchus, Linn.
R. alba, Lacép.
R. clavata, Linn.
R. maculata, Mont.
R. circularis, Couch.
R. macrorhynchus, Raf.
R. radiata, Don.
Trygon pastinaca, Linn.
Petromyzon marinus, Linn.
P. fluviatilis, Linn.

LIST OF THE MARINE MAMMALIA.

[See Report on Seals and Whales, by Mr. MOORE, in 'Fauna,' ii. p. 134.]

PINNIPEDIA.
Phoca grœnlandica, Fabr. ii. 136.
P. vitulina, Linn. 10th A. R.
Halichœrus grypus, Fabr. ii. 136.
Cystophora cristata, Erxl. ii. 137.

CETACEA.
Megaptera longimana, Rud. ii. 139.
Hyperoodon rostratus, Chem. ii. 140.
Balænoptera musculus, Linn. 10th A. R.
Phocæna communis, F. Cuv. ii. 142.
Orca gladiator, Lac. ii. 143.
Lagenorhynchus albirostris, Gray. ii. 144.
Delphinus delphis, Linn. ii. 147.
Tursiops tursio, Fabr. ii. 148.

CONCLUDING REMARKS.

Although this is put forward as a final report of the present Committee, they do not desire thereby to indicate that the work of exploring the zoology, botany, and geology of the Irish Sea is finished. Probably such an investigation can never be finished; but the Committee feel that the occasion of the British Association meeting in Liverpool is one that they ought to take advantage of to present a report which is final, in the sense that it completes the present series of reports, and brings together and sums up the results of all previous marine biological work in the district (see figs. 1 and 2).

For the future, they hope that the work will be carried on actively by the Liverpool Marine Biology Committee, the body of investigators by whom most of the work has been done in the past. The Port Erin Biological Station is equipped for such work, and the British Association can best render effective help by supporting the general investigations carried on at that station, or by giving grants for special researches.

As may be seen from this and the preceding reports, the greater part of the work of the Committee has been zoological; botany, however, has been represented by several investigators, and lists are given above of the marine algæ, including diatoms. Professor Weiss, a member of the Committee, has commenced observations on the reproduction of diatoms, and has collected much material for an investigation of the coralline algæ, upon both of which he will report to the Liverpool Biological Society during next session.

In regard to the geology of the sea-floor, Mr. Clement Reid considers it premature to report at any length. He has already in previous reports remarked upon the characteristics of the deposits; he has all the material, in the form of samples of the various bottoms brought up by the dredge,

FIG. 1.—Plan of the L.M.B.C. District.

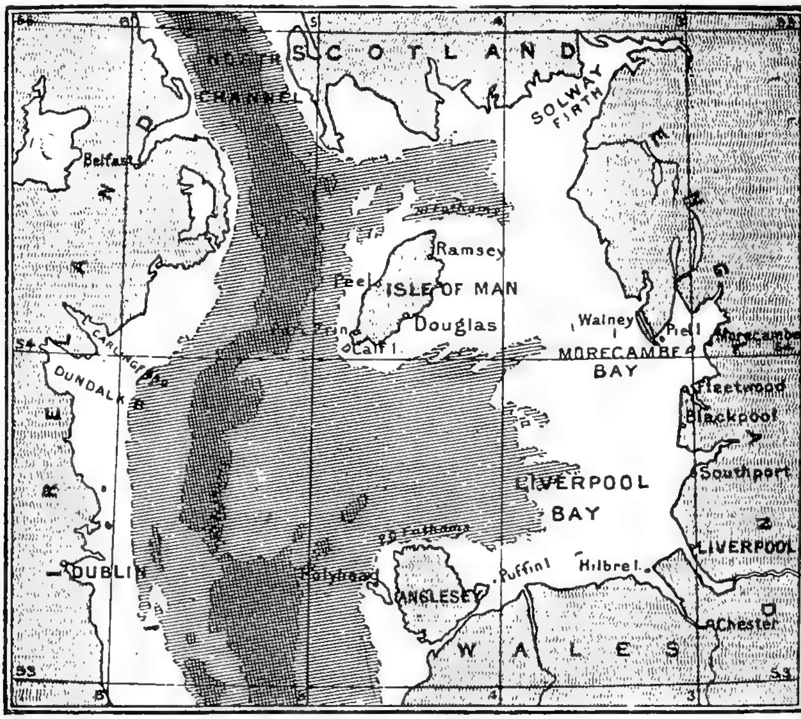
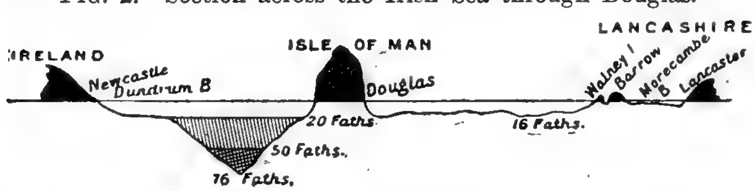


FIG. 2.—Section across the Irish Sea through Douglas.



before him at the Jermyn Street Museum, and he proposes to work these up at some future date, when he is able to compare them with deposits from the other seas around the British Isles.

The Life-History and Economic Relations of the Coccidæ of Ceylon, by Mr. E. E. GREEN.—*Report of the Committee, consisting of* Mr. R. MCLACHLAN (*Chairman*), Professor G. B. HOWES (*Secretary*), Lord WALSINGHAM, Professor R. MELDOLA, Professor L. C. MIALL, Mr. R. NEWSTEAD, Dr. D. SHARP, *and* Colonel C. SWINHOE.

PART I. of this work is expected to be ready in October. In addition to the letterpress it will contain thirty lithographic plates. The estimated cost of the entire work is about 1,000*l.*, and up to the present time the promises of financial support received do not amount to 200*l.*, and the Committee ask to be reappointed, and to receive a grant of 100*l*

Bird Migration in Great Britain and Ireland.—Report of the Committee, consisting of Professor NEWTON (*Chairman*), Mr. JOHN CORDEAUX (*Secretary*), Mr. JOHN A. HARVIE-BROWN, Mr. R. M. BARRINGTON, Mr. W. EAGLE CLARKE, *and* Rev. E. P. KNUBLEY, *appointed for the purpose of making a Digest of the Observations on the Migrations of Birds at Lighthouses and Lightvessels*, 1880–1887.

YOUR Committee have at last the pleasure of reporting that the Digest which they were appointed to make of the observations on the Migration of Birds taken at Lighthouses and Lightvessels from 1880 to 1887 has been completed, and of presenting the same to the Association.

As has been before stated at meetings of the Association, this Digest is the work of one of their number, and the remaining Members of the Committee have to record their deep sense of the obligation under which they lie to Mr. William Eagle Clarke, of the Science and Art Museum, Edinburgh, for the assiduity with which he has so long laboured on the enormous task he undertook, and to congratulate him on the success with which he has overcome the countless difficulties it presented.

In these congratulations the Committee feel that they are entitled to ask the Association to join, as well as ornithologists of all countries.

It cannot be doubted that henceforth, as regards the British Islands, there is now established a firm basis on which may rest a sound and proper conception of many of the phenomena of British migration, for this Digest contains a plain statement of ascertained facts, and is wholly free from theory or speculation of any kind. Thus it will be found to differ from almost everything that has hitherto been published on the subject.

In saying this much your Committee would, however, guard themselves from the inference that the business is exhausted—on the contrary, a very great deal more is yet to be learned from a further examination of the observations which have been collected at the Lighthouses and Lightships, while the whole subject of inland migration is untouched. Whether it will be possible for the Committee to proceed further must entirely depend on the action of the Association; but they may say that Mr. Clarke, so far from being deterred by the magnitude of the task with which he has so successfully grappled, is willing to work out the details of migration for each of the species to which the observations refer, and has even already begun to do so; and it is to be hoped that he will receive some encouragement to continue such useful work. And the Committee may remark that the very considerable funds that private generosity has placed at their service are now exhausted.

Though on the present occasion the thanks of the Committee are so certainly due to Mr. Clarke, they feel that, while presenting what may be their final Report, they must again acknowledge their indebtedness to all who have helped them in prosecuting their enquiries; first, to the Master and Elder Brethren of the Trinity House, the Commissioners of Northern Lights, and the Commissioners of Irish Lights; but more especially to the men of the several Lighthouses and Lightships, without whose cheerful and intelligent co-operation nothing could have been done.

DIGEST.

Introduction.

In presenting this Digest of the Results obtained concerning the Migration of Birds, as observed at Lighthouses and Lightships around the coasts of the British Islands, to the Committee appointed by the British Association for the investigation of that subject, during the years 1880–1887 inclusive, I beg to offer an explanation regarding the lapse of time that has taken place between my appointment and the completion of the work.

In a word, this has been entirely due to the magnitude of the undertaking.

I was instructed to base the Digest upon an examination *de novo* of the whole of the information furnished to the Committee during the eight years of its active existence. Thus the whole of the data required to be reduced to order before it was available for the purposes of the Digest. Moreover, at the outset there presented itself for consideration an extremely perplexing problem, namely—How to treat or arrange such a vast array of facts on a systematic plan which would render them comprehensive, and at the same time suited to the enquiry in all its varied aspects. It was not until a number of abortive attempts had been embarked upon that a plan was devised which met the very special requirements of the case. The scheme finally adopted took the form of a Schedule. This was designed to show graphically for each species during each month (1) on what Day ; (2) Coast ; (3) Station ; (4) in what Numbers ; and (5) whether during the Day or Night the particular species was observed during the particular month and year. It is needless to remark that such a systematic tabulation of at least one hundred thousand records, culled from several thousands of forms filled in by the Light Keepers, in each of which species were numerous and the dates wide-ranging, proved to be both a long and laborious task.

The results now presented are, for the first time, based upon the examination of the *whole* of the information communicated to the Committee *for all the coasts* : a most necessary condition, for from such a complete and comprehensive examination alone could it be at all possible to obtain results worthy of the enquiry, and an accurate knowledge of the nature of the various phenomena associated with the migration of British and Irish birds. Indeed, it is now in our power to declare that it is quite impossible, at certain seasons, to distinguish between the widely different Immigratory and Emigratory movements, without due examination and consideration of the whole of the observations, a fact the non-realisation of which has been fruitful of much misconception and of many misleading statements in the past.

It is manifestly impossible to conduct an enquiry into the migration of birds over the entire British area, or even of the smallest section of it, under other than imperfect conditions. A hundred circumstances are against such a desirable consummation—even if a party of trained ornithologists were placed at each station, it would fail to secure anything like perfect results.

Remembering, then, the peculiar difficulties and the drawbacks that beset such an investigation, and the further fact that the entire staff of observers were volunteers, the nature of the data obtained is most satisfactory. It has proved to be adequate for the purpose of the inquiry, and surprisingly accurate. Indeed, it is often quite wonderful how the observations made at a particular station are borne out by the records at others.

The object of the enquiry was to obtain full and trustworthy information in connection with the migratory movements of birds as observed on our coasts, and not to solve problems connected with the causes of the phenomena, the evolution of the migratory instinct, or other purely theoretical aspects of the general subject.

As regards the importance of this investigation, it must be borne in mind that the observers were most favourably stationed for witnessing migration in its various phases, and that such a voluminous and complete set of observations has never been amassed at any previous period in the history of the study of bird-migration. Its special nature can only be fully appreciated when it is realised that, in order to study the phenomena of bird-migration in the British Islands, it is necessary that the data upon which any deductions may be satisfactorily or safely founded should be based upon observations taken synchronously at stations encircling the entire coasts. This cardinal and most important condition has been attempted and accomplished for the first time, either in this or any other country, through the labours of the Committee.

The meteorological aspect of the subject has received very careful attention, and with interesting and important results. In connection with this portion of the work the 'Daily Weather Reports' issued by the Meteorological Office have been consulted and correlated with the data relating to the migratory movements for each year of the inquiry.

Finally, I may state that the results now communicated are based absolutely upon the records obtained by the Committee; and, also, that I have approached the subject with an open mind and without preconceived ideas. I have considered this not the place for theory, but for the establishment of facts, and for deductions drawn from a direct study of the observations placed in my hands.

Bird Migration as observed on the British and Irish Coasts.

The migration of birds, as observed in the British Islands, is a very complex phenomenon; more so, perhaps, than in any other region of the globe. This is readily accounted for.

First, the Geographical position of the British Islands is eminently favourable. Placed, as our Isles are, between South-western Europe and the Scandinavian Peninsula, Iceland, and Greenland, they lie directly in the course of the legions of migratory birds which annually make a double journey between their northern summer and their southern winter quarters. For these Birds of Passage our shores form not only a main and much accustomed highway, but afford convenient resting quarters.

Secondly, our Islands have a vast bird-population of their own, and the majority of these birds belong to purely migratory species. Some of them are either Summer Visitors from the southern regions or Winter Visitors from continental Europe, Iceland, &c.

Thirdly, many individuals of species which are sedentary in our Islands are strictly migratory. This is especially the case in the more northern and elevated portions of the British area; hence these species are said to be 'Partial Migrants.'

Finally, our remarkably variable climate is a constant element of disturbance, causing much migration within the British area itself and intermigration with the islands off our western coasts, especially with Ireland. This occurs during the winter months, and hence these migrations will be alluded to in this report as 'Winter Movements.'

The above important considerations and influences result not only in much migration of a varied nature being witnessed on our shores, but often, through a combination of meteorological conditions, in more than one movement being observed in progress simultaneously, adding much further intricacy to an already complicated series of phenomena.

Having thus shortly described the British Islands as a highway for and as a source of migration, having mentioned the nature of the various movements observed on our coasts, and having alluded to the influence exerted by climatic conditions upon the bird-population of our area, I may now proceed to discuss the main results obtained through the enquiry under the following sections: (1) Geographical, (2) Seasonal, and (3) Meteorological.

GEOGRAPHICAL.

General.—In passing from their summer to their winter haunts, birds proceed from a northern to a southern clime, and *vice versâ* in the spring. It does not at all follow, however, that these seasonal haunts are reached by a simple movement from north to south, or the reverse. Each species or individual of migratory bird has its particular summer and winter resorts, and these do not necessarily lie in the same meridian—indeed this is often far from being the case. To attain these particular seasonal habitats many of the voyagers must depart more or less considerably from a direct course. This is especially the case in Western Europe, where, owing to the south-western extension of the land-masses, and the consequent irregularity of the coast line, various more or less devious routes must be, and are followed. The interposition of the British Islands between the north-western portion of the Continental Area on the one hand and Iceland and Greenland on the other, is an important additional factor in this deviation.

The geographical distribution of birds during migration on the British and Irish Coasts, and the routes traversed, naturally depend upon the nature of the particular movement.

The chief and most interesting movements from the geographical standpoint are the intermigrations between our Islands and Europe. There are, however, a number of movements between the various sections of the British and Irish areas which are of considerable importance.

Intermigration between Britain and Northern Continental Europe.—Between Britain and Continental Europe travel a host of migrants which are either birds of passage on, or winter visitors to, our shores. The former visit our eastern coast-line in spring when journeying to their northern summer haunts lying to the north-east of Britain, and again in autumn when returning to their winter quarters to the south of our Islands. The winter visitors are chiefly individuals from the ranks of certain species of the birds of passage which winter in the British area and emigrate to the north-east in the spring.

In the autumn these numerous migrants cross the North Sea and arrive on the east shores of Britain at points between the Shetland Isles and the Humber or the northern seaboard of Norfolk. All the movements do not necessarily cover this extensive stretch of coast-line, but such is not infrequently the case. Indeed, as a rule, they are recorded from the greater part of the region indicated. It is possible to define the southern limit on the coast at which these birds strike Britain, with a considerable degree of precision. No section of the British coast is so well equipped with light-stations as that which lies between the north coast of Norfolk and Dungeness. In addition to an average number of lighthouses, there is a fleet of lightships off the coast, which are most favourably situated for recording the movements of birds crossing the North Sea to the English coast. These lightships have furnished the Committee with some of the most carefully kept records to be found among the returns, and it is a very significant fact that these great autumn immigratory movements are not observed at these south-eastern lighthouses and lightships. Evidence of a particularly important nature, in this connection, is also afforded by the records kept at the Outer Dowsing Lightship, the most isolated of the stations in the North Sea, situated about 38 miles E.S.E. of the mouth of the Humber. At this station these important movements are not observed—another significant fact, indicating unmistakably that these migrants pass to the northward or westward of this Lightship.

The conclusion at which I have arrived, after a long and careful study of the records, is that these immigrants and emigrants from and to Northern Europe pass and repass between this portion of the Continent and Britain by crossing the North Sea in autumn in a south-westerly direction, and in spring in a north-easterly one,[1] and that, while the limit to their flight in the north is the Shetland Islands, that on the south extends to the coast of Norfolk.[2] During these movements the more southern portion of the east coast of England is reached *after* the arrival of the immigrants on the more northern portions.

It is to be remarked, also, as bearing upon this important point, that *all* the species occur on migration in the Orkney and Shetland Islands, but not in the Færoes.[3] And, further, *all* the British birds of passage to Northern Europe are either summer visitors to Scandinavia or are regular migrants along the western shores of that peninsula.

After arriving on our eastern shores, these immigrants from the north—some of them after resting for a while—move either down the east coast, *en route* for more southern winter quarters, or, if winter visitors, to their accustomed haunts in Britain and Ireland. A few occur as birds of passage on the west coast and in Ireland, which they reach by overland routes across Britain, and then pass southwards to their winter quarters. The west coasts, however, do not receive *directly* any immigrants from Continental Europe.

Intermigration between the South-east Coast of England and the Coast

[1] The direction varies. It is probably more westerly (in autumn) or easterly (in spring) at the most northern British stations, and south-south-westerly (in autumn) or north-north-easterly (in spring) at the stations on the east coast of England.

[2] The formation adopted by the migrants during passage would seem to be an extended line—perhaps a series of lines—whose right wing extends to the Northern Islands and its left wing to the coast of Norfolk.

[3] A few species occur in the Færoes on migration, but these are also summer visitors to those islands and to Iceland.

of Western Europe—'East and West Route.—This is one of the discoveries of the enquiry. It has been already shown that the more southern section of the East coast of England does not receive immigrants *direct* from Northern Europe. There is, however, a considerable amount of migration of a particular description, and on the part of certain species, observed at the lightships and lighthouses between the Kentish coast and the Wash. During the autumn, day after day, a stream of migrants, often of great volume, is observed off the coast, flowing chiefly from the south-east to the north-west at the more northerly stations, and from east to west at the southerly ones, across the southernmost waters of the North Sea. This will be hereafter mentioned as the 'East and West Route.' From the stations off the mouth of the Thames as a centre, the birds either sweep up the east coast, sometimes to and beyond the Tees (many proceeding inland as they go), or pass to the west along the southern shores of England. These important immigrations set in during the latter days of September, reach their maximum in October, and continue at intervals until November. They are chronicled with wonderful precision and regularity in the returns from the stations on the south-east coast of England. They are renewed during winter on occasions of exceptionally severe cold, but the birds then pass to the westward along our southern shores.

There are some remarkable features associated with these movements: (1) They are frequently observed for several or many consecutive days; (2) they often occur when there is an almost entire absence of bird-migration on other parts of our shores; (3) the movements appear to be entirely confined to the daytime, and are usually timed as from soon after daylight to 1 P.M., sometimes until 3 P.M.—this being probably due to, and indicative of, the shortness of the passage; (4) the autumn migratory flocks are chiefly composed of Larks in vast numbers; 'Black Crows' (Rooks) very many; Grey Crows, many; also numerous Redbreasts, Goldcrests, Chaffinches, Greenfinches, Tree-Sparrows, Swallows, Starlings, and occasionally Woodcocks; and during the winter Larks, various Thrushes, and Lapwings; (5) and lastly, on certain occasions these immigrants, while passing northward along the English eastern seaboard, actually *cross* the movements of 'coasting' emigrants proceeding southwards.[1]

Whether this east to west stream is a branch of one that passes down the coast of Continental Europe, or whether it has its source in Central Europe, is a matter of conjecture.[2]

The conclusions relating to these continental migration-routes have been chiefly based upon the autumn data, because the information for that season is much more voluminous and complete. When, however, we come to examine the information relating to the spring movements, with a view to ascertaining how far they corroborate the conclusions so clearly indicated by the autumn chronicles, it is satisfactory to find decided evidence that the birds retrace their flight to the north and east along precisely the same lines as those along which the autumnal

[1] It is probable that such species as the Golden Oriole, Hoopoe, &c., which occur annually during spring and autumn migration in southern and south-eastern England, and the Black Redstart as a winter visitor, are birds that proceed along this route to and from our Islands.

[2] There are no essentially northern species recorded for this route, and the occurrence of the Rook so frequently and in such numbers is suggestive of a Central (Western) European source.

southerly and westerly journeys were performed. Thus in the spring these birds depart from the same sections of our eastern seaboard as witnessed their arrival in the autumn.

Intermigration between Heligoland and Britain.—Much prominence has been given in some of the Annual Reports issued by the Committee, and in Herr Gätke's book, 'Die Vogelwarte Helgoland,' to an intermigration between Heligoland and the east coast of England by a direct east-to-west autumn, and it is to be presumed west-to-east spring, movement. Herr Gätke most obligingly communicated the details of the bird-movements observed on Heligoland for four of the years (1883–1886) during which the inquiry was being prosecuted over the British area. These two sets of data have been carefully examined and compared, and it has been found that the dates of the chief movements of the species common to Heligoland and Eastern Britain seldom if ever correspond, and do not bear out this theory; that particular species which are irregular as migrants in Britain, such as the Ortolan Bunting, and others, occur regularly, often indeed in 'rushes,' at the more favoured isle off the mouth of the Elbe; that other species, which are very rare on our British shores, occur in Heligoland as regular migrants and in considerable numbers, as *Motacilla flava*, *Anthus Richardi*, &c.; while species common to both islands occur in 'flights like clouds,' in 'hundreds of thousands,' 'thousands upon thousands,' in 'marvellous numbers,' 'astonishing flights,' and so on, at Heligoland, at periods when there is not a single observation for the same species on the English shores. A study of the phenomena of migration at the stations on the east and west sides of the North Sea compels the investigator to come to the conclusion that Heligoland and Britain draw their migratory hosts from different sources. The ordinary movements of any common migratory bird occur in each month of its seasonal flight-periods, and the mere coincidence of the species being observed simultaneously in *ordinary numbers* on both sides of the North Sea has no significance whatever. It is not impossible or improbable that birds may *occasionally* cross the German Ocean by an east-to-west flight in the latitude of Heligoland, but our data lead us to believe that such cases are the *rare exception* and not the rule.

Intermigration between Britain and Færoes, Iceland, and Greenland.—The Færoes, Iceland, and Greenland are the summer home of several Palæarctic species which occur as birds of passage on the British coasts. The majority of these visit Iceland, and Greenland claims only two or three of them (Wheatear, White Wagtail, and Whimbrel). It is natural that these birds being of strictly Old World species, our Islands should lie in the course of their migrations. It is quite possible that these migrants may pass along both the eastern and western coasts of Britain and the coasts of Ireland. Here, at any rate, we have evidence that these birds are observed on passage on our western shores. It may be that some of the birds proceed also along our eastern seaboard, but this is a point difficult to determine. There is good evidence, however, that important movements of Redwings, Wheatears, and Whimbrels are observed on the western coast of Great Britain and the Irish coasts (both east and west as regards the passage of the Whimbrel), which are not observed elsewhere. Such a fact points to the independent nature of these west coast flights, and indicates that, in some instances at least, the western route alone is followed.

It is thus evident that, so far as concerns the movements of the birds of passage to and from their northern breeding haunts, the British east and west coast migratory movements are very distinct in their characters. The west coast does not receive immigrants direct from Europe, nor do these continental breeding species depart from its shores in the spring. Indeed, it is quite remarkable how rare, or comparatively rare, certain well-known east coast species are on the western portion of our shores.

With the movements of the British migratory birds next to be considered it is quite different, for, with the exception of a few species whose summer haunts are much circumscribed in our Islands, the movements are not only common to both coasts, but the great emigratory flights are usually simultaneously observed on the east, west, and south coasts, and also on those of Ireland.

The west coast of Great Britain and the Irish coasts are thus only under much migration during the great autumn departure movements from our shores, and to a less extent during the return movements in spring.

Intermigration between Great Britain and Ireland and the South, &c.—Having shortly described the migratory movements between the British Islands and Northern and Western Europe, undertaken by birds of passage and winter visitors to our Islands, the routes on our coasts along which the summer visitors[1] travel to and from their breeding quarters in Great Britain and Ireland now demand attention in their geographical aspect. It will be convenient also to refer to the routes between the different portions of the British area under this division.

The autumn or emigratory movements will be described—but it is necessary to remark that the data clearly indicate that the spring migratory movements along our western shores are simply return movements, on the part of the same species, along the same lines of flight as those laid down for the autumn.

The movements of these groups of migrants will be treated of under the various sections of our coasts. The first movement on the part of all emigrants among British birds is to the coast, which is reached in some cases, no doubt, by particular inland routes.

East Coast of Great Britain.—The emigratory movements on the east coast are very simple in their geographical aspect. When the coast is reached, the emigrants follow the coastline southward, gathering strength as they go, and finally quit our shores at various points on the south coast of England.

It is during such autumnal movements that the more southern coastline of Eastern England, and its off-shore fleet of lightships, record night migration. The ranks of the British emigrants are, as we have said, recruited as they fly onward, and if a great movement should be in progress, the causing-influence will affect also many birds of passage which may be sojourning on our shores. Two wings of the migratory army thus combine, and a great 'rush' to the south is the result.

West Coast of Great Britain.—The emigratory movements which pass down the west coast are far from being so simple in their geographical details as those observed on the east.

That such should be the case is not surprising. Here we have Ireland, the Isle of Man, the Hebrides, and an extremely irregular coastline exercising their varied influences. In addition, there are intermigrations

[1] Those birds which have been described as 'partial migrants' are included in this category.

between these off-lying isles and the mainland, and often movements of an independent nature in some portion of the western area.

The general route followed by these departing birds has its north-western source in the Outer Hebrides, and after leaving Barra Head it joins an important stream from the Inner Hebrides at Skerryvore. The course then followed is *viâ* Dhuheartach, Islay, the Wigtonshire coast, the Isle of Man, Anglesey, and the South Bishop (off Pembrokeshire). Finally, the south-western coast of England is reached (possibly in part by an overland route across Devonshire and Cornwall) between the Scilly Islands and Start Point.

In its course southward considerable tributaries, so to speak, are received at Cantire, Arran, the Ayrshire and Wigtonshire coasts, and the Solway, of birds passing down the west coast of Scotland. At the Bristol Channel emigrants are received from western England and Wales, and often also important contributions are added from the south-eastern coast of Ireland.

In connection with these movements there are several more or less important features to note. (1) The English shores of the Irish Sea,—*i.e.* the coasts of Cumberland and Lancashire—lie off the main line of these movements. (2) The north coast of Ireland, which seems to lie right in the course of the birds, and which would naturally be expected to come in for a considerable share of such movements, appears to be only occasionally affected by them. (3) The Irish contributory movements when they occur are chiefly, nay almost entirely, observed on the southern, and especially the south-eastern coasts. (4) The south-western coast of England and Wales—*i.e.* from the mouth of the Bristol Channel to the Land's End and the Scilly Isles—appears to be especially affected when there are considerable movements on the southern and south-eastern coasts of Ireland, implying that there is much intermigration between these particular portions of the English and Irish coasts. Sometimes, however, these emigrations from Ireland only affect the south-west coast of England from the Bishop's Rock (off Scilly) to Start Point.

Irish Coasts.—The Irish chronicles have been most excellently and carefully kept, and the returns of specimens killed against the lanterns at the stations have been larger and more valuable than those furnished from the coasts of Great Britain.

The coasts of Ireland do not constitute in themselves a main highway for birds, though they participate, along with the western shores of Great Britain, in certain movements to and from the far north on the part of the section of the birds of passage already alluded to. Indeed, the majority of the migrants observed on the shores of the sister isle are probably the migratory members of her own avifauna.

The movements of departing birds during the autumn at the southern and south-eastern stations have already been mentioned, and when migration is going on at this part of the coast there is often recorded an emigratory movement along the western coast from Slyne Head southwards, which probably forms a contributory stream to the general movement to the south. These Irish emigrations, as a rule, occur simultaneously with similar movements passing down the western coast of Great Britain, and the two streams meet and unite at points between the Bristol Channel and the Scilly Isles. Some of the Irish autumnal flights, however, are quite independent of these general movements.

There is much evidence to show that not only do the autumnal emigrants depart from the south-east coast of Ireland *en route* for more southern winter-quarters, but also, strange to say, that many birds (*e.g.* Thrushes, Redwings, Blackbirds, Chaffinches, Greenfinches, Linnets, Starlings, Larks) almost simultaneously *enter* that country by this very same section of her shores, in order to winter within her limits. These immigrants are often observed arriving from the south-east in great numbers for several days in succession. The English west coast observations also bear evidence that such movements proceed across St. George's Channel in a north-westerly direction. These cross-channel flights are usually observed during the daytime, but sometimes the arrival of certain of these birds on the Irish coast takes place during the night.

According to the records it is only occasionally, as already stated, that the southerly autumnal movements from Western Scotland are observed at the northern Irish stations. Now and then, however, there is evidence that a considerable number of birds do arrive on, or skirt, the north coast of Ireland during the more pronounced west coast emigratory flights.

Independently of, and in addition to, these main Irish migratory movements, Thrushes, Larks, and Starlings occur in October and November on the northern coasts of Ireland from Tory Island to the Maidens as immigrants from Scotland. These are to be correlated with movements of the same species observed at the Rhinns of Islay and the Wigton coast. Larks, too, are often recorded for this route during the daytime.

There are also autumnal movements between Ireland and England and Wales by an east to west flight across the Irish Sea, on the part of Starlings, Chaffinches, Greenfinches, Larks, and sometimes of various species of Thrushes. Anglesey is the chief Welsh point, and Rockabill (off the north coast of Co. Dublin) the main Irish station at which these departures and arrivals are observed.

The migratory movements observed on the west coast of Ireland are neither many nor important, and consist almost entirely of movements on the part of emigratory Irish birds. There are, however, remarkable immigrations from home sources witnessed on the west coast and its off-lying islets during great cold and snow, to which we shall have occasion to refer under the Seasonal and Meteorological Sections of this Report.

South Coast of England.—It is much to be regretted that observations relating to the migrations of birds on the southern coast of England *as a whole* were not obtained by the Committee. The data bearing upon this important English coast-line are from a few stations on the south-eastern and south-western portions only.

This information points to (1) a considerable amount of migration taking place between these portions of the coast-line and South-western Europe, and (2) important movements passing *along* the entire coast-line from east to west in autumn and probably *vice versâ* in spring.

The south coast is naturally the great scene of the arrival and departure of migratory birds of all descriptions, but the movements along shore are, perhaps, in some of their aspects, more interesting. Regarding these last, much remains to be ascertained concerning their precise nature and the destination of some of the birds travelling along this route.

In the autumn this coasting stream of birds has its source chiefly in the immigratory movements from the Continent across the southern waters of the North Sea by the East and West Route, of which it is but a continuation. It is possible also that British emigrants, after passing down the east coast of England, may turn to the westward and skirt the south coast, but this is not shown with certainty.

The continental immigrants strike the Kentish shore, and, as has been already stated, some pass to the north along the east coast of England, while others pursue a westerly course along our shores of the Channel. The stations on the south-western coast again record these migrants, and the probable destination of many, perhaps most of them, is Ireland, on whose south-eastern shores the birds are chronicled, almost simultaneously, as arriving in great numbers from the south-east.

It is possible, however, that some of these birds—the Skylark especially—may reach a much more remarkable destination, for one branch of the stream sweeps northwards, being observed at the mouth of the Bristol Channel, at Anglesey, and at the Isle of Man stations, proceeding to the west and north-west, probably to Northern Ireland; while on the Wigtonshire coast and at the rocks of Dhuheartach and Skerryvore these birds are noted as moving in the direction of the Outer Hebrides.

The great autumnal movements from east to west along the south coast of England are renewed in winter, when that season is characterised by periods of unusual cold. At such times it is possible that this western stream is composed in part of native emigrants which have passed down our eastern coasts, as well as of birds of continental origin.

Channel Islands.—Records from the Hanois Lighthouse, situated some two miles off the west coast of Guernsey, were furnished for each of the years of the enquiry, and afford some useful information. These, when compared with the English and Irish chronicles, show that on nearly every occasion on which considerable migration was observed at this station in the autumn, there was also much emigration going on practically simultaneously on the south-west coast of England. It is necessary, however, to state that a number of important movements on the south-west coast of England do not appear in the records for Hanois, indicating, perhaps, that many movements to the south in autumn and to the north in spring pass to the westward of this station. In the spring, Swallows are observed passing to both the north-east and north-west in great numbers during April and May, and a number of other summer birds are recorded on passage.

SEASONAL.

The Seasonal Section of the Report is readily subdivided for treatment into Autumn, Winter, and Spring.

A few words are necessary in explanation of the differences between the autumn, spring, and winter migratory movements as observed in the British Isles, for they are performed under very different conditions and influences. These remarks apply more particularly to the birds of passage, yet they are also applicable, to some extent, to our native seasonal visitors.

In the Autumn the birds, when they appear on our shores, have accomplished *the* great business of the year—procreation. Food is still abundant in their favourite resting haunts, and hence there is no particular hurry to move southwards. Thus many species tarry on our coasts or in their vicinity, some for a considerable period. Their numbers are, of course, incomparably greater than during the northward journey, as they are swelled by the numerous young birds, now a few weeks old. All these circumstances and conditions combine to make the autumn movements comparatively easy of observation.

In Spring the conditions are quite different. The all-absorbing duties of the season and the procreative influence are upon the voyagers, and since our Islands form one of the last stages in the journey of many species, the birds usually hurry on after a short sojourn for rest and food only. Thus the spring movements do not afford much facility or opportunity for observation; indeed, with most species their appearance amounts to 'here to-day, off to-morrow.' Hence some species and many individuals entirely escape notice at a number of the observing stations.

All that it is necessary to say here regarding the Winter Movements is that they are entirely the effect of severe weather.

Autumn Immigration.—As the summer, more particularly the arctic summer, is at its height during JULY, it is not to be expected that immigrants among the northern summer-birds would appear on our shores on their return journey during this month. The initial movements of the autumn, whatever their significance may be, do, as a matter of fact, set in towards the end of July. Of the species observed, the Whimbrel and the Knot are the most frequently recorded. The Green Sandpiper, Curlew Sandpiper, Bar-tailed Godwit, and Turnstone are less frequent. A few others appear only occasionally in the chronicles of the month.

In all probability these July immigrants, or the majority of them, are non-breeding birds of their respective species, which have not, perhaps, proceeded far beyond the limits of Britain on their spring journey northward. That such is the case is borne out by the fact that these July birds are *all*, so far as reported, adults.

Immigration sets in in earnest during AUGUST on the part of those species breeding northwards beyond the British area, and either occurring as birds of passage or as winter visitors to our isles. The former include the northern representatives of several species which are summer visitors to Britain. The return movements of twenty-six species of birds whose summer haunts lie entirely beyond the British area are chronicled for the month.

During SEPTEMBER a marked increase in immigration takes place as regards both species and more especially individuals. In all, over forty species of European birds which do not summer in Britain are recorded as migrants for September, including all the species regularly recorded for August. In some years (1881 and 1883) there have occurred in September the first of the great autumnal 'rushes' of immigrants from the north to our shores. These decided movements are, however, entirely the effect of meteorological conditions at the seat of emigration, of which special mention is presently to be made in the Meteorological section.

In OCTOBER the flood of immigratory birds reaches its highest level, and there are experienced those vast 'rushes' upon our shores just mentioned. The additions to the list of extra-British breeding species are comparatively numerous, forty-seven species of regular birds of passage, besides many other birds breeding in both Northern Europe and Britain, being recorded. But, on the other hand, the movements of certain other species have, according to our chronicles, already ceased to occur, and it may be taken that the majority have passed,[1] while a few others do not appear so numerously as heretofore.

[1] These are the White Wagtail, Temminck's Stint, Wood Sandpiper, Green Sandpiper, and Spotted Redshank.

The immigratory movements occurring in NOVEMBER are not only on a very much reduced scale, *but after the middle of the month the immigration of such birds as spend the summer in the North entirely ceases,* with the exception of those of certain marine species (Ducks, Gulls, Grebes, Swans), whose late movements to the South are dependent upon severe weather conditions.[1] This is entirely contrary to the views hitherto propounded regarding the limits of these movements, but it is, nevertheless, a fact well established by this inquiry.

A few (six only [2]) northern summer birds which do not breed in Britain still occur as immigrants during the earlier days of the month, often in considerable numbers. The additions for the month are species which only occasionally occur, and whose appearance is in some cases indicative of weather influences. A few northern species are recorded more numerously during November than earlier in the autumn—namely, the Lapland Bunting, the Swans, Ducks generally, the Ringdove, the winter Grebes, and the Little Auk, the last, however, irregularly.

The immigrants hitherto considered are those derived from the north. There now remain for treatment those which reach us by a westerly movement along the East and West Route, and arrive on the south-eastern shores of England. These diurnal movements set in during the latter days of SEPTEMBER, when Larks, 'Crows' (Rooks), Tree-Sparrows, and some Redbreasts are observed. Immigration increases in volume in OCTOBER, when, in addition to the species mentioned, Blackbirds, Thrushes, Grey Crows, Chaffinches, Greenfinches, Goldcrests, and, occasionally, Woodcocks are observed. The movements continue until the middle of NOVEMBER, when they too, during ordinary seasons, cease to be observed. They are renewed again, however, on the part of Larks, Starlings, Thrushes, and Lapwings on the advent of great cold, when the birds chiefly pass westwards along the south coast of England.

During immigration our shores are reached during the late night or early morning on the part of migrants from the north. On the contrary the immigratory movements from the east, across the narrows of the North Sea, appear to be performed during the daytime.

Autumn Emigration.—It is somewhat difficult to determine what species among our British summer visitors are true emigrants during JULY. There is no doubt, however, that the departure of adult Cuckoos dates from the latter days of the month, when they not only appear on the coast-line, but are occasionally killed against the lanterns of the light-stations. The Swift is another species that appears with some frequency at the stations, which fact indicates that the ebb of its summer sojourn in Britain has begun. During the month, especially towards its close, there are now and then records of the movements of small numbers of * Thrushes, * Blackbirds, * Wheatears, Whinchats, Redstarts, * Redbreasts, Whitethroats, Goldcrests, Chiffchaffs, Willow Warblers, Pied Wagtails, Grey Wagtails, Meadow Pipits, Swallows, House Martins,

[1] On a few occasions during the years of the inquiry *several* Thrushes, Fieldfares, Woodcocks, Snipes, and Plovers have been observed in the Orkneys and Shetlands (*e.g.* during the exceptionally severe winters of 1882 and 1886). These may, perhaps, have been immigrants, or they may have been birds that had moved to island-haunts from the mainland during the period of great cold.

[2] These are the Redwing, Fieldfare, Great Grey Shrike, Brambling, Jack Snipe, and Knot. The Snow Bunting also occurs in some numbers.

Chaffinches, Starlings, Rooks, * Skylarks, Short-eared Owls, Herons, Grey-lag Geese, Land Rails, and Richardson's Skuas.[1]

It is well, however, to bear in mind, in connection with such July movements, that during this month there is a vast increase in our feathered population in the shape of birds but a few weeks old. These youngsters are many of them outcasts whose parents are engaged with second families, and many of them may, in their wanderings, finally reach the coast, where their appearance is duly chronicled by the observers.

Another class of migratory birds, namely, certain Plovers and Sandpipers which spend the summer inland and the autumn and winter on the shore, also appear on the coast in small numbers accompanied by their young. The young of several species of sea-fowl—Razorbill, Guillemot, and Puffin—are mentioned as leaving their rocky nurseries during the month. Lastly, it is certain that some of the movements recorded for this month are due to spells of ungenial weather. This aspect of July emigration, however, belongs to, and will be treated of under, the Meteorological Section of this Digest.

During August much emigration among our summer visitors is witnessed, and thirty-three species are recorded as departing. Of the birds which are partially migratory, no fewer than thirty-four species are noticed as emigratory during August, though, perhaps, all are not necessarily passing beyond the British area.

Both these groups of emigrants are in all probability swelled during this and other months by birds of the same species, which pass the summer in countries north of the British Isles, and which, having reached our shores as immigrants, are also moving southwards along our coast-lines.

September witnesses the height and close of the emigration of the bulk of the smaller British summer visitors, most of which are absent from the chronicles for October. The movements of forty-two of these emigrants appear in the records for the month ; while those of the partial migrants are also considerable, over forty species being recorded. There are often during this month considerable emigratory 'rushes' on the part of both these groups of migratory birds, due to outbursts of ungenial weather in our Islands.

The October emigrants among the summer birds are not numerous, and consist of laggard representatives of their kinds. Only twenty-two species are recorded in the chronicles for the month, and some of these are only observed occasionally. The partial migrants, on the other hand, are much on the move, and are numerous both as regards individuals and species, their ranks, no doubt, being considerably recruited by numbers of the same species from the north, which sooner or later emigrate in their company. These movements are often pronounced, and 'rushes' are recorded ; but they cease by or during the first half of November.

It is during the great autumn emigrations that the birds are observed on *all our shores simultaneously*.

Emigratory birds are observed passing southwards, and feeding as they go during the daytime ; but their flight to lands beyond our shores is usually undertaken during the nighttime.

Under certain peculiar weather conditions, which will be fully ex-

[1] Those species marked * are recorded as being occasionally killed against the lanterns.

plained in their proper place, there are immigratory and emigratory movements simultaneously observed on our coasts, the former affecting the east coast line only.

Winter Movements.—In NOVEMBER, and not later than the middle of the month, the *ordinary* autumnal southward movements on the part of birds of passage and of British emigrants cease.

These normal seasonal movements are followed later in the month by emigratory movements of a very different nature, and entirely due to a decided fall in temperature, usually in the form of outbursts of frost, and to snow. These conditions drive certain species specially affected either to warmer districts within the British area, or to southern regions beyond our shores. Such movements as these naturally become more pronounced as the winter advances, and especially so during severe seasons. They are repeated during each cold spell in the months of DECEMBER, JANUARY, FEBRUARY, and in some exceptional seasons as late as the third week of MARCH.

As soon as frost sets in, particularly if accompanied by snow and sleet, even if it is only locally diffused, it causes an immediate rush to the coast and its adjacent islands, especially to the western seaboard and to Ireland, where a milder climate usually prevails.

The appearance of these birds on the coast in the late autumn and winter has led them to be regarded as immigrants from abroad. But when the whole of the data relating to their distribution is examined, the true nature of these movements is no longer doubtful ; and this is the case quite apart from the weather conditions, which, in all instances, also afford an unfailing clue to their true character.

If the cold is very severe and prolonged, the isles off the south-west coast, such as Scilly and those off the west coast of Ireland, are sought, and many birds are observed at the southern stations to quit both Britain and Ireland. At such times these great western movements form the most prominent feature of the winter migratory records.

In the terrible DECEMBER of 1882, even these usually safe western retreats failed the refugees, and many succumbed, the hardy Snow Bunting perishing along with the rest. The Januaries of 1881, 1885, and 1887 were also very severe, and were months of great cold-weather movements. In 1881 many birds died of starvation at Valentia, then the least cold corner of the British area.

During exceptionally severe winters there is a renewal of immigratory movements from the continent by way of the East and West Route across the southern portion of the North Sea. On arriving on our south-eastern shores the Larks, Starlings, Thrushes, and Lapwings, which are the species recorded, move along the south coast of England, and probably seek the warmth of the South-west, the Scilly Isles, and Ireland.

The species which appear to be specially susceptible to cold, either constitutionally or through deprivation of food (most probably the latter), are the Mistletoe Thrush, Song Thrush, Redwing, Fieldfare, Blackbird, Greenfinch, Linnet, Starling, Lark, Water Rail, Lapwing, Curlew, Snipe, and Woodcock.

In mild winters the only movements recorded are a few local migrations, which strictly coincide with the occasional periods of cold from which hardly any season is entirely exempt.

Cold-weather migration is performed during both the night- and day-time. If the flight is an extended one it is probably undertaken at night, for much emigration is observed at southern stations during the hours of darkness.

Spring Immigration.—The first bird-harbingers of spring are recorded for FEBRUARY, when during genial periods such partial migrants within the British area as the Pied Wagtail and Lapwing return to the Orkneys and other northern stations, where these species are summer birds. Certain rock-breeding sea-fowl are also noted as visitors to their nesting haunts.

There is in addition indication of a return movement during mild weather on the part of Fieldfares, Redwings, Thrushes, Blackbirds, &c., which had fled the country through the winter cold. During February certain summer visitors have occasionally put in a phenomenally early appearance. In 1885 and 1887 the Wheatear was seen; in 1887 a Ring Ouzel was shot at one of the light-stations; and in 1886 (on the 24th) a solitary Swallow was observed at the Eddystone.

During the genial periods usually experienced in the changeable month of MARCH there is a considerable immigration or return of the birds which quitted our Islands through the pressure of the severe weather conditions of winter, and also of some partial migrants, including many Gold Crests and Pied Wagtails. In most years the advent of a few summer visitors is recorded. The Ring Ouzel, Wheatear, Whinchat, Willow Wren, Chiffchaff, Swallow, Sand Martin, Cuckoo,[1] Land Rail, Garganey, Whimbrel, and Sandwich Tern are recorded for the month, some of them once only, and others rarely.

APRIL is a month of pronounced immigration on the part of the summer visitors, for no less than thirty-seven species are recorded in the chronicles. It thus witnesses the arrival of certainly the majority of species among the spring migrants, though, perhaps, not of individuals. There arrive, also, a number of migratory birds belonging to species which are either resident in, or winter visitors to, Britain, which have wintered to the south of us and now appear as summer birds, or as birds of passage on their way to the north.

In connection with the arrival of these earliest immigrants among our summer visitors during March or April a remarkable and interesting fact remains to be mentioned—namely, that the great majority of these birds are recorded first for the south-western area of the British region—the south-west coast of England and Ireland. Thus in March, out of 94 observations 71, or 75 per cent., were made in the south-west. In April, out of 157 first records of the arrivals of summer visitors, no less than 115, or nearly 74 per cent., are chronicled for the south-west coast and Ireland. These numbers and percentages, however, should be *considerably higher* and more remarkable, for it must be explained that during the years 1880 and 1881 there were no spring data for Ireland, and in 1883 there was no return made for the west coast of England, while the east coast has been credited, in the statistics quoted, with the observations made during all the years of the inquiry. It thus seems probable that the first arrival of the spring migrants not unnaturally occurs on those parts of our isles which are the warmest so early in the season.

During MAY the immigration of summer birds still flows into our Islands. Several species make their first appearance, and a number of

[1] At Langness, Isle of Man, March 28, 1887.

others are more abundantly recorded than hitherto. There are also considerable arrivals of Wheatears, Warblers, Swallows, and Sandpipers and Plovers of various species, on our southern coast quite down to the end of the month, some of their movements being very marked. These are undoubtedly birds of passage, on their way to northern summer haunts beyond the limits of the British Isles, for our own birds of the same species are then busily engaged in incubation or tending their young.

During the first half of JUNE several species whose breeding range extends to the Polar regions appear in considerable numbers on our shores on their way to the far north ; a few appear even still later. The chief among these late birds of passage are the Grey Plover and the Knot, and less numerously or less frequently the Snow Bunting, Wigeon, Barnacle Goose, 'Grey Geese,' Swans, the Dotterel, Turnstone, Sanderling, Ruff, Bar-tailed Godwit, Whimbrel, and a few Great Northern Divers.[1]

In connection with the spring immigration it has to be remarked that the observations are all in favour of the theory that the earliest arrivals among the summer visitors to our Islands are British-breeding birds. This is borne out by the fact, well known to all field-naturalists, that our summer birds appear in their *breeding haunts* in our islands *immediately* after their first appearance on our coasts in the spring. Additional proof is furnished by the fact that summer birds arrive in Britain at earlier dates than in Heligoland, where nearly all the species observed are *en route* for more northern lands than ours. The further fact already mentioned, that down to the end of May, and in some instances the first half of June, large numbers of birds of species which are summer visitants to Britain, arrive on and pass along our coast as birds of passage, proves that the migrants bound for the north are the last of their kind to appear in the British area.

Spring Emigration.—The spring emigration from the British Isles to continental Europe sets in on the part of certain species early in the year, indeed before the winter emigratory movements have ceased to take place.

Thus in FEBRUARY, in some seasons, 'Geese' are recorded as moving northwards in considerable numbers. The chief emigratory movements of this month, however, are the departure of Larks and Rooks along the 'East and West Route' to the Continent. These take place in some years during the early days of the month, and are observed on the south-east coast of England—chiefly at the lightships off the coasts of Essex and Kent—where the birds observed are proceeding in a south-easterly and easterly direction across the North Sea, returning by the same lines of flight as those along which they travelled to our shores in the autumn.

During MARCH these south-easterly movements become more pronounced, and the emigrants include the Hooded Crow, Rook, and Skylark. Emigration for the north also commences, and the following winter visitors are recorded as leaving our Islands during the month : Great Grey Shrike, Shore Lark, Swans, 'Wild Geese,' Gadwall, Scaup, Golden-eye, Long-tailed Duck, Red-throated Diver, and probably many others. In March, too, certain species (Greenfinch, Chaffinch, Twite), which regularly seek the islands off the west coast of Ireland as winter retreats, are mentioned as taking their departure for the summer.

[1] The fact that these birds, or most of them, should *arrive on our shores* as birds of passage thus late in the migratory season, lends some countenance to the theory that the birds of certain species going furthest north in summer go the furthest south for winter quarters.

The mild spells of APRIL induce a considerable amount of emigration, for their northern summer haunts, on the part of no less than thirty-four species. These comprise fifteen Passeres, two Birds of Prey, nine Ducks and Geese, six Waders, one Skua, and one Diver, all of them belonging to species which have wintered in our Islands, or off our shores. The emigration to the Continent by the 'East and West Route' across the North Sea also proceeds during April, the species observed departing during the month being the Rook, the Hooded Crow, and the Tree Sparrow. No migratory movements, however, are recorded for this route after this month.

MAY is a month of much emigration on the part both of birds which have wintered in our Islands, and of birds of passage (including many individuals of species which are summer visitors to Britain). In all, no less than fifty-three species of regular emigrants are recorded in the May returns, showing that the movements to the northern breeding grounds reach their maximum during this month, and often take the form of 'rushes' after the birds have been held back by spells of ungenial weather. The northward movements from our shores of a few species, whose breeding range lies within the Polar regions, are also observed down to the middle of JUNE, or even beyond that date, and have already been noticed.

The departure for their northern summer quarters of the spring birds of passage and of the winter visitors to Britain takes place from our eastern coasts and the northern isles; a few only of the species, such as the Redwing, Wheatear, White Wagtail, Barnacle Goose, Swans, Whimbrel, &c., passing up our western coasts, possibly *en route* for Iceland.

METEOROLOGICAL.

Special attention has been bestowed upon this section of the Digest, since the actual relationships between migrational and meteorological phenomena have not hitherto received the attention they deserve, no doubt because the necessary sets of data for a satisfactory investigation of the problem were not obtainable. The material collected by the Committee has proved in all respects most valuable for establishing a useful comparison between these two sets of phenomena, and for determining, to a certain extent, the precise influence exercised by the weather upon bird movements. The standard for the weather has been the 'Daily Weather Reports' issued by the Meteorological Office. For the loan of a complete set of these valuable official records for the eight years of the inquiry, I am indebted to the Council of the Leeds Philosophical and Literary Society, through its esteemed Hon. Secretary, Richard Reynolds, Esq., an obligation I here desire to fully acknowledge.

It may be well to state that these 'Daily Reports' are based upon observations made at fifty-four stations, distributed over Western Europe between Haparanda and Bodö in the North, and Toulon, Biarritz, and Corunna in the South; as well as all parts of Great Britain and Ireland.

When studying bird migration in connection with meteorological conditions, it is essential that the weather peculiarities synchronous with the setting in of the emigration, and prevailing in the particular area in which the movement had its origin, should be considered. This alone has any true bearing upon emigration; not the weather prevailing upon the shores reached after an extended migratory flight. Thus the continental weather conditions must be consulted in connection with the arrival of immigrants in the British Isles in spring and autumn, and our home records referred to for an explanation of the movements of emigrants during the spring, autumn, and winter.

As the result of an extensive series of comparisons instituted between the two sets of phenomena, it has been ascertained that they are most intimately associated, and that a knowledge of the meteorological conditions prevailing during the movements in most instances contributes in no small degree to a correct interpretation of their precise nature and the seat of their origin.

The weather influences are of two kinds, as treated of separately below—

I. *Ordinary Weather Influences.*—It is found that in both the spring and autumn migratory periods there are spells of genial weather without marked features, other than those favourable for migration. During these the movements of the various species are of an even-flowing and continuous nature. If the weather should prove slightly unsettled during such periods, it is a matter of indifference to the migrants; if more pronouncedly so, their movements are slightly quickened thereby.

This may be termed normal migration under ordinary weather conditions.

The duration of such favourable spells, however, is sooner or later broken by the advent of a cyclonic period of a more or less severe type. This interferes, to a greater or lesser degree, with the progress of the migratory movements.

II. *Extraordinary Weather Influences.*—These are exerted by the prevalence of particular weather conditions, which may act either (1) as barriers to the ordinary movements, or (2) in diametrically the opposite direction as incentives to great movements or 'rushes,' as they have been termed.

The weather barriers to bird-migration are unfavourable conditions of a pronounced nature, which interrupt and make impossible, during their prevalence, the ordinary seasonal movements.

The weather incentives to migration are widely different in their nature and may take several forms. First, there may be favourable weather-periods immediately following unfavourable periods. Secondly, they may be due to weather in certain respects unfavourable to the birds, such as a decided fall in temperature, which either compels the birds to move, or acts as a warning that the time has arrived for their departure southwards. Such cold spells are characteristic of anticyclonic periods, when the weather is calm and highly favourable for a prolonged flight. Thirdly, and on the other hand, the advent in spring of a genial spell, especially if accompanied by a rise of temperature, is an incentive to a move to the northward for the summer haunts.

The weather influences thus vary considerably; but temperature plays the most important part in the various seasonal movements, and is the main controlling factor in all extraordinary movements, other meteorological conditions being suitable. Each movement, however, has its peculiarity, and the conditions controlling it are often due to meteorological phenomena of a more or less complex nature, most of which, perhaps, admit of explanation.

Meteorology and Autumn Immigration.—The immigratory movements of the early autumn are those already mentioned as normal migration under ordinary weather conditions, and need no further notice.

It is not until late in September, and during October and early November, that the movements into our Islands from the north-east are sufficiently pronounced to permit of their being associated with and attributable to the great weather changes of the autumn. In ordinary seasons the period named is characterised by a series of great immigratory movements simultaneously performed not only by many species, but also by a vast number of individuals.

It has been ascertained that *all* these great movements are due to the prevalence in north-western Europe of weather conditions favourable for emigration. These conditions are the result of the following type of pressure distribution—namely, the presence of a large and well-defined anticyclone over the Scandinavian Peninsula, with gentle gradients extending in a south-westerly direction over the North Sea. On the other hand, cyclonic conditions prevail to the westward of the British area, with a low-pressure centre off the west coast of Ireland, or, though less frequently, over areas further to the south. Under these pressure conditions the weather is clear and cold, with light variable airs over Norway and Sweden ; while in Britain the sky is overcast, and moderate to strong easterly winds are experienced, with fog not unfrequently prevailing at many east coast stations.

The formation of these conditions in the autumn usually follows the passing away from Scandinavia—the area in which the movement has its origin—of a spell of a more or less pronounced cyclonic nature, during the prevalence of which the ordinary course of the emigratory movements is either interrupted or rendered impossible.

The effects of this sequence of meteorological conditions on bird migration are remarkable.

During the cyclonic spell a weather barrier arrests the progress of, and dams back as it were, the ordinary seasonal migratory stream. These periods, too, are not unfrequently characterised by weather of great ungeniality, and this, no doubt, gives the summer birds warning that the time for seeking the south has arrived. Upon the duration and severity of these preliminary conditions depends, to some extent, the maguitude of the emigratory movement that follows.

The formation of the anticyclone removes the cyclonic weather barrier, releases the flood, and provides conditions favourable for migration, adding also an incentive in the form of a decided fall in temperature. Thus it is not a matter for surprise that such a combination of meteorological conditions in the north should produce a rush to the southwards of those vast numbers of migratory birds which appear during the hours of darkness on our eastern coasts at the fall of each year, and whose movements often extend over several successive nights.

These great movements occur most frequently in October, but during that month in the year 1887 no such immigration was recorded for our coasts. On examining the Meteorological Record, it is found that this peculiar type of weather only prevailed for a few hours on the 9th, and that a marked immigratory movement immediately set in, only to be checked by the dispersal of the conditions necessary for a great emigration from North-Western Europe. This fact illustrates in a remarkable manner how very direct the bearing of these conditions is upon the great autumn migratory movements between Northern Europe and Eastern Great Britain.

The movements just described take place when gentle pressure-gradients bridge, as it were, the North Sea, with fine weather between Scandinavia and Britain. Such an extension, however, of the favourable conditions does not always prevail for the entire journey—that is to say, they do not always reach to the British side of the North Sea. Indeed, it not unfrequently happens that the birds reach our shores under more or less unfavourable weather conditions. When such is the case the immigrants arrive in Britain in a correspondingly exhausted condition, and, no doubt, many sometimes perish during the journey. An examination of the weather data for such occasions reveals a very simple explanation of this peculiar, and partially unfavourable, phase in Migration-Meteorology. It is as follows:—Though the weather-conditions at the area of departure be entirely favourable for emigration, and induce the birds to move southwards, the conditions prevailing on the British coast are unfavourable, *owing to the too close proximity or the depth of the western low-pressure centre*. On the location and character of this cyclonic centre entirely depends the nature of the weather in the immediate neighbourhood of our shores. If the western cyclonic system is too close to Britain, or if the depression is exceptionally deep, then unfavourable conditions for migration, with strong winds, prevail beyond our eastern shores, and the birds perform the latter portion of their journey under trying conditions. On the other hand, if it is off our western shores and shallow, then fine-weather gradients entirely bridge the North Sea.

Between these extremes of autumnal migration-weather there are intermediate phases, whose influences are easily determined by a study of the two sets of phenomena.

The autumnal immigration from the east by the 'East and West Route' across the narrows of the North Sea to the south-east coast of England remains to be considered in connection with its meteorological aspects. Concerning this, however, there is not much to be explained. It has been ascertained that the movements take place during favourable weather conditions, and that they are most pronounced when the perfectly calm conditions and cold of anticyclonic periods prevail. They are interrupted by rough weather, to be renewed with increased momentum when the cyclonic spell is broken.

Simultaneous Autumn Immigration and Emigration.—It has been mentioned in the Seasonal Section of this Report, that under certain conditions in the late autumn decided immigratory and emigratory movements are witnessed in progress simultaneously. On these not very frequent occasions, it has been clearly ascertained that the anticyclone in North-western Europe covers an unusually wide area. This is due to the gentle character of its gradients, which, having their centre over Scandinavia, extend in a south-westerly direction to and beyond the limits of the British Isles. Thus there prevail over this exceptionally extensive region all the conditions already described as favourable for great emigratory movements. The result is a great simultaneous inpouring of birds on our east coast and a general outpouring from *all* British coasts of migrants of many species.

Autumn Emigration.—The autumnal emigratory movements are controlled, so far as they may be affected by meteorological phenomena, by weather-conditions prevailing in the British area.

The chief feature in migration during the earlier autumn days is the departure of British summer birds, including those which have been described as partial migrants. During the prevalence of fine weather or of weather not ungenial for the time of the year, these emigrants slip away gradually and almost unobserved, except by those favourably stationed on and off our coasts, by whom land birds are only seen when migrating. The pulse, so to speak, of these movements is, however, from time to time manifestly quickened under the influence of ungenial weather conditions of a not too pronounced nature, the chief stimulant being a fall in the temperature.

Even JULY, in certain seasons, has its ungenial spells, and so it was in the years 1882 and 1883, which were remarkable for their periods of unseasonable weather. These outbursts make themselves felt on our feathered population, and result in movements of a partial nature, perhaps, but which have left their mark on the migration record. The weather influences inciting these incipient movements are a complete break-up of genial and normal conditions and the prevalence of unsettled conditions, not unfrequently accompanied by thunder and heavy rains, and a decided fall in temperature. The result upon our summer visitants, or it may be upon their young, is that many of them move from their accustomed haunts, and appear on the coast at the light stations—sometimes at the lanterns—where their occurrence is duly chronicled. The species chiefly affected are the *Thrush, *Redbreast, Wheatear, *Whitethroat, Willow Warbler, Swallow, Martin, *Swift, and *Cuckoo.[1]

During AUGUST the ordinary emigratory movements of the autumn set in, and are usually performed under ordinary conditions—namely, fine weather. The weather influences other than normal are the same ungenial spells, especially if accompanied by cold, alluded to for July. These, however, are not frequent in most seasons, and yet no season is entirely free from them.

With the great increase to emigration that characterises SEPTEMBER, there are recorded, usually on several occasions during the month, very decided movements which may be fairly termed emigratory 'rushes.' These occur simultaneously with the weather spells which, among other characters, are remarkable for a decided fall in temperature, sometimes amounting to many degrees. In one instance, on September 15, 1886, the difference in temperature amounted to as much as 20° in twenty-four hours, and naturally produced a marked effect in the emigration returns. The conditions causing such decided falls in the thermometer, in the great majority of instances, are northerly winds, and as these may be due to anticyclonic weather conditions their force is usually slight. Sometimes, however, these cold spells prevail with a light southerly wind. This was the case on September 5, 1885, when a cold, showery period caused much emigration. That low temperatures are the prime factors is clearly demonstrated by the September records; inasmuch as during this month there are unsettled periods which are not characterised by cold, and it is found that their influence on migration is comparatively insignificant. When the unsettled periods become very pronounced or develop gales, which is sometimes the case during this month, the weather barrier thus formed arrests the emigratory movements, which are rendered impossible under such adverse conditions.

The great autumnal emigratory movements, however, occur late in

[1] Those marked thus * are recorded as having been killed at the lanterns during this month.

SEPTEMBER, during OCTOBER, and early in NOVEMBER. These are the result of the identical weather-conditions which cause similar emigratory movements from northern Europe, except that the conditions favourable for emigration prevail over the British area and to the southwards, and do not extend northwards. Indeed, the movement is usually kept quite distinct from an immigration by the interposition of weather barriers to the north, which cut off migratory communication between our shores and those of north-western Europe. These barriers most frequently take the form of a subsidiary low-pressure area lying over the North Sea between Great Britain and Scandinavia.

These great emigrations from Britain and Ireland, like the great immigrations from northern Europe at the same season, set in on the passing away of the cyclonic conditions unfavourable for bird-migration, and on the prevalence of an anticyclonic, or fine weather, spell with its characteristic calm and cold. In this case, too, the unfavourable conditions which have passed away probably act as a warning to many laggards among the migratory birds, while the cold adds an additional spur and swells the ranks of the departing birds.

During October movements are observed locally, which are directly traceable to the influence exerted on emigration by a considerable lowering of the temperature over a particular area. Thus, for example, on October 20, 1883, there was a remarkable movement of Swallows to the south-east coast of Ireland. On this day there was a decided fall in temperature, the lowest readings being recorded for Ireland, where these laggard summer-birds had until then found congenial quarters.

Again, on October 10, 1885, a local movement to the southward of Thrushes and Blackbirds was recorded at stations in the north of Scotland, and in this instance, too, the meteorological data afford the information that a fall in temperature had occurred within that area.

The emigratory movements in the late autumn and winter are, as has been already stated in this Report, attributable to the direct pressure of severe weather-conditions, in the shape of frost or heavy snow. It has been said, too, that these movements on the part of our resident and visitant birds are renewed with each outburst of cold, &c., during November, December, January, February, and early March—in some years down to the third week of the latter month. Little more need be said regarding these simple weather influences on British bird-emigration.

In certain years, however, the months of midwinter are characterised by conditions of Arctic severity. The January of 1881 was the most terrible month of the period covered by the inquiry. During its severe days many hundreds of birds perished even in the climatically most favourably situated portions of the British area—namely, the isles off the south-west coast of Ireland. The dominant feature of this month was intense cold, which for about three weeks reigned supreme in all parts of the British area, and was accompanied by severe, harsh gales and heavy snow. Thus, in spite of an exceptionally warm period during the month, the mean temperature for this January was from 5° to 12° below the average.

Spring Immigration.—In connection with the spring immigration, two very remarkable instances occurred on February 17, 1887. On this day several Wheatears arrived at the Chicken's Rock Lighthouse, and a Ring Ouzel was observed and shot at the Longship station. This date is exceptionally early for these species—indeed, they are the earliest records registered for any spring migrants during the eight years of the inquiry. It is noteworthy to find, from the 'Daily Weather Report,' that this portion of the British area was the warmest spot in Western Europe on the date in question.

During genial intervals in March, summer birds arrive, the Wheatear appearing some years in considerable numbers. In 1884, during a prolonged spell of warm weather, exceeding in warmth anything recorded for very many years, which followed a period of sharp frosts and snow, no fewer than six species of spring migrants were recorded as arriving in our Islands. Again, in 1886, five species were noted for a similar genial period. On the other hand, in the cold wintry March of 1883 one summer-bird alone—the Wheatear—was noted. Another March colder than the average was experienced in 1885, during which the arrival of three species only was chronicled.

Since the first arrivals of the summer birds appear, as a rule, in March, it may here be remarked that the climatic peculiarities of the British area would appear to play an important part in the geographical distribution of these early immigrants.

The remarkable fact that the great majority of the summer visitors to our Islands are first observed on the shores of the south-west of England and Ireland, has already been mentioned. This holds good even in ordinary and genial seasons, but in cold ones it is almost entirely the case. Thus in March, 1887, with its monotonously low temperature, the arrival of six species was recorded on twelve occasions, *all* for the south-west. During the exceptionally cold and rough March of 1883, only one species—the Wheatear—was observed on two occasions, both at stations on the west coast of Ireland where the temperature was highest. Again, in the cold March of 1885 every record but one of the fourteen chronicled was made in this same mild region of the British area.

It must not, however, be supposed that the thermometric conditions prevailing in our Islands are the cause of the northward movements to Britain and Ireland in the spring. We must seek their cause in weather conditions and influences prevailing and acting in regions to the south of our Islands.

A careful comparison has been made between the migrational and meteorological phenomena in connection with these spring emigratory movements from the continent. As the result it has invariably been found that all such movements, except those performed late in the season, are to be correlated with a rise of temperature in south-western Europe and perhaps in northern Africa. That this induces the birds to embark on their northward journey does not admit of doubt. It is worthy of note that in not a few instances such movements are recorded for dates on which the temperature in our Islands was lower than immediately before the immigration. This clearly indicates that the increase of warmth at the seat of emigration is the main factor controlling the spring movements to the north. This rise in temperature in south-western Europe may, and sometimes does, extend to and prevail over the British Isles.

Apart from this simple phenomenon no other peculiar meteorological condition appears to be associated with these spring movements from southern Europe to the British Islands.

Spring Emigration from Britain.—The movements of birds from our Islands to the northern breeding grounds in spring are influenced by the weather conditions which prevail in the British area, as all our emigratory movements naturally are. That such is the case is manifest on a comparison being instituted between the migrational and the meteorological data for spring. Here, as abroad, it is found, other conditions being equal, that increase in temperature is the main influencing factor, and also that upon it depends, to a considerable degree, the extent of the movement.

The emigratory movements from Great Britain and Ireland naturally take place at later dates than the corresponding movements into our Islands from the south. Thus it is not until April, and especially May, that the decided or great departure movements are recorded which are relevant to the particular investigation under consideration.

In April the fine weather or anticyclonic periods have varying emigrational values, depending entirely on their temperature. They are favourable if characterised by high, or moderately high, temperatures ; or they may be distinctly unfavourable through their decided cold. There is, however, a medium even in the influence of anticyclonic spells, and thus during periods which are moderately cold but calm, some emigration, of a straggling nature it is true, is recorded.

In spring, too, cyclonic periods vary also in their influences on emigration. They are, as a rule, unfavourable owing to their high winds and ungeniality. On the other hand, when they are of a mild type and characterised by warm rain and soft breezes, following a cold anticyclonic spell in April, they are found to be distinctly favourable to a northward movement from our Islands.

The great spring emigratory flights, and most of the lesser ones too, are embarked upon under precisely the same type of pressure distribution as that described as being so markedly favourable for the autumn passage of birds across the North Sea to our Islands, namely, the presence of a high pressure centre to the north-east of our Islands over Norway and Sweden, with gentle gradients to the south-west. Under such circumstances of pressure distribution the North Sea between our Islands and the Scandinavian peninsula is spanned by fine weather, and moderate easterly or southerly breezes prevail. Such highly favourable periods, as in the autumn, usually follow spells of weather decidedly ungenial for bird migration.

Some of these spring movements to the north are occasionally undertaken during somewhat unfavourable weather. Even in May there are a few records of emigration during sleet, cold rain, and north-east breezes, but it has to be explained that these flights followed prolonged spells of ungenial weather, with decidedly low temperature, late in the season, and were genial when compared with the preceding conditions.

Late in the spring—at the end of May and in June—it is not surprising to find that meteorological influences do not play an important part in the last movements to the north. That this should be the case is due, no doubt, to the advanced state of the season and its settled, or comparatively settled, weather.

Winds.—The importance attached to winds in connection with bird-migration has hitherto been much over-estimated by popular writers, and their influence, such as it is, misunderstood.

The conclusions to be drawn from a careful study of the subject are : (1) that the *direction* of the wind has no influence whatever *as an* *incentive to migration*; but that (2) its *force* is certainly an important factor, inasmuch as it may make migration an impossibility, arrest to a greater or lesser degree its progress, or even blow birds out of their course. We have the clearest proof, indeed, that birds do not emigrate when the winds are exceptionally high, though they sometimes pass into high winds and gales when *en route*, under the meteorological conditions which have already been described and explained. Ordinary winds—that is, winds not too strong—appear to be of small concern to the birds, for they are recorded as migrating with winds blowing from all quarters.

It is, however, a fact that particular winds almost invariably prevail during the great autumnal movements, and these have hitherto been considered by some as the direct incentives to such migrations. Such is not the case, and it may be at once stated that these supposed favourable breezes are simply another direct result of the pressure distribution favourable to the movements. This peculiar type of weather has already been fully described and its effects discussed; the winds prevailing and dependent upon these barometric conditions are easterly, chiefly south-easterly breezes. There is really no reason why westerly (west, north-west, and south-west) winds, not too strong of course, should not, *other things being equal*, be in every way as suitable for migratory movements as those varying between such divergent points as north-east to south. When, however, we come to inquire into the meteorological conditions producing these westerly winds, the reason for their unsuitability becomes at once apparent. These winds are the result of types of pressure-distribution which are fatal to migration between north-western Europe and Britain, namely, the presence of cyclonic areas to the north-east or east of the British Isles. This means that the area under disturbed conditions would be the very region from which we derive our autumn immigrants and render emigration from such sources impossible. Such areas of disturbance, with their high westerly and north-westerly winds, indeed, often extend to and influence the weather in our Islands, and interfere with the British emigratory movements in both autumn and spring.

Strong winds have a curious effect on the flight of Gulls, compelling them to move in a direction more or less directly heading the wind. Thus a strong westerly wind causes great numbers of Gulls to seek the estuaries and bays of our east coast. On the other hand, strong easterly winds will fill the estuaries and sea-lochs of the west coasts with these birds. The lee side of islands is also sought under similar conditions of the wind. A south-easterly wind, for the same reason, causes considerable numbers of Gulls of various species to pass southward along the eastern coast of Britain. Large parties of Gulls are also recorded as passing N.—sometimes for a whole day—with a N.N.W. wind. These movements are more or less local, and the birds return, no doubt, to their regular haunts in a few hours' time. They are, moreover, chiefly observed in the autumn.

Gales.—One effect of gales has already been alluded to, namely, that they arrest or make impossible the migratory movements.

At sea, however, they have a direct influence on the migrations of certain marine species, such as Skuas, Phalaropes, Petrels, &c. These birds in the autumn are occasionally driven out of their course by severe gales, and appear on our coasts in exceptional numbers. At such times, indeed, they are often blown far inland. Later in the season (in winter) Guillemots, Razorbills, Puffins, and Little Auks, are in like manner swept from their winter retreats on to our shores. Some of these last-named birds are sometimes cast up dead in great numbers during the winter months; the result of prolonged spells of rough weather at sea, which render the procuring of food, and perhaps rest too, an impossibility.

Fog.—It often happens that during an important migratory movement in the autumn or winter, fog prevails. On such occasions more birds than usual approach the lanterns of the light-stations and are killed, sometimes in considerable numbers, by striking against the glass. This phenomenon is another effect of those anticyclonic spells which have been mentioned as favourable to and causing emigration, and it is thus not surprising that the birds should encounter foggy weather during their movements. Such atmospheric conditions are well known to meteorologists to be characteristic of these high-pressure systems, and of their frosty periods, which latter are also the chief cause of the winter movements.

There is also some direct evidence that birds lose themselves in foggy weather, since practically non-migratory species, such as Sparrows, appear during its prevalence at unusual seasons at stations just off the coast.

CONCLUSION.

In conclusion it remains to be stated that this is merely a Summary of the Results obtained from a careful study of the data. It is not claimed for the Digest that it is exhaustive in any department. Indeed, such is far from being the case, and it is recognised that much yet remains to be extracted from the enormous mass of information now reduced to order. Further research will, no doubt, yield results of a useful, if not an important nature.

It has been found impossible here to enter into many interesting details in connection with the facts now established, while a vast amount of useful information of a statistical nature awaits publication. Much of the latter, however, can only be treated of under the numerous species to which it relates.

To the further consideration of the data, with a view to obtaining possible new and interesting facts, I am still actively devoting my attention. I trust in due course to make a more detailed and supplementary communication on Bird-migration in the British Islands, and on the interrelationship existing between it and the various other phenomena with which it is associated.

Post Office Regulations regarding the Carriage of Natural History Specimens to Foreign Countries.—Report of the Committee, consisting of Lord WALSINGHAM (*Chairman*), Mr. R. MCLACHLAN, Dr. C. W. STILES, Colonel C. SWINHOE, *and* Dr. H. O. FORBES (*Secretary*).

YOUR Committee have to report that they have been in communication with the Postmaster-General in reference to the object for which they were appointed, namely, to obtain from the Post Office the relaxation of the rule which prevents small parcels of natural history objects, sent for purely scientific purposes, from passing through the post to addresses abroad at sample-post rates, a privilege enjoyed by the Continental naturalists when transmitting to England. Your Committee regret that the latest reply from his Grace leaves no immediate hope of obtaining this concession, and they therefore do not ask for reappointment.

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Dr. P. L. SCLATER, Professor E. RAY LANKESTER, Professor J. COSSAR EWART, Professor M. FOSTER, Professor S. J. HICKSON, Mr. A. SEDGWICK, Professor W. C. M'INTOSH, *and* Mr. PERCY SLADEN (*Secretary*).

APPENDIX.

THE Table in the Naples Zoological Station hired by the British Association has been occupied during the past year, under the sanction of your Committee, by Mr. H. Chas. Williamson, whose objects of research were (*a*) the life-history of the eel and (*b*) the absorption of the yolk, and other points in the development of pelagic teleostean ova. Mr. Williamson's investigations extended from August 15, 1895, to July 16, 1896, with two intervals of absence for the purpose of prosecuting observations in other localities in connection with these researches. The nature of the work undertaken is indicated in the report furnished by Mr. Williamson, which is appended.

An application for permission to use the Table during the ensuing year has been received from Mr. M. D. Hill, who wishes to investigate the ova of certain Hydrozoa.

Your Committee trust that the General Committee will sanction the payment of the grant of 100*l.*, as in previous years, for the hire of the Table in the Zoological Station at Naples.

Early in the coming year the Naples Zoological Station will celebrate its twenty-fifth anniversary, the foundation-stone having been laid in April 1872. The occasion will be one of special interest, as it marks a period during which about 1,000 naturalists of various nations have worked at Naples, and more than thirty smaller institutions have sprung into existence elsewhere. It is not too much to say that the Naples Station, as their forerunner, has entirely changed the conditions of marine biological study.

As evidence of the successful management of the undertaking, it is sufficient to refer to the steady development and extension of scope recorded year by year, as well as to the constantly increasing popularity of the Naples Station as an international centre for research. That this feeling is actively maintained is shown by the fact that since the last report the Smithsonian Institute has renewed its contract with the Station for a term of years, and that new tables have been taken by the Columbia College of New York, as well as by Roumania and Bulgaria. The University of Strassburg has also renewed its contract for five years.

During the past year the two steamers belonging to the Station have been repaired and improved at a cost of 20,000 francs, and a new compound engine by Thornycroft has been bought for 10,000 francs. Other improvements and additions to the general equipment of the station, too numerous to mention here, have also been made.

The small zoological station established on the island of New Britain (mentioned in your Committee's last report) has been developing slowly, under the auspices of the Naples Station. The German Colonial Office and the Berlin Academy have recently granted 250*l.* and 150*l.* respectively for the purpose of sending out Dr. Dahl, of Kiel, to investigate the fauna, both terrestrial and marine.

The progress of the various publications undertaken by the station is summarised as follows :—

1. Of the 'Fauna und Flora des Golfes von Neapel,' the monograph by Dr. O. Bürger on 'Nemertinea' (pp. 743, 31 plates) has been published.
2. Of the 'Mittheilungen aus der zoologischen Station zu Neapel,' vol. xii. parts i. and ii., with 15 plates, have been published.
3. Of the 'Zoologischer Jahresbericht' the whole 'Bericht' for 1894 has been published.
4. A new English edition of the 'Guide to the Aquarium' is being printed.

The details extracted from the general report of the Zoological Station, which have been courteously furnished by the officers, will be found at the end of this report. They embrace lists (1) of the naturalists who have occupied tables since the last report, and (2) of the works published during 1895 by naturalists who have worked at the zoological station.

APPENDIX.

I. *Report on the Occupation of the Table. By* Mr. H. Chas. Williamson.

During 1895–96, for three separate periods of three months each, I have been engaged in the study of (*a*) the life-history of the eel and (*b*) the absorption of the yolk, and other points in the development of pelagic teleostean ova.

(a) *On the Life-history of the Eel.*

In connection with this subject, I have been enabled to examine the large eggs first described by Raffaele,[1] and referred by that author with reservation to the family of the Murænidæ, a diagnosis which has since received support from Grassi.[2] A large number of elveos and of eels of various sizes above that stage were supplied me during the winter. In the intervals between the periods of occupation of the Table I was absent from Naples in connection with this research.

(b) *On the Absorption of the Yolk in Pelagic Teleostean Ova.*

The process of the absorption of the yolk in teleostean ova is not one which has received much direct attention. In *demersal* eggs the absorption of the yolk is mainly effected by means of an elaborate vitelline blood circulation. In *pelagic* ova, with one or two rare exceptions, it is stated generally no vitelline circulation exists. The study of this subject involves an examination almost solely of *live* eggs. I find that, in a

[1] Raffaele, 'Uova galleggianti del Golfo di Napoli,' *Mittheil. Zool. Stat. Neapel*, 1888.

[2] Grassi e Calandruccio, 'Ancora sullo sviluppo dei Murenoidi,' *Bollet. dell' Accademia Gioenia in Catania*, Fasc. xxxiv. 1893.

number of pelagic ova which I have been able to examine, there is a distinct, though very much modified, vitelline circulation. The elements of this circulation are not, however, blood corpuscles, but yolk corpuscles. In the ova of *eight* species [1] I found this circulation, the corpuscles of which are derived from the periblast. Contemporaneously with the formation of the heart have appeared the primary vessels—viz. (*a*) the two lateral arteries uniting to form the median trunk, which passes posteriorly a point a little short of the tip of the tail; (*b*) the primitive caudal vein, which debouches into the posterior end of the yolk-sac. The pulsations of the heart are at first feeble and slow. The venous end of the heart is open to the interior of the yolk-sac. A *few* corpuscles are now seen to pass from the yolk-sac into the heart. These corpuscles, which proceed *singly and at intervals*, are seen moving along the arterial trunks to the tail, and immediately thereafter appear in the caudal vein, from which they pass into the yolk-sac. They then, with varying speed, pass over the ventral surface of the yolk and enter the heart. Some of the corpuscles proceed directly from the posterior end of the yolk-sac to the heart without; others become attached to the periblast, and remain fast for longer or shorter intervals. On the posterior surface of the yolk, where the caudal vein enters the yolk-sac, the periblast shows a well-marked furrow, which has been worn in it by the circulating fluid. Before the heart begins to beat, corpuscles, similar to the later circulating corpuscles, are seen on the periblast, and that these corpuscles, derived from the periblast, become the circulating corpuscles there is no doubt. At first, and even up to the time of hatching, the corpuscles are few in number. Only in the case of the three species of the eggs of Murænidæ have I been able to study the circulation fully. Eggs of other species which I examined presented difficulties, owing to their small size, presence of oil globules, or on account of the supply of specimens being insufficient. Only in the case of two species, in addition to those of the Murænidæ, was I able to obtain the ova in abundance. The corpuscles are minute, irregular in shape and size. In certain of the eggs the presence of the corpuscles on the periblast, and in motion in the yolk-sac, the connection between the caudal vein and yolk-sac, and the furrow continuing the caudal vein on the periblast have been regarded as sufficient evidence that a circulation of yolk corpuscles, similar to that clearly followed in others, was present. A certain amount of yolk-absorption no doubt takes place at the parts of the embryo in connection with the yolk, but after the formation of the tail of the embryo that absorption is probably very slight. The heart of the embryo in a pelagic ovum is said to pulsate before any blood is present, but the heart is not, however, without a circulation. It is extremely probable that there is, in addition to the yolk corpuscles, a circulating fluid of some sort being directed through the vessels by the heart. The first corpuscles are then formed in the periblast, and pass into the circulating fluid, the existence of which it is not unreasonable to postulate. A second method of adding corpuscles to the circulation is shown in a number of ova. This is a process of *budding* from the periblast. Slender pseudopodium-like pro-

[1] The eight species included:—Ova of *Murænidæ*, Raff. (three species); *Pleuronectes italicus* (?); *Merluccius vulgaris*; *Engraulis encrasicholus*; Species No. 3 (*Coryphæna ?*), Raff.; *Uranoscopus scaber*. (In the case of the last species I refer to a stage previous to the appearance of the complete vitelline circulation.)

cesses are thrown out from the surface of the periblast, and from the tips of these processes are budded off corpuscles which enter the heart and the circulation. These processes have been noticed by several authors, among others by Ryder. I have been able to observe these processes in the eggs of *seven* species. The eggs of the Murænidæ, from their large size, offer facilities for the study of this process of budding, and in these eggs the different stages have been successfully followed. The process is very slow, and may easily be overlooked. In the other species, the ova of which are small, the presence of the pseudopodial processes was noted. In these, unless a large number of eggs is obtainable, it is almost impossible to follow the actual budding off of the corpuscle. The corpuscles derived from the process of budding do not appear to differ from the primary corpuscles derived from the periblast. They are irregular in shape and size, and show, at least in some cases, nuclei. There is thus, previous to the advent of the blood circulation, a circulation of corpuscles derived from the periblast in two ways, (1) by simple direct transference from the surface of the periblast; (2) transference by means of a process of budding.

That the processes mentioned above are general I am led to believe; but I have not yet had the opportunity of examining a sufficient number of species to enable me to make a generalised statement.

Other points in development, which occupied my attention at Naples, I must leave over until I have had an opportunity of continuing my observations.

Any reference on my part to the advantages afforded by the Zoological Station at Naples is quite uncalled for. This subject has more than once been treated by zoologists more competent to judge than I am. To me the opportunity given by the Committee of the British Association to occupy the Table at Naples has been of incalculable value, and my sincere thanks are offered for the honour so done me.

II. *A List of Naturalists who have worked at the Zoological Station from the end of June* 1895 *to the end of June* 1896.

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
857	Prof. F. S. Monticelli	Italy	July 6, 1895	Nov. 4, 1895
858	Prof. J. Ogneff	Russia	„ 30, „	Aug. 14, „
859	Prof. V. Faussek	„	Aug. 1, „	—
860	Dr. F. Massa	Italy	„ 1, „	Nov. 1, „
861	Stud. V. Diamare	„	„ 1, „	—
862	Dr. G. Mazzarelli	„	„ 1, „	—
863	Dr. A. Romano	„	„ 3, „	—
864	Dr. G. Salvi	„	„ 7, „	Sept. 10, „
865	Prof. A. Della Valle	„	„ 7, „	Oct. 18, „
866	Mr. H. Ch. Williamson	British Association	„ 15, „	July 16, 1896
867	Stud. W. Daudt	Hesse	„ 24, „	Nov. 1, 1895
868	Dr. N. Germanos	Zoological Station	Sept. 2, „	„ 10, „
869	D. J. Wagner	Russia	„ 11, „	Apr. 1, 1896
870	Prof. B. Grassi	Italy	„ 14, „	Oct. 20, 1895
871	Dr. F. Savorani	Italian Navy	„ 24, „	„ 15, „
872	Mr. J. S. Gardiner	Cambridge	Oct. 1, „	Feb. 13, 1896
873	Dr. T. Reibisch	Saxony	„ 7, „	„ 14, „
874	Dr. G. Schischkoff	Bulgaria	„ 7, „	—
875	Dr. C. Apstein	Prussia	„ 14, „	Mar. 6, „

II. A LIST OF NATURALISTS, &c.—*continued.*

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy — Arrival	Duration of Occupancy — Departure
876	Dr. H. Driesch	Hamburg	Oct. 22, 1895	June 11, 1896
877	Dr. C. Herbst	Prussia	„ 22, „	„ 11, „
878	Dr. Vastarini Cresi	Italy	Nov. 13, „	—
879	Dr. M. Märtens	Prussia	Dec. 31, „	Apr. 1, „
880	Dr. Tagliani	Italy	Jan. 1, 1896	„ 1, „
881	Dr. G. Jatta	Zoological Station	„ 1, „	—
882	Mr. E. S. Goodrich	Oxford	„ 6, „	July 14, „
883	Prof. D. Voinov	Roumania	„ 11, „	„ 10, „
884	Dr. A. Borgert	Prussia	„ 18, „	May 24, „
885	Dr. R. S. Harrison	Agassiz Table	Feb. 1, „	„ 1, „
886	Dr. F. v. Wagner	Strassburg	„ 18, „	Mar. 28, „
887	Mr. H. Bosshard	Switzerland	Mar. 3, „	July 3, „
888	Prof. E. Ziegler	Baden	Feb. 19, „	Apr. 13, „
889	Dr. A. Russo	Italy	Mar. 3, „	„ 9, „
890	Dr. K. Hescheler	Switzerland	„ 9, „	May 7, „
891	Mr. W. T. Swingle	Smithsonian Table	„ 10, „	„ 30, „
892	Prof. Oltmanns	Baden	„ 11, „	Apr. 18, „
893	Dr. F. M. MacFarland	Smithsonian Table	„ 11, „	June 24, „
894	Miss Hyde, Dr. Ida	Zoological Station	„ 12, „	May 1, „
895	Dr. Beneke	Strassburg	„ 12, „	Apr. 18, „
896	Prof. T. Boveri	Bavaria	„ 12, „	„ 22, „
897	Prof. E. Korschelt	Prussia	„ 12, „	„ 17, „
898	Prof. E. Lahousse	Belgium	„ 15, „	„ 25, „
899	Dr. R. C. Coe	Agassiz Table	„ 17, „	May 6, „
900	Dr. J. v. Uexküll	Würtemberg	„ 18, „	July 17, „
901	Dr. A. Weysse	Agassiz Table	„ 19, „	June 18, „
902	Dr. A. Matthews	Columbia College	„ 19, „	„ 28, „
903	Prof. Solger	Prussia	Apr. 1, „	—
904	Dr. N. Iwanzoff	Russia	„ 6, „	July 17, „
905	Prof. P. Mitrophanow	„	„ 10, „	May 25, „
906	Dr. O. van der Stricht	Belgium	„ 18, „	„ 5, „

III. *A List of Papers which were published in the year* 1895 *by the Naturalists who have occupied Tables in the Zoological Station.*

W. E. Ritter . . . . On budding in Goodsiria and Perophora. 'Anatomischer Anzeiger,' B. 10, 1895.

S. Fuchs . . . . Ueber die Function der unter der Haut liegenden Canalsysteme bei den Selachiern. 'Archiv f. d. gesammte Physiologie,' B. 59, 1895.

„ . . . . . Beiträge zur Physiologie des Kreislaufes bei den Cephalopoden. *Ibid.*, B. 60, 1895.

W. M. Wheeler . . . The behaviour of the Centrosomes in the fertilised egg of Myzostoma glabrum. 'Leuckart's Journal of Morphology,' vol. 10, 1895.

H. Ludwig . . . . Ueber die im Mittelmeere vorkommenden Seestern Arten Luidia. 'Verh. Nat. Ver.,' Bonn, Jahrgg. 52, 1895.

A. Russo . . . . Studii anatomici sulla famiglia Ophiotrichidæ del Golfo di Napoli. 'Ricerche fatte nel Laboratorio di Anatomia normale della R. Università di Roma,' vol. 4, 1895.

„ . . . . . Sulla morfologia del Syndesmis Echinorum François. 'Ricerche Laborat. di Anatomia normale,' Roma, vol. 5, 1895.

G. Mazzarelli . . . Ricerche intorno al così detto apparato olfattorio delle Bulle. 'Ricerche fatte nel Laboratorio di Anatomia normale della R. Università di Roma,' vol. 4, 1895.

G. Mazzarelli . . . . . Intorno al rene secondario delle larve degli Opistobranchi. 'Boll. Soc. Naturalisti di Napoli,' vol. 9, 1895.

C. Crety . . . . . Contribuzione alla conoscenza dell' uovo ovarico. 'Ricerche fatte nel Laboratorio di Anatomia normale della R. Università di Roma,' vol. 4, 1895.

J. v. Uexküll . . . Physiologische Untersuchungen an Eledone moschata 4. Zur Analyse der Functionen des Centralnervensystems. 'Zeitschr. für Biologie,' B. 31, 1895.

" . . . . Vergleichende sinnesphysiologische Untersuchungen 1. Ueber die Nahrungsaufnahm des Katzenhais. *Ibid.* B. 32, 1895.

H. Driesch . . . Von der Entwickelung einzelner Ascidienblastomeren. 'Archiv für Entwickelungsmechanik,' B. 1, 1895.

H. Driesch and T. H. Morgan. Zur Analysis der ersten Entwickelungsstadien des Ctenophoreneies. 1. Von der Entwick. einzelner Ctenophorenblastomeren. 2. Von der Entwick. ungefurcht. Eier mit Protoplasmadefekten. 'Archiv Entw. Mechanik.' B. 2, 1895.

N. Iwanzoff . . . Der mikroskopische Bau des elektrischen Organs von Torpedo. 'Bull. Soc. Naturalistes Moscou.' Moskau, 1895.

" . . . . Das Schwanzorgan von Raja. 'Bull. Soc. Imp. Naturalistes Moscou,' N. 1, 1895.

Ch. Hargitt . . . Character and distribution of the genus Perigonimus. 'Mittheil. Zool. Station Neapel,' B. 11. 1895.

N. Léon . . . Zur Histologie des Dentalium-Mantels. 'Jenaische Zeitschrift,' B. 30, 1895.

T. H. Morgan . . Half embryos and whole embryos from one of the first two blastomeres of the frog's egg. 'Anatomischer Anzeiger,' B. 10, 1895.

" . . . . The formation of one embryo from two blastulæ. 'Archiv für Entwicklungsmechanik der Organismen,' B. 2, 1895.

" . . . . A study of a variation in cleavage. *Ibid.*

" . . . . Studies of the 'partial' larvæ of Sphærechinus. *Ibid.*

" . . . . Experimental Studies of the Blastula and Gastrula stages of Echinus. *Ibid.*

" . . . . The fertilisation of non-nucleated fragments of Echinoderm-eggs. *Ibid.*

" . . . . A Study of Metamerism. 'Quart. Journal Micr. Sc.' (2), vol. 37, 1895.

H. Pollard . . . The oral cirri of Siluroids and the origin of the head in Vertebrates. 'Zool. Jahrbücher, Abth. für Anat. und Ontogenie,' B. 8, 1895.

V. Diamare . . . I corpuscoli surrenali di Stannius ed i corpi del cavo addominale dei Teleostei. 'Boll. Soc. Nat. Napoli,' vol. 9, 1895.

H. Klaatsch . . . Beiträge zur vergleichenden Anatomie der Wirbelsäule. III. Zur Phylogenese der Chordascheiden, &c. 'Morphol. Jahrbuch.' B. 22, 1895.

" . . . . Ueber Kernveränderungen im Ektoderm der Appendicularien bei der Gehäusebildung. *Ibid.*, B. 23, 1895.

G. Tagliani . . . Intorno ai centri nervosi dell' Orthagoriscus mola. Notizie anatomiche e critiche. 'Boll. Soc. Natur. Napoli,' vol. 9, 1895.

" . . . . Intorno ai così detti lobi accessorii ed alle cellule giganti della midolla spinale di alcuni Teleostei. *Ibid.*

Th. List . . . . Morphologisch-biologische Studien über den Bewegungsapparat der Arthropoden. 2. Theil. Die Decapoden. 'Mitth. Zool. Station Neapel,' B. 12, 1895.

R. Schneider . . . Die neuesten Beobachtungen über natürliche Eisenresorption in thierischen Zellkernen, &c. *Ibid.*

R. Krause . . . Die Speicheldrüsen der Cephalopoden. 'Centralbl. für Physiol.' B. 9, 1895.

Th. Beer . . . Der Schlaf der Fische. 'N. Wiener Tageblatt,' N. 196, 1895.

H. M. Vernon . . . The effect of environment on the development of Echinoderm larvæ; an experimental inquiry into the causes of variation. 'Phil. Trans. R. Soc. London,' vol. 186, 1895.

„ . . . The respiratory exchange of the lower marine Invertebrates. 'Journ. of Physiology,' vol. 19, 1895.

F. Reinke . . . Untersuchungen über Befruchtung und Furchung des Eies der Echinodermen. 'Sitz. Ber. Akad. Berlin,' 1895.

J. Sobotta . . . Die Befruchtung des Eies von Amphioxus lanceolatus. 'Anat. Anz.,' B. XI., N. 5, 1895.

H. Bury . . . The Metamorphosis of Echinoderms. 'Quart. Journal Micr. Sc.,' V. 38 (2), 1895.

O. vom Rath . . . Ueber den feineren Bau der Drüsenzellen des Kopfes von Anilocra mediterranea, Leach, &c. 'Zeitschr. wiss. Zool.' B. 60, 1895.

J. E. S. Moore . . On the structural changes in the reproductive cells during the spermatogenesis of Elasmobranchs. 'Quart. Journ. Micr. Sc.' (2), vol. 38, 1895.

M. D. Hill . . . Notes on the fecundation of the egg of Sphærechinus granularis, and on the maturation and fertilisation of the egg of Phallusia mammillata. *Ibid.*

C. Nutting . . . Notes on the Reproduction of plumularian Hydroids. 'American Naturalist,' Nov. 1895.

R. Hesse. . . . Ueber das Nervensystem und die Sinnesorgane von Rhizostoma Cuvierii. 'Zeitschr. wiss. Zoologie,' B. 60, 1895.

E. Korschelt . . . Uber Kerntheilung und Befruchtung bei Ophryotrocha puerilis. *Ibid.*

S. Trinchese . . . Ricerche anatomiche sul Phyllobranchus Borgninii (Tr.). 'R. Accad. Sc. Istituto Bologna' (5), t. 5, 1895.

African Lake Fauna.—Report of the Committee, consisting of Dr. P. L. SCLATER (*Chairman*), Dr. JOHN MURRAY, Professor E. RAY LANKESTER, Professor W. A. HERDMAN, *and* Professor G. B. HOWES (*Secretary*).

ON reaching Blantyre, Mr. T. E. Moore, to whom the Committee had entrusted the investigation of the fauna of Lake Tanganyika, being detained by the Nyasa war, took the opportunity of visiting Lake Shirwa, and made observations upon a Green *Bacterium*, which appears to swarm there. Proceeding subsequently to Tanganyika, he reports that the fresh-water Medusa there (*Limnoclida tanganyikæ*) is exceedingly abundant, and announces the discovery of an apparent dimorphism in certain specimens, with active proliferation of each of the dimorphic forms. He has also collected fishes, molluscs, crustacea, and plants, all of which bear out the conclusion that Lakes Tanganyika and Nyasa are quite distinct in origin, and has discovered a large fresh-water sponge. Mr. Moore has also made geological collections, with a special view to their bearings upon the origin of the great African Lakes. After visiting some of the smaller lakes, he proposes shortly to start on his return journey to this country. Under these circumstances the Committee propose to defer their final report on the results arrived at by Mr. Moore until the next meeting of the Association, and ask that they may be reappointed in the meanwhile without any further grant.

Marine Biological Association, The Laboratory, Plymouth.—Report of the Committee, consisting of Mr. G. C. BOURNE (*Chairman*), Professor E. RAY LANKESTER (*Secretary*), Professor M. FOSTER, *and* Professor S. H. VINES, *appointed to investigate the Relations between Physical Conditions and Marine Fauna and Flora.*

Algological Notes for Plymouth District. By Mr. GEORGE BREBNER.

FROM January to April (1896) inclusive I had the privilege of occupying the British Association's table. As a result of my investigations the following marine algæ were added to the local flora, several of which were new to Britain, and others (marked thus *) were species or forms new to science.

NEW TO BRITAIN.

MYXOPHYCEÆ.

Oscillatoria rosea, Crn. (Queen's Ground.)
Symploca atlantica, Gom. f. *purpurea*, Batt. (Yealm.)
Hyella cæspitosa, Born. et Flah. var. *nitida*, Batt.

PHÆOPHYCEÆ.

Ralfsia disciformis (Crn.), Batt. (Yealm.).

FLORIDEÆ.

**Acrochætium endophyticum*, Batt. (Off west end of breakwater.)
Cruoria rosea, Crn. f. *purpurea*, Batt. (Yealm.)
Cruoriopsis cruciata, Duf. (Queen's Ground.)
Cruoriopsis Hauckii, Batt. (Off west end of breakwater.)
Peyssonelia rupestris, Crn. (Queen's Ground.)

NEW TO PLYMOUTH DISTRICT.

CHLOROPHYCEÆ.

Cladophora hirta, Kütz. (Drake's Island.)

PHÆOPHYCEÆ.

Lithoderma fatiscens, Aresch. (Bovisand Bay). (Plurilocular sporangia not previously found in Britain.)

FLORIDEÆ.

Acrochætium microscopicum, Näg.
Peyssonelia Harveyana, Crn. (Queen's Ground.)
Rhododermis elegans, Crn. (Queen's Ground, &c.)
Lithothamnion Strömfeltii, Foslie. (Queen's Ground.)
Peyssonelia Rosenvingii Schm. (Wembury Bay.)

The new species of *Acrochætium* is interesting on account of the main part of the thallus being endophytic—namely, in *Dasya coccinea* (Huds). Ag.—this alga therefore occupying in the genus *Acrochætium* a position analogous to that of *Rhodochorton membranaceum* Magn. in its genus. *A. endophyticum*, Batt., was described in the barren condition at the Linnean meeting of December 19, 1895, but the monosporangia were not found till January 1896.

Cruoria rosea, Crn. f. *purpurea*, Batt., is probably only a more advanced stage in the life-history of *Cruoria rosea*, Crn., than had hitherto been recognised. It is so like the figure of Crouan's *Cruoria purpurea* that it would have been identified as such by Mr. Edw. Batters and myself but for the fact that our solitary specimen showed several intermediate connecting stages.

Cruoriopsis Hauckii, Batt., is an interesting member of the Squamariaceæ, obtained from a stone dredged off the west end of the breakwater. The tetraspores showed almost every transition from zonate to cruciate. It most nearly resembles *Cruoriella armorica* of Hauck (non Crouan). As one of the two species bearing the name *Cruoriella armorica* will have to be renamed, Mr. Batters proposes to call our plant as above.

The other finds do not call for special mention.

Interesting results were obtained from a cultivation experiment with *Ahnfeltia plicata*, Fr. The nature of its fructification has not been satisfactorily made out. The late Professor Fr. Schmitz maintained that it was a parasite (*Sterrocolax decipiens*, Schm.), and that the true reproductive organs had not yet been found. His view, however, while widely accepted by algologists, was opposed by Reinke and others. This plant, richly supplied with 'nemathecia,' was placed in sterilised sea-water on February 1, 1896, and after two months (March 30) a very great number of germinated spores, in the shape of small discs, were found on the sides of the glass jar. The structure and appearance of those discs were such as to strongly support the view that the supposed parasite of Schmitz was in reality the sporogenic nemathecium, or fructification, of *Ahnfeltia plicata*. Unfortunately, owing to the difficulties of cultivation, I did not succeed in definitely settling this point, as the culture did not get beyond the disc stage; but, if the opportunity offers, another year I hope to repeat this experiment under more favourable conditions.

As part of my investigation I am studying the attaching-discs of the red sea-weeds, or Florideæ, in order to ascertain to what extent the conditions found by me in *Dumontia filiformis* (Fl. Dan.) Grev. ('Journal of the Linnean Soc.'—Botany—vol. xxx. p. 436) prevail in other species. So far I have found no other red sea-weed which shows a mode of development, from an attaching-disc, similar to that described for *D. filiformis* (l. c.). A large number of the Florideæ (e.g. *Gigartina*, *Polyides*, *Stenogramme*) are connected with their attaching disc by a simple parenchyma-like tissue; one or two species of those which have attaching discs present somewhat different features, and when their structure is more fully worked out will be worth describing and figuring, but they in no way resemble the conditions found in *D. filiformis*.

In conclusion I should like to state that two or three of the above finds are entirely due to Mr. Batters, the material having simply been forwarded to him from the Laboratory at my request. He, moreover, has very kindly acted as expert for me by naming such algæ as seemed to me to be interesting or new, the Plymouth Marine Biological Laboratory not being well supplied with the literature necessary for algological research.

The diagnosis of *Acr. endophyticum*, Batt., and particulars with regard to the other new to Britain marine algæ, may be found in 'The Journal of Botany' for September, 1896, under 'New or Critical British Sea-weeds,' by Mr. Edw. Batters.

The Necessity for the Immediate Investigation of the Biology of Oceanic Islands.—Report of the Committee, consisting of Sir W. H. FLOWER (*Chairman*), Professor A. C. HADDON (*Secretary*), Mr. G. C. BOURNE, Dr. H. O. FORBES, Professor W. A. HERDMAN, Dr. JOHN MURRAY, Professor A. NEWTON, Mr. A. E. SHIPLEY, *and* Professor W. F. R. WELDON. (*Drawn up by the Secretary.*)

THOSE students of Botany, Zoology, and Anthropology who have at all considered the matter, are impressed with the fact that the present time is a very critical period for the native flora and fauna of many parts of the world. Owing to the spread of commerce, the effects of colonisation, and the intentional or accidental importation of plants and animals, a very rapid change is affecting the character of the indigenous life of numerous districts. This is notably the case in oceanic islands, the area of which is often extremely limited, and whose native forms have been found to be specially liable to be swamped by the immigrants; but it is just those spots which are of especial interest to the naturalist, on account of their isolation from the great land areas. Thus the flora and fauna of many of the most interesting districts for the field-naturalist are in our day becoming largely exterminated before they have been adequately recorded. The Committee, while fully recognising that it is unwise to compare the relative values of different branches of science, are strongly of opinion that the naturalists of a future date will have a just cause of complaint against us if we have not done our best to save to science a record of these vanishing forms. Certain branches of enquiry may safely be left to the next generation, but the investigation of disappearing animals and plants can, in many cases, be undertaken by us alone—and even now much has disappeared and more is fast passing away. It is, perhaps, scarcely necessary to point out that this investigation is not a matter of interest to the systematist only, but it is of great importance in connection with the problems of geographical distribution, variation, adaptation to the environment, and the like.

We need only refer to the Reports of the Committee on the Zoology of the Sandwich Islands, and those of the Committee of the Zoology and Botany of the West India Islands, to show that some work is being done in this direction by the British Association and other scientific societies, but we would urge that much more should be done by the Governments, scientific societies and private individuals of this and other countries.

Mr. Perkins' investigations in the Hawaiian group prove that quite a noticeable decrease in the indigenous fauna is taking place each season. The district around Honolulu was perhaps originally the richest in endemic forms, but now introduced forms are in vast preponderance; the distinctive fauna of the plains, if there was one, has quite disappeared. Captain Cook found certain birds, for example, near the shore; of these, some are extinct, and others are to be found only in the mountains. The area of the whole group is somewhat larger than Yorkshire. If the diminution of the fauna is so marked in such a comparatively large group as the Hawaiian Islands, how much greater must it be in the small islands.

Mr. Knight, in the 'Cruise of the Falcon,' describes the prostrate forests of the island of Trinidad in the South Atlantic. We never can know what was the nature and extent of this vanished flora and fauna.

What is taking place in the small islands holds good to a somewhat less extent for the larger ones. In New Zealand the Government is taking steps to preserve certain well-known vestiges of its ancient fauna, which are in imminent danger of extermination; but it does not interest itself in the inconspicuous forms, which are subject to the same danger, nor does the New Zealand Government systematically investigate the existing fauna of the group.

It is necessary that such investigations should be undertaken by a competent naturalist. He should not only be a good collector, but a keen observer, in fact, a naturalist in the true sense of the term; for unless the work is well done it had almost be better left undone. There are many examples of collecting being so imperfectly done as to lead to very erroneous conclusions. It takes time for a naturalist to become acquainted with the local types. The endemics do not show themselves, as usually the conditions of life are such that insects, for example, live retired lives and are not seen, while those that manifest themselves are often foreigners.

The extermination of animal life is more rapid and striking than that of plants, but what has been stated for animals must be applied to plants as well.

Not less important than the foregoing is the study of the anthropology of these districts. The Tasmanians have entirely disappeared and we know extremely little about this interesting people. In many islands the natives are fast dying out, and in more they have become so modified by contact with the white man and by crossings due to deportation by Europeans, that immediate steps are necessary to record the anthropological data that remain. Only those who have a personal acquaintance with Oceania, or those who have carefully followed the recent literature of the subject, can have an idea of the pressing need there is for prompt action. No one can deny that it is our bounden duty to record the physical characteristics, the handicrafts, the psychology, ceremonial observances and religious beliefs of vanishing peoples; this also is a work which in many cases can alone be accomplished by the present generation.

There is no difficulty in finding men competent to undertake such investigations if the funds were forthcoming. For the Committee to satisfactorily organise any expedition it would be necessary to have a permanent income or at all events an adequate amount for a defined number of years. Experience has shown that an annual sum of 400*l.* is necessary to equip and maintain one naturalist.

The Committee ask to be reappointed, and hope to propose a definite scheme at the next meeting of the Association.

Since the above was in print Dr. D. Sharp has received a letter from Mr. Perkins, in which the following passage occurs: this is so appropriate that we do not hesitate to quote it in full:—'The country where I camped here (Lihue, Kauai) was a low-lying, densely covered forest bogland, *at first sight* a paradise for Carabidæ, and differing from any other place known to me. Its fauna is entirely lost for ever.

'I turned during my stay thousands of logs, any one of which at 4,000 feet would have yielded Carabidæ. Of all these *there was not a* *single one* under which *Pheidole megacephala* had not a nest, and I never beat a tree without this ant coming down in scores. The only endemic insects seen were two earwigs, which appear to be (as I had already found out on Oahu and Maiu) the only native insects which can resist the ant. It was hardly possible for me to reach the ground behind the forest, but when I did get beyond the ant on one occasion, in pouring rain, I got some native beetles.'—*July* 21, 1896.

Index Generum et Specierum Animalium.—Report of a Committee, consisting of Sir W. H. Flower (*Chairman*), Mr. P. L. Sclater, Dr. H. Woodward, *and* Mr. F. A. Bather (*Secretary*), *appointed for superintending the Compilation of an Index Generum et Specierum Animalium.*

In consequence of Mr. W. L. Sclater leaving England for South Africa, your Committee has added to its number Mr. F. A. Bather, who has served as secretary. During this past year considerable interest has been aroused in this work in connection both with the synopsis of species of living animals proposed to be issued by the German Zoological Society, under the title 'Das Tierreich,' and with the scheme for a subject catalogue of scientific literature discussed at the recent International Congress on scientific bibliography. The importance of this work has been acknowledged by the British Association Committee on Zoological Bibliography and Publication, and a resolution bearing on the subject will be found in the Report of that Committee. A paper entitled 'Explanation of the Plan adopted for preparing the *Index Generum et Specierum Animalium*' was read by Mr. Sherborn before the Zoological Society on June 2, and will be published in its 'Proceedings.' To this paper those who require detailed information on the present condition of the work may be referred. Since the commencement of this work in 1890, a total of 130,000 references has been accumulated in duplicate, and a mass of literature has been carefully and thoroughly indexed. The time available for the work has amounted to about three years, and the whole work has been done by Mr. C. Davies Sherborn, the compiler. Every reference slip is at once sorted into its alphabetical order under the Genus, and the MS. is accessible at the British Museum (Natural History) for daily reference. The Museum Authorities furnish cabinets and accommodation for the MS., and the work is also carried on in that building. A considerable number of bibliographic researches of value have been made, the fixation of the dates of publication being regarded as of prime importance.

Your Committee has requested Mr. Sherborn to conduct his work in such a manner that the Index should be published in three parts, dealing with the literature from 1758 to 1800, 1800 to 1850, 1850 to 1900, respectively, and to complete the first of these parts as quickly as possible.

Your Committee begs to urge upon the Association the importance of completing this work at as early a date as possible, and venture to recommend that it be reappointed with a grant of £100, so that Mr. Sherborn may be provided with some secretarial assistance.

Zoological Bibliography and Publication.—Report of the Committee, consisting of Sir W. H. Flower (*Chairman*), Professor W. A. Herdman, Mr. W. E. Hoyle, Dr. P. L. Sclater, Mr. Adam Sedgwick, Dr. D. Sharp, Mr. C. D. Sherborn, Rev. T. R. R. Stebbing, Professor W. F. R. Weldon, *and* Mr. F. A. Bather (*Secretary*).

In consequence of the International Conference on scientific bibliography convened by the Royal Society, and held from July 14 to 17, your Committee has deferred expressing any opinion with regard to questions of international co-operation or the use of any system of numerical notation.

With a view of obtaining a body of opinion to guide it in its decision, your Committee is circulating among various experts, both British and foreign, not included in the Committee, the following questions :—

(A) The first questions to be decided are those of Publication, since a bibliography cannot be compiled till it is settled what is to be included.

(1) *What constitutes publication?* It is suggested that private presentation by the author is not publication, but that the work must be obtainable by any individual through ordinary trade channels. An exception must be made in the case of *reports* and *bulletins* issued by public bodies *gratis* to all *bona fide* applicants, since some of these are not allowed to be sold.

(2) *What is the date of publication?* If private presentation be disregarded, as suggested, then the date of private distribution of an author's separate copies cannot be accepted ; neither can we accept the date of the reading of a paper before a learned society, or even that of the issue of an abstract thereof to the fellows of such society.

(3) As a corollary to the above, it was recognised at the meeting on May 7, that the *issue of authors' separate copies before the issue of the complete volume* leads to confusion. Various reasons, however, seem to render this practice a common one, and it is desirable that some remedy should be found. It would be possible either to issue each paper or memoir as soon as printed, with separate pagination and in a separate wrapper, as done by the Royal Society and the Swedish Royal Academy of Science ; or to issue the volumes sheet by sheet, as matter might come to hand and be printed. On this any suggestions would be very welcome.

(4) *Is it advisable to limit the recognition of publication* (*a*) *in manner, or* (*b*) *in matter?* (*a*) Zoologists have generally refused to accept names of species appearing in the daily press, accompanied by descriptions possibly sent by telegraph ; but where are we to draw the line between the popular newspaper or magazine, and, say, the *Philosophical Transactions* of the Royal Society? It is a serious matter to restrict publication, yet the modern increase of mushroom magazines suggests the desirability of legislation in this direction. Again, are we to recognise new names published in an unsigned footnote to a report on a public discussion on a totally distinct subject? Here, again, where is the line to be drawn? Is a name appearing in the explanation to a plate and not in the text to be accepted? (*b*) Can any restriction be placed on language? Russian and Czech are recognised; what about Japanese? Is it advisable to

ignore certain authors who refuse to comply with the recognised usages of zoologists, *e.g.*, by brazenly misdating their publications or by persistent ignoring of the work of others?

(B) The following questions arise in connection with Bibliography :—

(1) *What limits should be set to bibliography?* The aim is to bring to the workers on any one subject information as to all works published on that subject. Bibliography is limited (*a*) in degree, (*b*) in kind). (*a*) There are limits to the minuteness of subdivision : is the minute system of slips (such as a slip for every mention of each species), proposed by the Royal Society, feasible or desirable? (*b*) Bibliography being a 'description of writings,' it does not include criticism or interpretation other than may be needed to explain obscurities. How far should criticism enter into bibliography?

(2) *What means can be adopted for producing co-operation between the various bibliographers?* Two means have lately come into prominence : (*a*) the International Bureau at Zurich ; (*b*) the Dewey Decimal System of Classification. (*a*) The International Bureau has suffered at the inception of its work through the serious illness of Dr. H. H. Field, so that the results can hardly be criticised as yet. (*b*) The Dewey Decimal Classification has recently been explained for English readers by Mr. W. E. Hoyle in 'Natural Science,' vol. ix. pp. 43–48, July, 1896. Both of these means will necessarily be discussed by the International Congress on Scientific Bibliography, and the Zurich Bureau would doubtless be absorbed in any ultimate scheme. Any suggestions for the improvement of the Royal Society schemes, so far as they refer to zoology and paleontology, will be welcomed by the present Committee.

(3) Is it advisable that authors and editors should co-operate with bibliographers in the ways that have recently been suggested, viz. : (*a*) by construction of catalogue or index slips ; (*b*) by heading articles with their decimal number? Examples of catalogue slips may be seen in recent issues of the *Proceedings* of the Royal Society, and the *Quarterly Journal of Microscopical Science*, while the decimal number has been employed in the *Revue Scientifique*, *Bulletin de l'Association pour l'Avancement des Sciences*, *Bulletin de la Société Zoologique de Paris*, *Zoologischer Anzeiger*, *Natural Science*, &c.

It is proposed to sift opinions obtained on these points, and to report on them on a future occasion.

Your Committee has also ventured to utilise its existence in sending out the following circular to the editors of all publications connected with zoology :—

Dear Sir,—I am desired by the Committee of the British Association on Zoological Bibliography and Publication to draw your attention to the following statement :—

It is the general opinion of scientific workers, with which the Committee cordially agrees :

(1) That each part of a serial publication should have the date of actual publication, as near as may be, printed on the wrapper, and, when possible, on the last sheet sent to press.

(2) That authors' separate copies should be issued with the original pagination and plate-numbers clearly indicated on each page and plate, and with a reference to the original place of publication.

(3) That authors' separate copies should not be distributed privately before the paper has been published in the regular manner.

The Committee, however, observes that these customs are by no means universal, and constant complaints are made that one or other of them is not put into force. In case the Publication or Society with which you are connected does not comply with these desiderata, the Committee ventures to ask whether it would not be possible for it so to comply in future. Should you, however, have any good reasons against the adoption of these suggestions, the Committee would be much obliged if you would kindly inform it of your reasons, in order that it may be guided in its future action.

The Committee further begs to ask for your co-operation in the following matter. There are certain rules of conduct upon which the best workers are agreed, but which it is impossible to enforce, and to which it is difficult to convert the mass of writers. These are :—

(4) That it is desirable to express the subject of one's paper in its title, while keeping the title as concise as possible.

(5) That new species should be properly diagnosed and figured when possible.

(6) That new names should not be proposed in irrelevant footnotes or anonymous paragraphs.

(7) That references to previous publications should be made fully and correctly, if possible, in accordance with one of the recognised sets of rules for quotation, such as that recently adopted by the French Zoological Society.

The Committee ventures to point out that these and similar matters are wholly within the control of editors (*rédaction*) and publishing committees, and any assistance which you can lend in putting them into effect will be valued, not merely by the Committee, but, we feel sure, by zoologists in general.

The answers received to this circular will, it is hoped, enable your Committee to make further suggestions upon certain practical points.

Your Committee desires that the following unanimous resolution should be conveyed to the Committee of Recommendations : 'Considering how important to zoologists is the speedy completion of the *Index Generum et Specierum Animalium*, now being compiled by Mr. Charles Davies Sherborn under another Committee of this Association, the present Committee begs to urge upon the Association the advisability of extending to this *Index* substantial pecuniary support.'

Finally, your Committee ventures to recommend its re-appointment, with a grant of 5*l.* towards the expenses of printing and posting circulars.

The Zoology of the Sandwich Islands.—Sixth Report of the Committee, consisting of Professor A. NEWTON (*Chairman*), Dr. W. T. BLANFORD, Professor S. J. HICKSON, Professor C. V. RILEY, Mr. O. SALVIN, Dr. P. L. SCLATER, Mr. E. A. SMITH, *and* Mr. D. SHARP (*Secretary*).

THE Committee was appointed in 1890, and has been annually reappointed. Since it reported to the Association last year, Mr. R. C. L. Perkins has been continuing his work of exploration, and has revisited the islands of Molokai, Hawaii, Maui, and Kauai in order to fill up certain gaps in previous work. Papers resulting from the Committee's work have been published—on Orthoptera by Herr Brunner von Wattenwyl (P.Z.S., 1895), on Slugs by Mr. W. E. Collinge (P. Malacological Soc., 1896), and on Earthworms by Mr. F. E. Beddard (P.Z.S., 1896). The arrangement with the trustees of the Bernice P. Bishop Museum in Honolulu, alluded to in the last report, has been ratified, and the Committee is consequently not in need of funds at present. Immediately after its last reappointment, the Committee lost one of its members, Professor C. V. Riley, through his decease consequent on a lamentable accident. It again applies for reappointment and the sanction of the Association for having availed itself of the offer of the trustees previously mentioned. This was asked for last year, and no doubt it was intended that it should be granted; but by some inadvertence the power actually given was only 'to avail themselves of such assistance in their investigations as may be offered by the Hawaiian Government.' No assistance of any importance has been rendered by the Hawaiian Government.

Zoology and Botany of the West India Islands.—Ninth Report of the Committee, consisting of Dr. P. L. SCLATER (*Chairman*), Mr. GEORGE MURRAY (*Secretary*), Mr. W. CARRUTHERS, Dr. A. C. L. GÜNTHER, Dr. D. SHARP, Mr. F. DU CANE GODMAN, Professor A. NEWTON, *and* Sir GEORGE F. HAMPSON, Bart., *on the Present State of our Knowledge of the Zoology and Botany of the West India Islands, and on taking Steps to investigate ascertained Deficiencies in the Fauna and Flora.*

THIS Committee was appointed in 1887, and has been reappointed each year until the present time, Sir G. Hampson having been added to it during the present year.

The Committee has continued the working out of the collections, and since the last report the following papers have been published :—

1. Lichenes Antillarum a. W. R. Elliott collecti, A. Wainio (Journal of Botany, 1896).

2. The Non-Marine Mollusca of St. Vincent, Grenada, and other neighbouring islands, by E. A. Smith (Proceedings Malacological Society, vol. i. part 7).

3. Report on the Parasitic Hymenoptera of the island of Grenada, comprising the families Cynipidæ, Ichneumonidæ, Braconidæ, and Proctotrypidæ, by W. H. Ashmead (Proceedings Zoological Society, London 1895).

4. On the Geometridæ, Pyralidæ, and allied families of Heterocera of the Lesser Antilles, by G. F. Hampson (Annals of Natural History, xvi., 1895).

5. Observations on some new Buprestidæ from the West Indies, by C. O. Waterhouse (Annals of Natural History, xviii., 1896).

The Committee has other papers in hand which it hopes to publish shortly, two being, indeed, already in type; one by W. Dollfus, on Isopod Crustacea; the other by Professor Williston on Diptera. The latter is to be produced with the assistance of a donation from the Council of the Royal Society.

During the year further collections of Cellular Cryptogams have been received from Mr. Elliott, and their working out has been undertaken—the Musci by Mr. Gepp, the Hepaticæ by Dr. Stephani, the Lichenes by M. Wainio, and the Fungi by Miss Smith.

The Committee recommends its reappointment, and applies for a grant of 50*l.* to aid it in the working out of the collections already made The Committee to be constituted as at present.

The Position of Geography in the Educational System of the Country.—Interim Report of the Committee, consisting of Mr. H. J. Mackinder, (*Chairman*), Mr. A. J. Herbertson (*Secretary*), Mr. J. Scott Keltie, Dr. H. R. Mill, Mr. E. G. Ravenstein, *and* Mr. Eli Sowerbutts.

No account of the position of geography in our educational system can be adequate which is not based on a comparison with Mr. Scott Keltie's well-known and admirable report on Geographical Education prepared for the Royal Geographical Society twelve years ago.[1] It is the best account we possess of the position of geography at that time, not only in our own, but also in other countries.

Since it was published several changes for the better have to be chronicled, but unfortunately much of the criticism of the comparative neglect of geography in the schools and colleges of the nation that should foster it most remains only too true. Changes have occurred abroad as well as at home, and the Committee deem it advisable to compare the advances made in other lands with our own progress in recent years.

The best way to do this would be to make personal inspections similar to those made by Mr. Keltie; but as the Committee have no funds at their disposal, it has been necessary to carry on their work mainly by correspondence. Information as to the position of geography has been sought and obtained from educational authorities all over the country, and from those of other lands, and the Committee desire to acknowledge their indebtedness to many correspondents.

In the case of secondary schools, the Committee have had the benefit of the inquiries carried on by the Geographical Association, whose object is to improve the position of geography in such schools. The Committee would draw attention to the memorial prepared by this Association, as a result of their investigation. This memorial has been sent to the principal examining bodies in the kingdom.

The Committee would also emphasize the need for immediate improvement in the training of teachers in geography, and the increase and extension of geographical work in the Universities, as recommended by the International Geographical Congress last year.

The Committee consider it better to postpone the presentation of their extended report to the Association until next year, as all the documents necessary for a complete report have not yet come to hand. Accordingly they ask that they may be reappointed.

[1] *Roy. Geog. Soc. Supp. Papers*, vol. i. Part IV. 1885.

The Climatology of Africa.—Fifth Report of a Committee, consisting of Mr. E. G. Ravenstein (*Chairman*), Sir John Kirk, Mr. G. J. Symons, Dr. H. R. Mill, *and* Mr. H. N. Dickson (*Secretary*). (*Drawn up by the Chairman.*)

Meteorological journals have been received in the course of last year from eighteen places in Tropical Africa.

Niger Territories.—We have a register from Captain Gallwey's old station (Warri), as also from a new station (Sapele), opened last year, about thirty miles to the north-west of the former. In next year's report we hope to be able to publish abstracts of important observations made by officials of the Royal Niger Company, which Sir George Taubman-Goldie has promised to communicate.

Congo.—The Rev. R. Glennie, the oldest and most constant correspondent of your Committee, has forwarded another year's register for Bolobo. No information has been received from the Gaboon. A set of instruments, with full instructions, has been furnished, on payment, to the Rev. Phillips Verner, who left for the Kasai in November last.

Nyasaland.—The only record received is one by Commander C. Hope Robertson, communicated by Mr. Robert H. Scott, the Secretary of the Meteorological Council; but we understand that Mr. Moir, who has been entrusted with a complete set of instruments, intends to read a paper on the Meteorology of Nyasaland at the Liverpool meeting of the Association. Sir Harry Johnston, who is at present in England, takes much interest in the work of your Committee, and there is some hope of organising a carefully considered scheme for meteorological work throughout the Protectorate so ably administered by him.

British East Africa.—Observations have been received from thirteen stations. Unfortunately, owing to the disturbed state of the country and to administrative changes, some of the registers are imperfect. The Foreign Office has met the wishes of your Committee in the most gratifying manner. Instructions have been given by Mr. Hardinge, Her Majesty's Commissioner, to have meteorological returns kept, and these will be sent to us for publication.

Three sets of instruments (including barometers and anemometers) have been forwarded by the Foreign Office to Uganda, and since the beginning of this year observations on the water-level of the Victoria Nyanza are being made by means of gauges erected at Port Alice and Port Victoria.

Transvaal.—An old series of observations made by Mr. W. H. Jessop on the Lataba River have been communicated by Dr. H. R. Mill, and further communications of the same class are very desirable.

The abstracts for Bolobo, Warri, Sapele, and Lataba River, which accompany this report were made by the Secretary, and those for the remaining stations by the Chairman of your Committee. The barometer readings, unless stated otherwise, have been reduced to 32° and corrected for gravity, but no attempt has been made to reduce them to the sea-level. This can only be done after the altitude of the stations shall have been determined by spirit-levelling, and with the extension of railway surveys this information is likely to be forthcoming at an early date.

Your Committee have expended the 10*l.* granted. They beg to propose that they be reappointed, and that a grant be made of 20*l.*

Bolobo (*Congo*). *Lat.* 2° 10′ *S.*, *Long.* 16° 13′ *E.*, 1,100 *feet.*

Observer: Rev. Robert Glennie, Baptist Missionary Society. (*From August* 15 *to* 31 *and November* 12 *to* 30, *Rev. George Grenfell.*)

Month	Mean Temperature (Shade)						Daily Range	Temp. Extremes		Mean Temp. Wet Bulb			Pressure of Vapour			Relative Humidity			Cloud—Amount (0–10)				Rain		
	7 A.M.	2 P.M.	9 P.M.	Max.	Min.	Mean		Max.	Min.	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	Mean	Amount	Days	Heaviest Fall
1895	°	°	°	°	°	°	°	°	°	°	°	°	In.	In.	In.	p.c.	p.c.	p.c.					In.		In.
January	74·0	85·3	76·1	87·1	71·3	77·9	15·8	92·4	67·0	72·4	76·5	73·2	·773	·793	·778	92	64	86	8·8	5·8	4·7	6·5	3·39	10	1·15
February	74·1	84·6	75·8	87·2	71·3	77·6	15·9	92·4	67·4	72·1	76·6	73·2	·760	·807	·782	90	68	88	7·5	6·5	8·1	7·4	7·79	10	1·90
March	74·6	85·1	76·6	88·4	71·8	78·2	16·6	95·5	68·3	72·4	76·3	73·4	·765	·787	·779	89	65	85	7·4	5·4	7·1	6·6	6·71	13	1·34
April	74·8	85·7	76·3	89·1	72·5	78·3	16·6	97·2	67·6	72·8	76·7	73·3	·779	·796	·779	90	65	86	6·6	5·4	5·0	5·7	9·17	11	3·25
May	74·3	85·9	75·0	88·5	71·9	77·5	16·6	95·5	66·6	72·6	77·3	72·6	·777	·820	·768	92	66	88	6·9	5·4	6·9	6·4	5·39	12	1·38
June	72·3	85·3	75·8	83·9	71·3	77·3	12·6	92·3	68·6	69·6	75·6	72·5	·686	·753	·753	87	62	84	6·5	4·1	4·6	5·1	·50	2	·35
July	71·0	86·5	75·7	88·2	70·0	77·2	18·2	91·4	67·4	67·4	74·1	71·4	·623	·674	·712	82	53	80	7·4	2·5	3·9	4·6	—	—	—
August	73·0	86·3	77·1	88·0	71·4	78·6	16·6	94·0	68·5	69·5	74·9	72·2	·673	·711	·724	83	56	78	—	—	—	—	2·75	4	1·80
September	73·4	82·2	75·7	85·1	71·8	76·8	13·3	92·4	68·4	71·1	74·8	73·0	·730	·762	·775	89	69	87	6·8	3·7	6·4	5·6	6·56	13	3·04
October	73·3	84·0	74·8	86·1	70·9	76·7	15·2	91·0	65·0	71·8	75·3	72·6	·759	·802	·770	93	69	89	7·0	5·6	6·9	6·5	6·08	14	1·37
November	72·7	82·1	74·8	85·4	70·7	76·1	14·7	90·4	67·5	71·7	76·2	72·9	·763	·824	·783	95	75	90	—	—	—	—	16·21	15	4·22
December	73·1	82·6	75·7	84·9	70·9	76·8	14·0	90·0	68·4	71·9	76·3	73·4	·765	·821	·791	94	74	89	8·7	4·8	4·6	6·0	6·68	15	2·70
Year	73·4	84·6	75·8	86·8	71·3	77·4	15·5	97·2	65·0	71·3	76·0	72·8	·737	·781	·765	90	66	86	—	—	—	—	71·23	113	4·22

Mean temperature assumed = $\frac{1}{4}(7+2+9+9)$. The rainfall seems to have been above the average (63·93 inches fell in 1891, 62·73 inches in 1894).

Warri (Benin). Lat. 5° 31′ *N., Long.* 5° 51′ *E.,* 10 *feet. Observers: Felix Roth, M.R.C.S., M.L.C.P., and B. H. Elliott, M.B.*

Month	Temperature					Temp. Extremes		Daily Range	Rain			Direction of the Wind: Number of Days on which it blew from a specified direction																	
												7 A.M.									6 P.M.								
	Mean 7 A.M.	Mean 6 P.M.	Max.	Min.	Mean	Highest	Lowest		Amount	Days	Heaviest Fall	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm
1895	°	°	°	°	°	°	°	°	In.		In.																		
January	73·1	81·8	93·1	71·4	82·2	97	66	21·7	2·42	4	2·38	2	1	5	0	2	21	0	0	0	1	0	0	1	0	29	0	0	0
February	74·0	82·9	95·6	71·9	83·7	99	69	23·7	·05	2	·03	2	1	1	2	5	17	0	0	0	0	0	0	0	0	25	3	0	0
March	74·9	81·1	95·0	70·9	83·0	98	63	24·1	8·87	14	1·71	2	2	3	7	2	15	0	0	0	0	0	1	2	0	27	0	1	0
April	75·5	81·8	94·8	71·7	83·2	99	65	23·1	5·44	14	1·11	2	1	4	5	1	12	5	0	0	0	1	0	0	4	20	5	0	0
May	74·9	80·0	93·3	71·3	82·3	98	60	22·0	11·12	13	3·45	0	4	3	2	1	17	4	0	0	1	2	1	2	2	21	2	0	0
June	74·5	78·2	88·7	72·1	80·4	82	69	16·6	18·09	20	4·60	0	1	0	0	1	26	2	0	0	0	0	0	0	5	19	6	0	0
July	73·5	76·7	86·3	72·0	79·1	93	70	14·3	18·71	25	3·00	0	1	0	0	4	9	16	1	0	0	0	1	0	1	4	25	0	0
August	73·4	77·5	87·5	70·8	76·9	92	67	16·7	8·69	18	2·59	0	0	0	0	1	9	20	1	0	0	0	0	0	0	5	26	0	0
September	74·9	77·3	85·6	72·6	79·1	94	69	13·0	30·13	27	3·24	0	1	0	0	0	4	21	1	0	1	0	0	0	0	2	27	0	0
October	73·5	78·0	90·0	71·5	80·7	96	69	18·5	9·59	21	1·86	1	5	3	1	5	5	9	2	0	2	1	1	0	5	8	14	0	0
November	74·4	80·1	94·0	72·7	83·3	96	69	21·3	5·67	8	3·65	1	6	0	0	4	7	12	0	0	0	5	2	0	8	5	10	0	0
December	73·6	82·0	94·2	72·5	83·3	98	70	21·7	·03	1	·03	0	2	0	0	0	7	21	1	0	1	1	0	0	1	10	16	2	0
Year 1895	74·3	79·8	91·8	71·8	81·8	98	60	20·0	118·79	167	4·60	10	25	19	17	26	149	113	6	0	6	10	6	5	26	165	134	3	0
„ 1894	74·1	79·1	91·4	71·7	81·5	102	62	19·7	111·93	171	5·36	24	20	21	27	23	140	95	15	0	7	3	7	7	14	179	133	15	0

The mean temperature assumed to be = ½ (max. + min.), and therefore in excess of the truth.

Sapele (Benin River, West Africa). Lat. 5° 55′ N., Long. 5° 30′ E. Observer: Captain Gallwey.

1895	Mean Temperatures (Shade) 6 A.M.	6 P.M.	Max.	Min.	Mean	Daily Range	Extremes Highest	Lowest	Mean Temperature: Wet Bulb 6 A.M.	6 P.M.	Force of Vapour 6 A.M.	6 P.M.	Relative Humidity 6 A.M.	6 P.M.	Rain Amount	Days	Heaviest Fall
	°	°	°	°	°	°	°	°	°	°	In.	In.	p.c.	p.c.	In.		In.
June	74·1	79·1	83·7	—	76·6	—	88	—	73·0	75·3	·797	·825	94	83	9·42	19	2·54
July	72·7	76·2	83·9	71·4	74·4	12·5	88	69	71·9	73·7	·771	·797	96	88	21·16	22	3·91
August	71·6	76·7	86·0	68·6	74·1	17·4	95	61	70·5	73·3	·731	·773	95	84	7·02	16	2·06
September	73·3	77·2	84·8	71·5	75·2	13·3	92	69	72·4	74·7	·783	·825	95	88	19·00	26	2·44
October	72·8	78·4	89·0	70·7	75·6	18·3	97	69	71·7	76·6	·762	·891	95	92	12·12	21	2·16
November	73·4	81·8	94·2	72·3	77·6	21·9	99	69	72·7	79·1	·794	·956	96	88	2·96	6	·65
December	73·4	81·8	94·1	72·6	77·1	21·5	97	70	72·8	78·4	·799	·925	97	85	·25		·25

New station started by Captain Gallwey. Instruments believed to be good, but maker's name and corrections unknown. Max. and min. are read and set at 6 A.M. and 6 P.M. Figures given above are 6 P.M. max. and 6 A.M. min. No min. observations in June. The mean temperature is deduced from ½ (6+6).

Birthday Camp, Klein Lataba River (Zoutpansberg, Transvaal). Lat. 22° 0′ S., Long. 30° 58′ E. Observer: W. H. Jessop.

Date	Mean Pressure	Mean Temperature	Highest	Lowest	Wind N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm	Rain Amount	Days	Heaviest Fall
1892	In.	°	°	°										In.		In.
August	28·926	78·2	96	62	3	—	—	9	1	—	—	1	17	·137	2	·070
September	28·826	83·3	96	66	4	1	3	13	1	—	—	—	8	·897	3	·720
October	28·807	78·1	95	62	1	5	6	7	—	—	—	—	12	2·534	10	·725
November	28·716	85·4	98	69	—	3	6	8	—	—	—	—	13	4·109	11	1·300
December	28·704	86·9	100	68	4	2	2	13	2	—	—	—	8	3·091	6	1·100
1893																
January	28·649	81·9	95	71	1	—	1	16	1	—	1	—	11	7·620	15	1·850
February	28·743	82·9	93	69	1	5	5	10	1	1	—	—	5	8·380	9	2·430
March	28·885	82·6	91	72	—	1	1	2	13	6	3	1	4	·588	2	·564
April	28·992	78·9	91	67	2	4	—	11	7	1	1	—	4	·373	2	·300
May	29·025	72·5	88	60	7	1	—	12	4	—	—	1	6	·061	1	·061
June	29·047	76·0	90	60	4	5	1	5	1	2	2	3	7	·000	0	·000
July	29·109	71·6	78	61	4	1	—	9	5	3	1	3	5	·280	1	·280
August	28·995	80·7	90	63	7	2	4	11	1	—	—	3	3	·000	0	·000
September	28·917	76·9	95	63	4	4	5	7	5	2	2	—	1	2·540	4	2·250
October	28·936	79·5	94	65	4	3	6	9	5	1	1	—	2	·900	2	·890
November	28·835	87·2	100	71	14	—	4	4	—	—	—	2	6	1·847	4	·967
December	28·804	86·0	100	70	8	—	—	11	—	4	—	2	6	9·243	11	2·338
Year 1893	28·911	79·7	100	60	56	26	27	107	43	20	11	15	60	31·832	51	2·430

These observations received through Dr. Mill. Nothing is known as to instruments or their exposure. The observations were made at *noon*.

Lake Nyasa. Observer: Commander C. Hope Robertson, C.M.G. (Communicated by Mr. Robert H. Scott, F.R.S.)

1894	Aneroid (Adie A. 571) 8 A.M.	Aneroid Noon	Aneroid 7 P.M.	Aneroid 8 P.M.	Mean Temperatures 8 A.M.	Mean Temp. Noon	Mean Temp. 4 P.M.	Mean Temp. 8 P.M.	Mean Temp. Max.	Mean Temp. Min.	Mean	Cloud (1–10) 8 A.M.	Cloud Noon	Cloud 4 P.M.	Cloud 8 P.M.
August . . .	28·661	28·633	28·570	—	70·1	77·6	80·0	—	82·0	62·0	[71·0]	3·5	3·8	4·4	—
September . .	·609	·541	·463	28·530	73·2	80·1	80·5	74·5	84·6	65·7	73·8	2·6	3·0	2·9	3·3
October . . .	·498	·423	·354	·409	79·8	83·3	84·8	79·5	89·0	71·0	79·6	2·1	3·2	2·8	3·1
November . .	·466	·389	·303	·378	80·8	85·9	85·6	79·9	90·3	74·9	80·3	4·4	4·4	4·8	4·5

The observations were made on board a Lake steamer, which remained at Fort Johnston up to August 27; navigated the southern half of the Lake, as far as Likoma, between August 28 and October 31; left Fort Johnston for a trip to Langenburg on November 5, and ultimately returned to Fort Johnston. The *Aneroid Readings* are given as recorded. The *Mean Temperature* is deduced from $\frac{1}{2}(8+8)$.

1894	8 A.M.						Noon						4 P.M.						8 P.M.					
	Mean Force	Prevailing Winds				Calm	Mean Force	Prevailing Winds				Calm	Mean Force	Prevailing Winds				Calm	Mean Force	Prevailing Winds				Calm
		Direction and Number of Days	Mean Force	Direction and Number of Days	Mean Force			Direction and Number of Days	Mean Force	Direction and Number of Days	Mean Force			Direction and Number of Days	Mean Force	Direction and Number of Days	Mean Force			Direction and Number of Days	Mean Force	Direction and Number of Days	Mean Force	
August (29 days)	1·8	S. 23	2·1	S.W. 1	2·5	3	1·7	S. 21	2·1	N. 2	1·2	1	1·5	S. 16	1·9	N. 6	1·3	3	—	—	—	—	—	—
September (30 days)	2·2	S. 11	3·1	E. 9	2·2	5	1·7	S. 7	2·9	E. 4	1·9	5	1·5	N. 9	1·3	S. 7	2·9	5	0·9	S. 6	2·1	N. 6	1·2	12
October (31 days)	1·5	N.E. 9	2·1	S. 7	2·1	7	1·7	N. 8	1·5	S. 4	3·0	2	1·2	N. 15	1·2	N.W. 5	1·0	4	0·4	N. 4	1·0	N.E. 3	1·2	20
November (27 days)	2·2	N.E. 8	3·4	S. 5	1·6	2	2·1	N. 7	1·7	S. 2	4·5	3	1·8	S. 8	2·9	N. 4	1·9	4	1·1	S. 4	2·9	N.E. 4	1·5	12

Winds.—The abstract gives the mean force (0–12) of the wind throughout each month; the direction, number of days on which observed, and mean force of the two winds most frequently recorded or most powerful; and the number of calms.

Mombasa. Lat. 4° 4′ *S., Long.* 39° 42′ *E.,* 60 *feet. Observer : J. J. W. Pigott.*

1895	Pressure of Atmosphere 9 A.M.	Temperatures: Extremes		Mean Temperatures					Daily Range	Humidity		Rain		
		Highest	Lowest	Dry 9 A.M.	Wet 9 A.M.	Mean Max.	Mean Min.	Mean		Vapour Pressure	Rel. Hum.	Amount	Days	Heaviest Fall
	In.	°	°	°	°	°	°	°	°	Inch	p.c.	Inch		Inch
January	29·818	85·0	75·4	80·0	76·7	82·4	76·7	80·0	5·7	·881	86	·01	1	·01
February	·824	85·2	75·5	81·6	76·6	83·7	77·8	80·8	5·9	·859	79	·34	3	·27
March	·787	89·1	78·0	83·7	78·0	86·4	79·6	83·0	6·8	·895	78	3·05	7	1·35
April	·820	88·0	76·8	82·0	77·5	86·1	78·8	82·4	7·3	·892	82	3·47	11	·91
May	·898	85·6	74·0	78·8	74·9	83·2	76·3	79·7	7·9	·831	85	9·99	19	2·22
June	·985	84·2	73·0	77·5	72·9	82·1	74·9	78·5	7·2	·756	80	1·44	4	·70
July	·991	83·0	71·0	76·8	72·0	80·7	73·7	77·2	7·0	·730	79	1·33	9	·42
August	·954	83·0	72·5	77·5	71·9	81·3	74·1	77·7	7·2	·719	78	·68	3	·47
September	·972	83·5	71·2	78·2	73·1	81·6	74·8	78·7	6·8	·757	79	6·21	9	1·86
October	·899	83·2	74·0	79·9	74·6	82·3	76·3	79·3	6·0	·797	78	3·04	3	2·06
November	·875	85·0	74·0	81·1	75·8	83·6	77·1	80·3	6·5	·832	78	3·37	10	1·03
December	·816	86·2	75·1	81·4	76·1	84·1	77·0	80·5	7·1	·841	79	1·42	6	·36
Year	29·888	89·1	71·2	79·9	75·0	83·1	76·4	79·8	6·6	·816	80	34·35	86	2·22

The barometrical observations have been reduced to 32° and corrected for gravity, but have not been reduced to sea-level.

The mean temperature is assumed to be the mean of all max. and min., and is therefore too high.

Machako's (Ukamba). Lat. 1° 31′ *S., Long.* 37° 18′ *E.,* 5,400 *feet. Observers : R. W. Lane, T. T. Gilkison, and John Ainsworth.*

1895	Temperature 9 A.M.		Humidity		Rain			
	Dry	Wet	Vapour Pressure	Relative Humidity	Amount: Total	Amount: 6 P.M. to 6 A.M.	Days	Heaviest Fall
	°	°	In.	p.c.	In.	In.		In.
January	68·1	58·7	·409	60	—	—	—	—
February	67·3	62·4	·519	78	3·85	3·19	11	1·52
March	66·3	62·9	·542	84	10·13	7·86	19	1·95
April	66·5	63·0	·543	83	12·38	10 68	23	2·59
May	65·7	62·7	·541	86	2·10	·72	7	·89
June	61·5	58·8	·470	86	·77	·75	4	·34

The rains generally end in May, and the amount recorded for April is exceptionally heavy. No entries were made for January; perhaps no rain fell. (January, 1894, 0·75 in. on three days.)

Prevailing Winds.—May, S.E.; June 1-7, S.W.; June 7–30, S.

Fort Smith (Kikuyu). Lat. 1° 14′ *S., Long.* 36° 44′ *E.,* 6,400 *feet. Observers : F. G. Hall (Jan. to Feb.), E. Russell (March to May), T. T. Gilkison (June to Oct.)*

1894–5	Temp.: Extrems.		Mean Temperatures					Variableness		Humidity		Rain		
	Highest	Lowest	Dry 9 A.M.	Wet 9 A.M.	Mean Max.	Mean Min.	Mean	Mean Range	Extreme	Vapour Pressure	Rel. Humidity	Amount	Days	Heaviest Fall
	°	°	°	°	°	°	°	°	°	In.	p.c.	In.		In.
Nov. 1894	—	—	[59·0]	—	—	—	61·3	1·27	4·5	—	—	6·68	c. 24	2·13
December	—	—	[60·0]	—	—	—	62·5	1·34	3·5	—	—	9·32	16	1·67
Jan. 1895	78	50	67·4	58·5	74·3	53·5	63·9	1·79	5·0	·408	61	·00	0	—
February	75	51	63·5	60·8	71·6	55·1	63·4	1·32	4·0	·506	86	7·43	13	2·13
March	74	52	62·8	60·1	79·9	55·1	67·5	1·17	2·5	·494	87	10·46	16	2·15
April	76	54	63·6	62·1	73·6	56·6	65·1	1·33	4·0	·543	93	16·33	22	2·75
May	74	52	63·7	61·8	73·1	56·8	64·9	1·24	4·5	·534	91	6·78	16	1·56
June	74	52	59·8	58·4	69·3	55·1	62·2	1·35	2·0	·475	92	3·68	9	·91
July	76	47	59·4	57·1	71·5	52·0	61·8	1·27	4·0	·445	88	·00	0	—
August	75	49	58·5	56·9	69·8	52·4	61·1	1·30	4·0	·448	91	·65	6	·35
September	78	50	62·6	58·5	73·5	53·1	63·3	1·86	3·5	·452	80	2·43	10	·49
October	82	50	65·0	59·7	77·8	53·8	65·8	1·50	6·0	·463	75	1·73	8	·64
Year	82	50	62·1	—	—	—	63·6	1·40	5·0	—	84	65·49	140	2·75

The following instruments were in use during 1896: Dry-bulb thermometer, B.T. 4634; wet-bulb B.T. 4635; max. thermometer, M.O. 1354; min. thermometer, M.O. 1460.

The Mean Temperature assumed = ½(max.+min.) is too high. Annual range, 5°·02; daily range, 19°·3.

Variableness (difference mean temperature from day to day): Mean 1°·40, extreme 5°.

Rain.—Only 10 thunderstorms are noted: 2 in February, 1 in March, 6 in April, 1 in May. On February 11 a heavy hailstorm, when 0·71 inch fell in less than half an hour.

Shimoni. Lat. 4° 38′ S., Long. 39° 21′ E.

Observers: D. Macquarie (Jan. to May) and D. Wilson (July to Dec.).

1895	Pressure of Atmosphere 9 A.M.	Mean Temperature: Dry Bulb 9 A.M.	Mean Temperature: Wet Bulb 9 A.M.	Humidity: Vapour Pressure	Humidity: Relative Humidity	Rain: Amount	Rain: Days	Rain: Heaviest Fall	Prevailing Winds
	In.	°	°	In.	p.c.	In.		In.	
January	29·854	82·2	77·9	·907	83	—	—	—	S.E., S.W.
February (18 dys)	·859	82·2	81·3	1·021	93	·25	1	—	S.E.
March (18 days)	·837	82·4	81·1	1·008	91	2·00	9	·47	E.
April	·818	81·0	76·6	·866	82	6·35	17	1·11	S.W.
May	·815	78·7	75·4	·840	86	8·92	22	1·26	W.S.W.
June	—	—	—	—	—	[7·39]	[19]	—	W.S.W.
July (1-15)	·824	76·4	73·7	·800	88	1·55	5	1·09	W.S.W.
August	·821	76·6	73·6	·794	87	1·22	10	·45	W.S.W.
September	·815	77·6	75·2	·846	89	5·62	12	1·43	S.E.
October	·801	79·7	77·2	·905	89	·69	5	·51	S.W., S.E.
November	·790	82·1	79·0	·955	87	3·32	9	1·62	S.E., W.
December	·787	84·5	80·3	·986	84	1·16	3	·57	S.E., N.E.
Year	[29·820]	79·9	—	—	—	[38·47]	[112]	1·62	W.S.W., S.E.

Barometer readings reduced to 32° and corrected for gravity.
Winds.—S.W. winds set in on April 1; on April 27 the wind veered round to W.S.W., and blew steadily from that direction to the end of August.

Malindi. Lat. 3° 13′ S., Long. 40° 7′ E.

Observer: K. MacDougall.

1895	Temperature 9 A.M.: Dry	Temperature 9 A.M.: Wet	Humidity: Vapour Pressure	Humidity: Relative Humidity	Rain: Amount	Rain: Days	Rain: Heaviest Fall
	°	°	In.	p.c.	In.		In.
January	79·1	76·6	·887	89	·08	3	·06
February	81·6	78·5	·939	87	·10	1	·10
March	85·1	81·4	1·029	85	·85	2	·75
April	83·9	82·3	1·083	94	2·54	7	·60
May	80·5	78·3	·942	91	13·85	10	4·59
June	78·5	74·6	·812	83	·03	1	·03
July	78·0	75·0	·833	87	3·89	10	1·50
August	81·8	74·9	·787	72	·44	3	·30
September	82·4	75·9	·810	73	·57	4	·27
October	82·6	76·2	·832	75	7·96	7	2·19
November	82·7	79·9	·988	89	3·29	7	1·20
December	81·3	79·0	·964	91	1·34	5	·65
Year	81·5	77·7	·909	85	34·94	60	4·59

Ndii Station. Lat. 3° 20′ S., Long. 38° 29′ E., 2,400 ft. Observer: Ch. Wise.

1895	Mean Temperature, 9 A.M.	Rain: Amount	Rain: Days	Rain: Heaviest Fall
		In.		In.
January	73·7	1·10	2	·70
February	76·0	2·22	2	1·12
March	81·0	5·01	10	1·00
April	78·5	1·49	7	·42
May	76·6	·35	6	·15
June	73·9	·07	1	·07
July	72·8	·03	1	·03
Aug. (1-20)	70·8	·02	1	·02
November	74·5	5·62	13	·81
December	73·5	4·89	14	1·14

A *second* return for March, from the same station, gives the following results: Mean temperature, 83°·5; rain 1·07 in., on 4 days; heaviest fall within 24 hours, 0·61 in.

Rainfall in British East Africa, 1895.

Stations	—	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Takaungu (3° 41′ S., 39° 52′ E.). Observer: K. MacDougall.	Inch	·00	·08	5·11	4·56	12·52	1·01	·98	·95	5·17	1·08	3·91	·34	35·71
	Days	0	2	8	7	15	3	1	7	9	5	9	2	68
	Heaviest fall	—	·05	3·30	1·37	2·67	·43	·98	·45	·94	·40	1·53	·27	3·30
Kulesa, Tana River (2° 10′ S., 40° 18′ E).	Inch	—	1·35	1·74	2·79	1·91	·10	2·10	1·00	—	—	—	—	—
	Days	—	4	7	5	3	1	6	4	—	—	—	—	—
	Heaviest fall	—	·50	·95	1·63	1·40	·10	1·20	·69	—	—	—	—	—
Kibwezi (2° 25′ S., 37° 55′ E., 3,000 ft.). Observer: Rev. T. Watson, E.A.S.M.	Inch	·06	1·72	5·80	6·99	·32	·00	·00	·01	·17	·14	11·76	6·14	33·11
	Days	2	[11]	[18]	13	6	0	0	1	3	3	16	17	90
	Heaviest fall	·04	·95	·99	2·12	·16	·00	·00	·01	·14	·09	2·68	1·76	2·68
Mbungu (3° 46′ S., 39° 30′ E.). Observer: Rev. J. Hofmann.	Inch	·00	1·09	4·17	4·03	3·31	—	—	—	—	—	—	—	—
	Days	0	2	[10]	7	11	—	—	—	—	—	—	—	—
	Heaviest fall	—	·90	1·02	3·20	1·41	—	—	—	—	—	—	—	—

Lamu, 2° 16′ *S.*, 40° 54′ *E.* *Observer: Donald MacLennan.*

1895	Mean Temp. 9 A.M.		Humidity		Rain		
	Dry	Wet	Vapour Pressure	Rel. Hum.	Amount	Days	Heaviest Fall
	°	°	Inch	p.c.	Inch		Inch
Jan.	84·0	77·4	·866	74	·00	0	—
April	84·7	78·7	·913	77	3·93	5	1·55
May	81·3	78·9	·960	90	13·46	16	2·65
June	79·3	76·4	·876	88	1·97	8	·51

Kisimayu, 0° 22′ *S.*, 42° 33′ *E.* *Observer: C. H. Craufurd.*

1895	Mean Temp. 9 A.M.	Rain		
		Amount	Days	Heaviest Fall
	°	Inch		Inch
Jan. . .	81·0	·00	0	—
Feb. . .	82·1	·00	0	—
March .	84·6	·00	0	—
April . .	84·7	·62	6	·36
May . .	82·1	4·88	11	3·33
June . .	—	—	—	—
July . .	77·7	1·55	8	·96
Aug. . .	78·7	·63	6	·34
Sept. . .	79·6	·03	2	·02
Oct. . .	81·0	·00	0	—

Magarini (Malindi Shambas), Lat. 3° 13′ *S., Long.* 40° 7′ *E.*, 8 *Miles N.W. of Malindi. Observer: James Weaver.*

1895	Temperature: Extremes		Mean Temperature			Rain		
	Highest	Lowest	Max.	Min.	Mean	Amount	Days	Heaviest Fall
	°	°	°	°	°	Inch		Inch
January	93	67	91·3	70·3	80·8	·00	0	·00
February	93	68	91·4	69·8	80·6	·11	1	·11
March	96	68	92·8	69·8	81·3	3·97	9	2·01
May *	—	—	—	—		7·76	18	2·21

* Violent earth tremors were experienced between May 15 and 23.

The Effect of Wind and Atmospheric Pressure on the Tides.—Report of the Committee, consisting of Professor L. F. VERNON HARCOURT, Professor UNWIN, Mr. G. F. DEACON, *and* Mr. W. H. WHEELER (*Secretary*). (*Drawn up by the Secretary.*)

AFTER the appointment of the Committee at the Meeting at Ipswich a copy of the paper on the Effect of Wind and Atmospheric Pressure, read at the meeting at Ipswich, was sent to the authorities of all the principal ports in the Kingdom; and also through the Foreign Office to the Hydrographic Departments of the principal maritime ports abroad. The paper was accompanied by a letter asking on behalf of the Committee for any information as to the records of tides affected by gales or in any way bearing on the subject dealt with in the paper, and a form showing the information required.

To these communications a large number of replies were received expressing the willingness of the senders to co-operate in the inquiry as far as possible. In the great majority of cases, however, the records of the tides at the ports and of the meteorological conditions were not kept in such a manner as to be useful in affording the information required.

Five ports were selected as fairly representing the tidal conditions round the English coast. The tidal records of these ports were freely placed at the disposal of the Committee: those at Liverpool for the tides by Mr. M. A. Sweney, R.N., the Marine Surveyor, and for the barometer and wind by Mr. W. E. Plummer, of the Bidston Observatory, with the consent of the Mersey Docks and Harbour Board; those for Sheerness and Portsmouth by Admiral Wharton, Hydrographer of the Admiralty; and those at Hull by Mr. E. Lake, the Manager of the Hull Docks of the North-Eastern Railway Company. Those for Boston are from the register of tides kept by Captain Hudson, the Harbour Master.

Mr. Deas, on behalf of the Clyde Navigation Trustees, furnished diagrams and particulars of the principal gales which occurred on the Clyde during the last few years.

The Government of India, through the Secretary of State for India, offered to place at the disposal of the Committee the records of the tides observed at the several ports, and also forwarded a copy of the Handbook of Cyclonic Storms in the Bay of Bengal. The time available has rendered it impossible as yet to make use of this information.

The Norwegian Government forwarded for the use of the Committee five volumes containing tables relating to tidal and meteorological conditions on the coasts of Norway. These volumes contain a large amount of valuable information, but there has not been time as yet to make use of them.

Copies of the Reports for 1894, 1895, 1896, prepared for the Canadian Government, on the 'Tides and Currents in Canadian Waters,' have also been sent by Mr. W. Bell Dawson, C.E., the Engineer in charge of the Tidal Survey.

A copy of 'De Ingenieur' of September 26, 1891, published at the Hague, containing an article by M. E. Engelenberg, C.E., on the 'Influence of the Wind both in Direction and Pressure upon the Sea Level,' was sent for the purpose of assisting in this investigation by M. Ortt, of the Hague

This article has been translated into English. It contains valuable information and statistics bearing on this subject.

The analysis of the Tidal Records of the ports of Liverpool, Portsmouth, Sheerness, Boston, and Hull has occupied all the time available. Had more opportunity been afforded it was intended to extend the investigation over a greater number of years.

In considering the report it must be borne in mind that the object of the investigation was only for the practical purpose of ascertaining whether the records of the wind and atmospheric pressure as obtained by an observer at any particular port afforded a reliable guide to pilots and mariners navigating vessels over bars and up the channels of tidal rivers, and to those engaged in coast work, as to the variations to be expected in the height of the tides from those ascertained by calculation and given in the Admiralty or local tables.

The deductions to be drawn from a careful examination of the information embodied in the following tables are—

1. That the tides are influenced both by atmospheric pressure and by the wind to an extent which considerably affects their height.

2. That the height of about one-fourth of the tides is affected by wind.

3. That the atmospheric pressure affecting the tides operates over so wide an area that the local indications given by the barometer at any particular port do not afford any reliable guide as to the effect on the tide at that port.

4. That although, so far as average results go, there can be traced a direct connection between the force and direction of the wind, and the variation in the height of the tides, yet that there is so much discrepancy in the average results when applied to individual tides that no reliable formula can be established for indicating the amount of variation in the height of the tide due to any given force of wind.

5. The results given in the tables relating to atmospheric pressure indicate that the effect of this is greater than has generally been allowed, a variation of half an inch from the average pressure causing a variation of 15 inches in the height of the tides.

It has sometimes been stated that an abnormally high tide is followed by a correspondingly low ebb. The investigations of the Dutch Engineers on the coast of Holland indicate that the effect of gales on the tides is to raise both the low and high water level.

The accompanying diagrams of the tides of December 1895 at Flushing, sent by M. Ortt, and of the corresponding tides on the Clyde, sent by Mr. James Deas, show that on this occasion the result of the gale was to raise the mean level of the sea at those places during the gale.

Atmospheric Pressure and the Tides.

The variation in the pressure of the atmosphere on the surface of the sea must exercise a considerable effect on the tides. It is, however, very doubtful whether any reliable forecast of the effect can be deduced from the readings of the barometer at any one station. Water being practically incompressible, the variation of pressure on the whole surface of a basin filled with water, to which there is no outlet, cannot have any effect in raising or lowering the surface. If, however, the pressure is high over one part of the basin and low on the other part, a variation in the height of the water in one part, as compared with the other, will take place.

DIAGRAM 1.

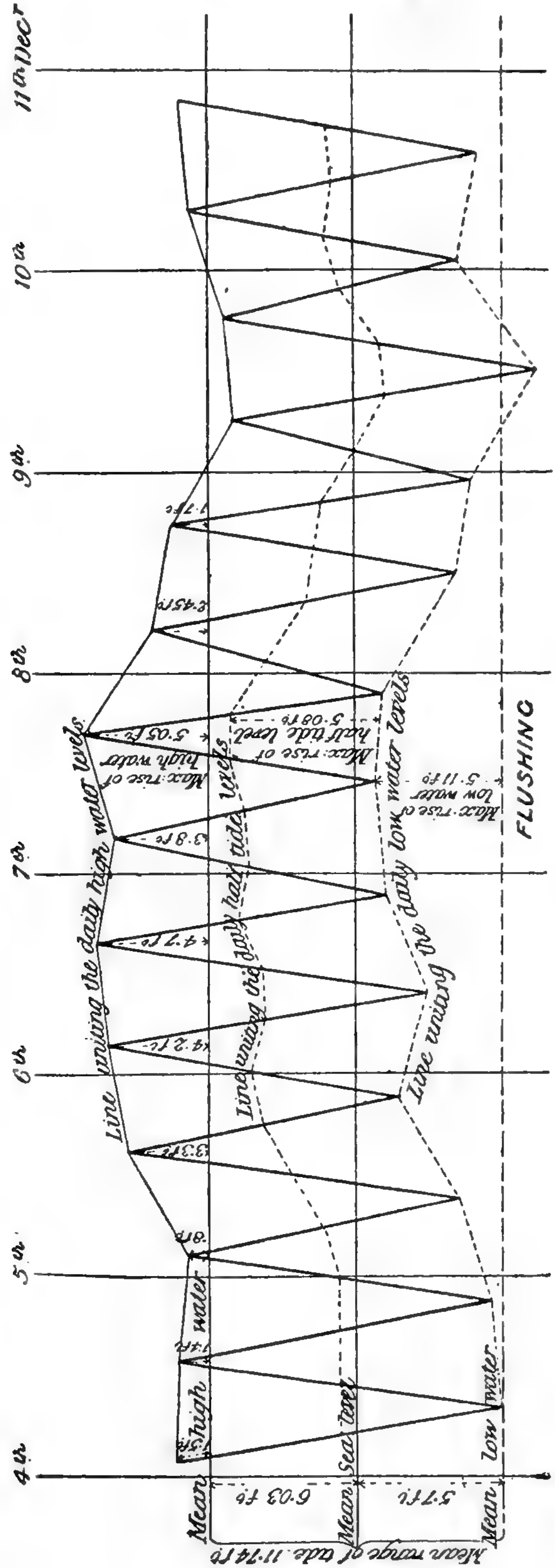
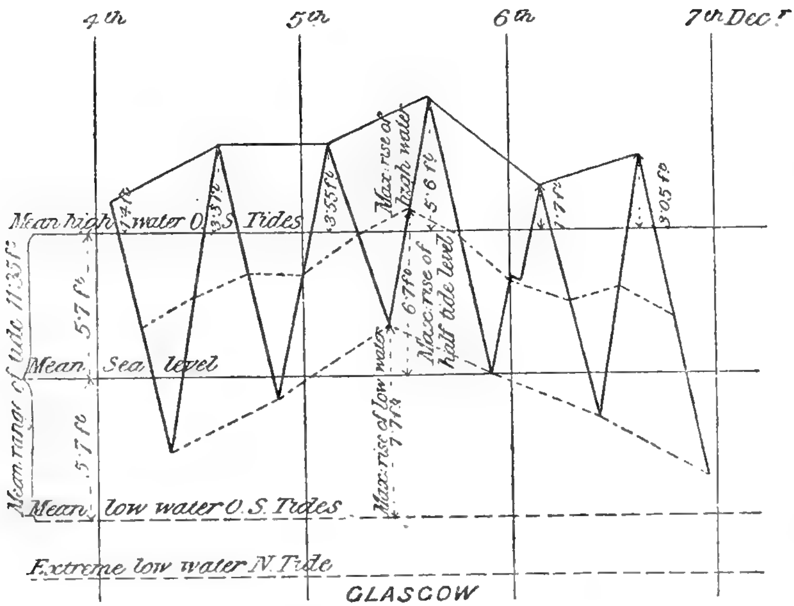

11th Decr
10th
9th
8th
7th
6th
5th
4th
Mean high water
Mean Sea level
Mean low water
6·03 ft
5·71 ft
Mean range of tide 11·74 ft
Line uniting the daily high water levels
Line uniting the daily half tide levels
Line uniting the daily low water levels
Max: rise of high water 5·05 ft
Max: rise of half tide level 5·08 ft
Max: rise of low water 5·11 ft
FLUSHING

DIAGRAM 2.



An instance of this is afforded by the effect of the great anticyclone which occurred over the South of Europe in 1882, when the level of the water of the Mediterranean at Antibes was lowered a foot, owing to the exceptionally high pressure, the surface of several inland lakes being lowered at the same time. It is stated by Mr. Bell Dawson, C.E., in his 'Report of the Survey of the Tides and Currents in Canadian Waters, 1894,' that a difference of barometric pressure tends to produce a flow from the higher towards the lower pressure, and that 'in the land-locked area of the Gulf of St. Lawrence he found that the atmospheric pressure influenced the flow of the water through the narrow inlets of that gulf, and that in the Gulf of Mexico, with a high barometer over the area of the gulf, and a lower pressure over the ocean outside, the speed of the Gulf Stream is appreciably affected.'

The effect of atmospheric pressure in raising and lowering the tides was investigated by Sir J. W. Lubbock and communicated to the Royal Society, the general conclusion he arrived at being that a rise of one inch in the barometer caused a depression in the height of the tides in the Thames of 7 inches, in the Mersey of 11 inches, and in the Avon of 13½ inches. The paper on the subject does not, however, give any adequate information as to the elimination of the effect of the wind from the calculations on which these figures are based.

Admiral Wharton, the Hydrographer of the Admiralty, in his address to the Geographical Section at Oxford in 1894, stated that a difference of one inch in the barometer has been shown to be followed by a difference of one foot in the mean level of the sea, and that in those parts of the world where the mean height of the barometer varies much with the seasons, and the tidal range is small, this effect is very marked.

This subject was brought before the Meteorological Society in 1886, and the Shipmasters' Society in 1894, in papers read by Captain Greenwood, of Glasson Dock. The results deduced were based on observations made over a lengthened period of the atmospheric gradients in the Irish Sea from the south of St. George's Channel to Morecambe Bay. The mean gradient over this distance—over 240 miles—he found to be 0·043 in., the mercury standing higher to that amount in the south. He also states that no storm of serious extent prevails over the United Kingdom, unless there be a difference of pressure between any two stations of the Meteorological Department exceeding $\frac{1}{2}$ in., and that the force of wind on the Beaufort scale does not exceed from five to six, unless the gradient is as high as 0·02 in fifteen miles. On the data obtained, Captain Greenwood prepared a table for use on that part of the coast, showing the effect of the difference of the gradient on the tides. This table is given in the 'Kludometric' Tide Table published by him annually.

From an analysis of the tides at five ports round the coast, given in the following tables, it will be seen that, taking all tides raised or lowered more than six inches from the calculated height, when the wind was blowing with a force less than three of the Beaufort scale, coincident with a variation in atmospheric pressure of 0·25 inch from the average, the number of tides affected by the pressure, as recorded by the barometer reading at local stations in a manner that would naturally be expected, was nearly equal to those affected in a contrary direction, 56 per cent. being depressed when the pressure was above the average, or raised when it was below, and 44 per cent. being influenced in the opposite direction.

These results indicate that the reading of the barometer at a single port is not a reliable guide as to the effect of pressure in raising or lowering the height of the tide, and that no reliable data as to the effect of atmospheric pressure on the tides can be arrived at, except by simultaneous observations of the barometer, the wind, and the tides over extended areas of both land and sea.

Barometer and the Tides.

Boston—Average of the Four Years 1892, 1893, 1894, 1895.

—	Average number of Tides affected in one year	Mean rise of Tide above L.W.S.T.	Mean variation of Tide from predicted height	Maximum variation of Tides	Mean variation of Barometer from average
1891.		Ft.	In.	In.	In.
High Bar.—Low Tides .	48	18·51	10·72	35	·367
Low „ High „ .	17	19·54	9·90	20	·439
Total and Means . .	65	19·02	9·81	—	·403
High Bar.—High Tides .	32	20·60	9·69	29	·376
Low „ Low „ .	13	18·14	10·59	27	·399
Total and Means . .	45	19·37	10·13	—	·387
1892.					
High Bar.—Low Tides .	45	18·60	9·62	—	·371
Low „ High „ .	15	19·00	8·66	—	·466
Total and Means . .	60	18·80	9·14	—	·418

BAROMETER AND THE TIDES (BOSTON, 1892)—*continued.*

—	Average number of Tides affected in one year	Mean rise of Tide above L.W.S.T.	Mean variation of Tide from predicted height	Maximum variation of Tides	ean variation of Barometer from average
		Ft.	In.	In.	In.
High Bar.—High Tides.	22	20·60	7·91	—	·374
Low „ Low „ .	21	18·00	11·57	—	·409
Total and Means . .	43	19·30	9·74	—	·391
1893.					
High Bar.—Low Tides .	68	18·84	10·78	—	·334
Low „ High „ .	23	19·87	10·87	—	·407
Total and Means . .	91	19·35	11·32	—	·371
High Bar.—High Tides.	42	20·73	9·26	—	·317
Low „ Low „ .	13	19·80	11·67	—	·384
Total and Means . .	55	20·27	10·46	—	·351
1894.					
High Bar.—Low Tides .	29	17·92	12·14	—	·365
Low „ High „ .	19	18·94	10·10	—	·340
Total and Means . .	48	18·43	11·12	—	·352
High Bar.—High Tides.	31	20·00	9·77	—	·359
Low „ Low „ .	5	16·28	8·60	—	·316
Total and Means . .	36	16·14	9·18	—	·337
1895.					
High Bar.—Low Tides .	48	18·70	10·37	—	·336
Low „ High „ .	12	20·32	10 00	—	·543
Total and Means . .	60	19·50	10·18	—	·439
High Bar.—High Tides.	33	21·07	11·82	—	·381
Low „ Low „ .	11	18·48	10·54	—	·488
Total and Means, 437 .	44	19·75	11·18	—	·434

Out of 437 tides affected in the four years, an average of 110 a year, 259, or about 59 per cent., were lowered when the pressure of the atmosphere was increased, or raised when it was decreased below the average; and 178, or about 41 per cent., were influenced in the opposite direction.

The tidal observations for Boston are taken from the register kept by the Harbour Master at Boston Dock. The slight discrepancy between the figures as given in the above table, and those in the paper read at Ipswich Meeting, is due to the fact that a different method has been pursued in separating the tides affected by the pressure from those affected by the wind.

HULL, 1895.

—	Average number of Tides affected in one year	Mean rise of tide above L.W.S.T.	Mean variation of Tide from predicted height	Maximum variation of Tides	Mean variation of Barometer from average
		Ft.	In.	In.	In.
High Bar.—Low Tides .	15	19·34	6·53	12	·388
Low ,, High ,, .	25	19·76	10·00	24	·329
	40	19·55	8·26	—	·358
High Bar.—High Tides .	43	19·60	9·32	20	·365
Low ,, Low ,, .	5	18·06	6·20	12	·394
	48	18·83	7·76	—	·379

The tidal observations are from the Register kept at the Albert Dock of the North-Eastern Railway Company, the calculated height of the tides being taken from the Admiralty Tide Tables, L.W.S.T. being taken as 6·15 feet below Albert Dock sill.

SHEERNESS, 1895.

—	Average number of Tides affected in one year	Mean rise of tide above L.W.S.T.	Mean variation of Tide from predicted height	Maximum variation of Tides	Mean variation of Barometer from average
		Ft.	In.	In.	In.
High Bar.—Low Tides .	—	—	—	—	—
Low ,, High ,, .	35	15·58	15·20	33	·420
	35	15·58	15·20	—	·420
High Bar.—High Tides .	72	15·58	12·54	24	·332
Low ,, Low ,, .	2	12·66	16·00	23	·570
	74	14·12	14·27	—	·451

The tides, as recorded at Sheerness, appear to rise on an average about 12 inches higher than the calculated height as given in the Admiralty Tables. Out of 686 times recorded in 1895, 702 were above the height given, an average of 1·02 foot, and only 26 were below, an average of 0·45 foot. This to some extent affects the results given in this table.

PORTSMOUTH, 1895.

—	Average number of Tides affected in one year	Mean rise of Tide above L.W.S.T.	Mean variation of Tide from predicted height	Maximum variation of Tides	Mean variation of Barometer from average
		Ft.	In.	In.	In.
High Bar.—Low Tides .	53	11·85	11·26	21	·378
Low " High " .	11	12·72	13·19	25	·389
	64	12·28	12·22	—	·383
High Bar.—High Tides .	8	11·06	9·25	14	·343
Low " Low " .	3	9·55	13·33	14	·286
	11	10·30	11·29	—	·314

The tidal observations for Sheerness and Portsmouth are from the register kept at the Royal Dockyards. The wind and barometer, not being recorded at Sheerness, is taken from the daily Weather Reports issued by the Meteorological Office.

LIVERPOOL, 1893 AND 1894.

—	Average number of Tides affected in one year	Mean rise of Tide above L.W.S.T.	Mean variation of Tide from predicted height	Maximum variation of Tides	Mean variation of Barometer from verage
		Ft.	In.	In.	In.
1893.					
High Bar.—Low Tides .	3	24·30	15·66	78	·61
Low " High " .	37	25·49	19·58	78	·40
	40	24·89	17·62	—	·50
High Bar.—High Tides .	18	24·99	12·33	54	·39
Low " Low " .	—	—	—	—	—
	18	24·99	12·33	—	·39
1894.					
High Bar.—Low Tides .	28	24·61	13·78	72	·40
Low " High " .	5	23·48	18·20	30	·38
	33	24·04	15·94	—	·39
High Bar.—High Tides .	—	—	—	—	—
Low " Low " .	—	—	—	—	—
	—	—	—	—	—

The tidal observations are from the register of the Mersey Docks and Harbour Board, and the barometer and wind from the observations recorded at the Bidston Observatory. The tides selected are those which were 12 inches or more above the predicted heights as given in Holden's Tables, when the wind did not exceed a force of 3 on the Beaufort scale (as reduced from the mean velocity), and the barometer was 0·25 inch above or below the average.

Low water of spring tides is taken as 9 feet below the Old Dock sill.

Holden's Tide Tables appear to give the predicted tides too low, 78 per cent. of the tides being above those given in the Tide Tables, a mean of 1·04 foot, and only 22 per cent. below—a mean of 0·46 foot. This, to a certain extent, affects the results obtained in the above table.

BAROMETER AND TIDES.

Summary.

—		Number of Tides affected in one year	Mean rise of Tide above L.W.S.T.	Mean variation of Tide from predicted height	Mean variation of Barometer from average
			Ft.	In.	In.
High Bar.—Low Tides }	Boston .	65	19·02	9·81	·403
Low Bar.—High Tides }	Hull . .	40	19·55	8·26	·358
" "	Sheerness .	35	15·58	15·20	·420
" "	Portsmouth	64	12·28	12·22	·383
" "	Liverpool .	36	24·46	16·78	·445
		240	18·17	12·45	·402

The average result is equal to a variation of 13 inches of the tide for half an inch variation in the barometer.

—		Number of Tides affected in one year	Mean rise of Tide above L.W.S.T.	Mean variation of Tide from predicted height	Mean variation of Barometer from average
			Ft.	In.	In.
High Bar.—Low Tides }	Boston .	45	19·37	10·13	·387
Low Bar.—High Tides }	Hull . .	48	18·83	7·76	·379
" "	Sheerness .	72	14·12	14·27	·451
" "	Portsmouth	11	10·30	11·29	·314
" "	Liverpool .	9	24·99	12·33	·390
		185	17·52	11·15	·385

Average result equal to a variation of 15 inches of the tide for half an inch of the barometer.

The above results show that out of an average of 425 tides recorded in a year at five ports varying from the calculated height 6 inches and upwards, coincident with a variation of 0·25 inch of atmospheric pressure in calm weather, 240, or 56 per cent., were lowered when the pressure was above, or were raised when it was below the mean; and 185, or about 44 per cent., were influenced in the opposite direction.

Wind and Tides.—Direction.

Boston, 1892–95.

Wind	Year	No. of Tides	Mean Force of Wind	Maximum Force	Tide, Height above Low Water	Increase in Inches	
						Mean	Maximum
High Tides:					Feet		
North-east . .	1892	29	3·90	8	19·59	11·70	25
,, ,, . .	1893	21	3·62	6	20·75	12·70	26
,, ,, . .	1894	31	3·80	6	19·34	12·61	23
,, ,, . .	1895	17	5·18	6	19·65	10·94	25
North-west . .	1892	18	3·77	8	20·56	19·40	41
,, ,, . .	1893	33	4·03	10	20·97	18·24	60
,, ,, . .	1894	36	4·22	8	20·11	13·50	28
,, ,, . .	1895	41	4·20	8	20 04	18·40	75
Means . . .	—	56	4·18	—	20·12	14·67	—
South-east . .	1892	4	3·72	5	21·70	13·00	18
,, ,, . .	1893	14	4·00	10	19·75	13·85	32
,, ,, . .	1894	9	4·77	6	18·08	14·66	26
,, ,, . .	1895	5	5·40	8	19·16	9·40	12
South-west . .	1892	11	4·27	6	20·95	12·82	22
,, ,, . .	1893	26	3·80	8	20·11	12·00	21
,, ,, . .	1894	26	4·50	8	20·16	13·18	29
,, ,, . .	1895	16	4·50	10	20·09	13·54	52
Means . . .	—	28	4·37	—	20·00	12·55	—
Low Tides:							
South east . .	1892	14	3·33	4	17·30	16·33	33
,, ,, . .	1893	7	5·14	9	16·42	14·14	27
,, ,, . .	1894	11	4·20	7	18·75	14·27	25
,, ,, . .	1895	8	3·75	8	18·45	14·30	18
South-west . .	1892	61	4·16	10	18·53	12·14	34
,, ,, . .	1893	56	4·65	10	17·42	14·67	48
,, ,, . .	1894	53	4·72	10	18·32	17·22	60
,, ,, . .	1895	38	4·67	10	20·25	12·50	24
Means . . .	—	62	4·32	—	18·18	14·32	—
North-east . .	1892	9	3·55	6	20·30	10·50	14
,, ,, . .	1893	9	3·22	4	19·42	9·66	16
,, ,, . .	1894	4	3·33	4	18·11	10·00	12
,, ,, . .	1895	8	3·75	5	18·47	16·25	35
North-west . .	1892	5	4·50	8	18·50	12·50	18
,, ,, . .	1893	20	5·00	10	19·66	15·70	42
,, ,, . .	1894	7	3·13	4	18·75	13·00	25
,, ,, . .	1895	8	4·50	6	16·20	12·24	21
Means . . .	—	17	3·87	—	18·68	17·48	—

WIND AND TIDES.—FORCE.

Boston, 1892–95.

Force	Year	Mean Height of Tide above Low Water in Feet	Mean Variation of Tide in Inches	Maximum Variation of Tide in Inches	Number of Tides
3	1892	19·99	11·64	28	82
	1893	19·99	12·75	32	103
	1894	18·71	12·28	25	57
	1895	19·14	13 06	35	63
	Mean .	19·20	12·43	30	76
4	1892	19·08	13·63	34	31
	1893	19·79	16·90	48	31
	1894	20·86	13·60	33	40
	1895	17·52	11·38	24	13
	Mean .	19·31	13·87	34·75	28·75
5	1892	19·28	12·69	25	13
	1893	18·14	11 82	19	11
	1894	19·94	14·96	27	23
	1895	19·01	11·28	31	34
	Mean .	19·09	12·68	25 5	20 25
6	1892	19·61	13·60	25	15
	1893	20·87	15·35	29	20
	1894	19·37	19·20	50	21
	1895	19·21	16·00	26	19
	Mean .	19·75	16·04	32·5	18·5
7 8 9	1892	20·10	15·62	26	8
	1893	17·56	21 43	50	15
	1894	18·99	21·07	60	14
	1895	21·80	32·57	75	7
	Mean .	19·61	22·67	52·75	11 25
10	1892	20·50	12·50	13	2
	1893	17·05	23·20	60	5
	1894	18·00	27·00	27	1
	1895	18·44	23·20	52	5
	Mean .	18·49	21·47	38	3·25

Wind and Tides.

Boston. Average result of 4 *years*, 1892–95.

Force of Wind	Average Number of Tides yearly	Mean Rise of Tide	Variation of Tide in Inches		Maximum Variation	
			Mean of 4 Years	Per Foot Rise of Tide	Mean of 4 Years	Per Foot Rise of Tide
		Feet				
3	76	19·20	12·43	0·65	30·00	1·54
4	29	19·31	13·87	0·72	34·75	1·79
5	20	19·09	12·68	0·66	25·50	1·34
6	18	19·75	16·04	0·86	32·50	1·63
7 to 9	11	19·61	22·67	1·15	52·75	2·68
10	3	18·49	21·47	1·16	38·00	2·06
—	157	19·24	16·52	·87	—	—

The figures in the tables are taken from the register kept by the Dock Master at Boston Dock.

From the tables it will be seen that out of 2,822 tides recorded in the four years, 655, or about 23 per cent., were affected by the wind. Taking the yearly average number of tides affected as 163, 56, or 35 per cent., were increased due to winds blowing from a northerly direction or with the flood tide, and 62, or 38 per cent., were decreased by southerly winds blowing in the opposite direction to the tide, leaving about 27 per cent. affected by the winds in an opposite way to that which might have been expected.

The number of tides raised by northerly winds is about the same as those depressed by southerly winds.

Wind and Tides.—Direction.

Hull, 1895.

—	Tides	Wind		Mean Height of Tide above L.W.S.T.	Increase in Inches	
		Mean Force	Maximum Force		Mean	Maximum
High Tides:						
North-east . . .	21	4·00	6	19·44	12·57	24
North-west . . .	84	4·12	7	19·51	14·78	52
	105	4·06	—	19·42	13·68	—
South-east . . .	27	3·70	7	19·80	10·93	18
South-west . . .	69	3·77	8	19·75	13·28	32
	96	3·73	—	19·77	12·10	—

DIRECTION (HULL, 1895)—*continued.*

—	Tides	Wind		Mean Height of Tide above L.W.S.T.	Increase in Inches	
		Mean Force	Maximum Force		Mean	Maximum
Low Tides:						
South-east . . .	24	3·42	6	18·65	10·02	25
South-west . . .	20	4·35	8	19·07	14·25	36
	44	3·83	—	18·86	12·13	—
North-east . . .	4	3·25	4	15·82	10·75	14
North-west . . .	6	4·00	5	17·30	11·00	13
	10	3·62	—	16·56	10·87	—

WIND AND TIDES.—FORCE.

Hull, 1895.

Force of Wind	Number of Tides	Mean Height of Tide above L.W.S.T.	Mean Variation of Tide		Maximum Variation in	
			Inches	Per Foot Rise of Tide	Inches	Per Foot Rise of Tide
		Feet				
3	104	19·83	11·82	0·59	4	2·01
4	65	19·23	13·09	0·67	32	1·06
5	46	19·26	13·68	0·71	29	1·50
6	14	18·82	15·14	0·80	34	1·88
7 to 10	12	19·58	21·66	1·10	52	2·65
	241	19·34	15·07	0·77	—	—

The figures in the above tables are abstracted from the tidal register kept at the Albert Dock, Hull, for the year 1895.

The heights of the tides given are above low water of spring tides. This has been taken as 6·15 feet above the sill of the Albert Dock. The calculated heights have been taken from the Admiralty Tide Tables.

Comparing the Hull tides with those at Boston for the same year, it will be seen that the wind was more effective in raising than in depressing the tides at Hull, 79 per cent. of the whole being raised against 21 per cent. depressed. At Boston the effect was more equal, 59 per cent. being raised and 41 per cent. depressed. Southerly winds appear to have much more effect in raising the tides at Hull than lower down the coast. The mean effect of the force of wind on the tides is about the same at both ports.

Wind and Tides.—Direction.

Sheerness, 1895.

—	Number of Tides	Mean Force of Wind	Maximum Force	Mean Height of Tide above L.W.S.T.	Mean Increase in Inches	Per Foot Rise of Tide	Maximum Increase in Inches
High Tides:				Feet		Inches	
North-west .	79	4·10	6	15·83	18·84	1·19	55
North-east .	43	4·80	9	15·95	14·70	0·92	32
	122	4·45	—	15·89	16·72	1·05	—
South-west .	54	3·82	6	16·21	14·00	0·86	33
South-east .	34	4·20	8	15·92	13 20	0·83	28
	88	4·01	—	16·06	13·60	0·84	—
Low Tides:							
South-west .	2	4·5	5	13·50	11·50	0·85	16
South-east .	—	—	—	—	—	—	—
	2	—	—	—	—	—	—
North-west .	—	—	—	—	—	—	—
North-east .	—	—	—	—	—	—	—
	—	—	—	—	—	—	—

Wind and Tides.—Force.

Sheerness, 1895.

Force	Number of Tides	Mean Height of Tide above L.W.S.T.	Mean Variation of Tide	Per Foot Rise of Tide	Maximum Variation in Inches
		Feet	Inches		
3	111	16·00	14·63	·91	34
4	105	16·03	14·47	·90	38
5	60	15·55	12·53	·80	44
6	18	17·25	21·40	1·24	55
7	7	15·66	14·70	·94	32
8	4	16·25	17·20	1·06	28
9	2	16·37	15·50	·95	18
	307	16·16	15·78	·97	—

The tides at Sheerness appear to be, on an average, 12 inches higher than the height calculated for the Admiralty Tide Tables, and this has to some extent affected the above results.

Of the 668 tides, 212, or about 32 per cent., were affected by the wind. Of these, 122, or about 60 per cent., were increased by winds blowing from a northerly direction, and 88, or about 40 per cent., were increased by winds blowing from a southerly direction.

Wind and Tides.—Direction.

Portsmouth, 1895.

Wind	Number of Tides	Mean Force of Wind	Maximum Force	Mean Height of Tide above L.W.S.T.	Mean Increase in Inches	Maximum Increase in Inches
High Tides:				Feet		
North-west . . .	23	4·08	6	13·52	13·00	44
South-west . . .	38	4·39	7	13·55	12·65	26
	61	4·23		13·53	12·82	
North-east . . .	8	3·75	5	12·37	12·62	23
South-east . . .	10	4·10	7	14·50	14·30	20
	18	3·92		13·43	13·46	
Low Tides:						
North-east . . .	18	4·22	6	10·98	13·72	23
South-east . . .	2	3·00	3	12·70	9·50	3
	20	3·61		11·84	11·61	
North-west . . .	10	3·80	5	10·70	9·90	20
South-west . . .	17	3·64	5	11·50	9·58	5
	27	3·72	—	11·10	9·74	—

Wind and Tides.—Force.

Portsmouth, 1895.

Force	Number of Tides	Mean Height of Tide above L.W.S.T.	Mean Variation of Tide		Maximum Variation	
			Inches	Per Foot Rise of Tide.	In Inches	Per Foot Rise of Tide
		Feet		Inches		
3	60	11·93	11·80	0·98	23	2·01
4	46	13·07	12·80	0·98	44	3·36
5	15	12·80	13·00	1·01	24	1·90
6	12	12·22	13·33	1·09	23	1·99
	133	12·50	12·73	1·01	—	—

Of the 668 tides recorded, 136, or about 20 cent., were affected by the wind. Of these, 61, or about 45 per cent., were increased by westerly winds blowing with the flood tide, and 20, or about 15 per cent., were decreased by easterly winds blowing in the opposite direction to the tide, leaving about 40 per cent. affected by winds in an opposite way to that which might have been expected.

The number of tides raised by westerly winds is three times as great as those depressed by easterly winds.

WIND AND TIDES.—DIRECTION.

Liverpool, 1893–94.

Wind	Year	Number of Tides	Mean Force of Wind	Maximum Force	Mean Height of Tide above L.W.S.T.	Mean Increase in Inches	Maximum Increase in Inches
High Tides:					Feet		
North-east .	1893	7	3·11	4	25·01	14·00	15
„ .	1894	9	3·60	5	23·95	15·30	22
North-west .	1893	43	4·23	7	24·97	19·74	46
„ .	1894	40	4·40	10	25·28	18·55	41
Means . .	—	45	3·83	6·5	24·80	16·84	31
South-east .	1893	9	3·66	5	23·13	16·33	20
„ .	1894	39	3·77	5	25·62	19·02	33
South-west .	1893	116	4·33	10	24·70	20·43	58
„ .	1894	116	5·40	11	25·11	21·25	80
Means . .	—	140	4·28	7·75	24·64	19·25	48
Low Tides:							
South-east .	1893	1	3·00	3	28·40	14·00	14
„ .	1894	4	3·00	4	27·75	14·50	20
South-west .	1893	1	3·00	3	24·84	14·00	14
„ .	1894	4	6·25	11	23·17	13·25	19
Means . .	—	5	3·81	5·25	26·04	13·94	17
North-east .	1893	—	—	—	—	—	—
„ .	1894	1	3	24	24·10	24·00	24
North-west .	1893	1	6	6	19·10	13·00	13
„ .	1894	2	3	3	22·43	11·50	12
Means . .	—	2	4	11	21·87	16·16	16

WIND AND TIDES.—FORCE.

Liverpool, 1893, 1894.

Force	Year	Number of Tides	Mean Height of Tide above L.W.S.T.	Mean Variation of Tide		Maximum Variation	
				In Inches	Per Foot Rise of Tide	In Inches	Per Foot Rise of Tide
			Feet				
3	1893 1894	70 72	24·78 25·08	18·10 16·60		36 33	
	Mean .	71·5	24·93	17·33	·69		1·52
4	1893 1894	49 50	24·63 25·39	19·60 18·24		46 33	
	Mean .	49·5	25·21	18·92	·74		1·54
5	1893 1894	33 27	25·37 24·75	22·40 20·40		58 37	
	Mean .	30	25·06	21·40	·85		1·87
6	1893 1894	16 27	19·43 25·56	21·18 21·88		35 37	
	Mean .	21·5	22·49	21·53	·96		1·64
7	1893 1894	2 18	19·47 26·10	22·50 21·88		25 36	
	Mean .	10	22·73	22·19	·98		1·32
8	1893 1894	1 4	18·50 26·33	19·00 17·70		19 25	
	Mean .	2·5	22·41	18·35	·82		0·97
9	1893 1894	— 9	— 17·92	— 25·20		— 40	
	Mean .	5			1·40		2·23
10	1893 1894	5 8	24·92 27·00	20·50 36·50		35 80	
		6·5	25·96	28·50	1·09		2·19
	Mean .	196	23·69		0·94		

The tidal observations at Liverpool are recorded from the Old Dock sill. In the above tables they are taken as above low water of spring tides as adopted for the Admiralty datum or 9 feet below the Old Dock sill. The calculated tides are reduced from Holden's Tide Tables: these appear to give the expected height less than it actually is, as 78 per cent.

of the tides are below those given, an average of 1·04 foot, and only 22 per cent. below, an average of 0·46 foot. This to some extent affects the results given.

Of about 2,800 tides recorded in the two years, 393, or 192 in a year, or about 14 per cent., can be traced as being affected by the wind. Of these 192 tides, 140, or about 73 per cent., were increased by south-easterly and south-westerly winds blowing more or less in the same direction as the flood tide, and only two depressed by northerly winds, leaving 50 tides, or about 26 per cent., as affected by wind blowing in an opposite direction to that which might have been expected.

Summary.

Taking the mean result of the five ports, the following results are obtained :—

180 tides are affected by the wind in a year, or about 26 per cent. of the whole.

123 are either increased by winds blowing with the tide or depressed by winds against the tide.

67 are influenced in an opposite way.

The mean force of the wind affecting these tides is 4·02 (Beaufort scale).

With the mean rise of the tide above low water of spring tides 18·14 feet, the mean variation in the height of the tides is 13·89 inches.

The mean variation per foot rise of tide due to wind is for force of

3	0·76 per foot rise of tide
4 and 5	0·80 ,, ,,
6	0·91 ,, ,,
7 to 10	1·06 ,, ,,

As showing the extent to which tides may be affected by wind during gales, the following variations from the expected or natural height are taken from the observations contained in the preceding tables :—

Port	Rise of Spring Tides above Low Water	Variations in Height of Tide due to Gale	Difference between two succeeding Tides
	ft. in.	ft. in.	ft. in.
Hull	21 0	6 4	5 0
Boston	22 0	5 1	7 8
Yarmouth	5 0	4 9	6 2
Sheerness	16 0	4 7	2 10
Flushing	15 0	5 1	2 8
Ymuiden	5 3	5 4	1 4
Schokland (Zuyder Zee)	0 9	7 9	1 9
Liverpool	27 6	6 8	7 9
Glasson Dock	20 0	4 9	3 0
Glasgow	11 3	6 2	3 11
Portsmouth	13 6	3 8	3 1

Wind and Tides.—Effect of Gales.

Gale of November 1893.

In November 1893, on the 16th and 17th, the general direction of the wind was from the south-east to south-west, blowing with a force from 4 to 6. In the North Sea the gradient between Yarmouth and

Aberdeen, about 270 miles, varied from 0·12 inch to 0·49 inch, the depression being in the north, the barometer there being 1 inch below the average. On the 18th and 19th, the days of the gale, the barometer rose rapidly until it became in the north 0·21 inch above the average, and in the south 0·43 inch below, the gradient being reversed to 0·65 inch on the 18th and 0·53 inch on the 19th, with the depression in the south. The general direction of the wind was north-west to north-east, blowing after midday on the 18th with a force from 8 to 10. The effect of these gales, blowing from opposite directions, affected all the ports round the coast, but in a very varying degree. On the north-east coast the effect was not great, but in the Wash and in the southern part of the North Sea its effect was felt to such an extent that at Boston the difference between two succeeding tides was 7 feet 8 inches; at Yarmouth 6 feet 2 inches, which is more than the total rise of a spring tide; at Dover the variation was 5 feet 3 inches; while at Portsmouth it was only 1 foot 9 inches, and at Avonmouth 3 feet 9 inches. At Liverpool, on the 17th, the wind was blowing from S.E. to S.W. with force of 5; on the 18th it backed to the N.W. with force of 6 to 7.

In the following table two tides are given at twenty-four hours' interval on the 17th and 18th.

Tides after the Gale of November 1893.

Port	Height of Tide on Gauge	Variation from Tide Table		Difference in Height of two Tides
		Above	Below	
	ft. in.	ft. in.	ft. in.	ft. in.
Leith	18 8	0 10	—	0 4
	19 0	0 10	—	—
Sunderland	11 11	0 9½	—	1 7
	13 6	2 9½	—	—
Grimsby	19 2	—	2 2	5 10
	25 0	3 3	—	—
Boston	15 0	—	2 3	7 8
	22 8	5 1	—	—
Yarmouth	3 4	—	1 5	6 2
	9 6	4 9	—	—
Lowestoft	15 0	—	—	4 0
	19 0	—	—	—
Sheerness	3 3	—	—	4 2
Dockyard	7 5	—	—	—
Victoria and Albert Dock	24 5	—	2 0	3 9
	28 2	1 4	—	—
London Dock	22 7	—	1 8	3 8
	26 3	1 7	—	—
Dover	9 9	—	2 1	5 3
	15 0	2 4	—	—
Portsmouth	9 8	—	2 7	1 9
	7 11	—	1 3	—
Avonmouth	24 6	—	2 7	3 9
	28 3	—	1 8	—
Liverpool	12 3	1 6	—	2 2
	10 1	—	1 8	—
Glasson Dock	10 6	—	4 9	3 0
	13 6	—	3 5	—
Belfast	22 4	1 10	—	4 4
	18 0	—	2 8	—
Cork	12 4	2 9	—	4 7
	8 1	—	1 10	—

Gale of November 1894.

In the gale of November 13th, 1894, the wind at the Scilly Islands blew strongly from the north-west, backing on the following day to the south-west with a force of 7. At Holyhead, on the 13th, the wind was from the west in the morning with a force of 6, backing to south-west in the evening, and blowing with force of 8, and continuing in that quarter during the rest of the week. At Belfast and Cork the direction was S.W., force 8. On the north-east coast the direction was S.W., force moderate; further down the coast on 13th the direction was W.N.W., force 5, changing to S.W., force 9; in the English Channel, direction S.W., force 7 to 10. The barometer was about 0·25 below the mean, the gradient between Scilly and Ardrossan being 0·84. The steepest gradient was across England, being as between Scilly and Denmark 0·84, the reading being 29·84 at the former place, and 29·00 at the latter. Full moon was on the 13th. With these conditions the tides were affected as follows:—

At Holyhead the evening tide on the 13th was raised 4 feet above the natural height. The wind continued to blow here stiffly from the south-west all the week, and the tides were all above the natural height, varying from 2 feet 5 inches to 4 feet above.

At Belfast the tide on the 13th was raised 4 feet 10 inches, and the mean increase for five tides was 2 feet 9 inches above.

At Cork on the 11th the tide was raised 2 feet 8 inches, and on the 13th 2 feet 5 inches.

At Liverpool the evening tide of the 13th was raised 3 feet above the natural height, and the succeeding tides 1 foot 2 inches and 1 foot 10 inches.

At Glasson Dock the evening tide of the 13th was 2 feet 6 inches higher, and the succeeding tides 10 inches and 12 inches higher.

At Leith on the east coast the evening tide of the 14th was raised 2 feet 3 inches; and at Sunderland 2 feet 9 inches.

Lower down the coast the force of the S.W. gale was more felt, blowing in the Wash with force of 8.

At Hull the tides of the 12th were depressed respectively 1 foot 6 inches and 1 foot; on the 13th 1 foot 2 inches and 0 foot 2 inches; and on the 14th 1 foot 8 inches and 1 foot 5 inches.

At Boston the evening tide of the 13th was depressed 1 foot 2 inches, and the morning tide of the 14th 3 feet 5 inches, the evening tide being raised 1 foot, and the next morning tide 11 inches.

At Dover, the force and direction of the wind being the same as in the Wash, the morning tide was depressed 3 feet 3 inches, the evening tide being raised 1 foot 6 inches.

At Sheerness the tide was depressed 1 foot 6 inches in the evening of the 14th, and raised 3 feet 3 inches on the morning of the 15th. At the Victoria and Albert Dock the tide was depressed 3 feet 5 inches in the evening of the 14th, and raised 1 foot 8 inches on the following morning.

At the lower end of the English Channel the effect of this south-west gale was to raise the tides 2 feet at Portsmouth on the evening of the 13th, and the two succeeding tides 1 foot 10 inches and 1 foot 6 inches. At Devonport the morning tide of the 14th was raised 2 feet 9 inches, and the two following tides 1 foot 9 inches and 2 feet 2 inches.

In the Bristol Channel the tides were raised 1 foot 4 inches at Cardiff, and 1 foot 5 inches at Avonmouth.

The mean result of the effect at fourteen ports round the coast was as follows:—The mean rise of the spring tides at these places is 20·43 feet, the mean force of the wind was 6·78, and the mean variation of the tides from the natural height 2·70 feet. On the west coast the tides were raised by the gale 3½ feet, and on the east coast depressed to a similar extent.

Gales, December 1894.

On the 20th the wind was from the N.N.W., force varying from 5 to 7. The barometer was about the average.

At Hull the morning tide was raised 3 feet 1 inch.

At Boston the morning tide was raised 3 feet 2 inches.

On the 22nd–23rd; on the evening of the 22nd the wind blew a gale from the S.W., force 10. The barometer at Hull was 0·97 in. below the average, at Boston 0·82 in. below.

The tide at Hull on the morning of the 22nd was raised 1 foot 1 inch, the following tide 1 foot, and the morning tide of the 23rd 4 feet 1 inch.

At Boston the morning tide of the 22nd was 6 inches depressed, the evening tide raised 1 foot 2 inches, and the morning tide of the 23rd 4 feet 4 inches. High water of the evening tide of the 22nd was 2 hours 33 minutes late, and the morning tide of the 23rd 1 hour 10 minutes early.

At Ipswich the evening tide of the 23rd was raised 4 feet 11 inches, and the tide flowed an hour longer than its proper time.

On the 28th, 29th, and 30th the wind blew a gale from W.N.W. with force varying from 10 to 6. The barometer was 0·52 to 0·72 below the average. The gradient between Aberdeen and Yarmouth was 0·48, the depression being in the north.

At Hull the morning tide of the 29th was raised 2 feet, the evening tide 6 feet 4 inches, and the morning tide of the 30th 1 foot 7 inches.

At Boston the evening tide of the 28th was depressed 3 feet 1 inch; the morning tide of the 29th was normal, the evening tide being raised 4 feet 3 inches, and the following tide 1 foot 4 inches.

On the west coast at Liverpool on the 21st the wind was from the S.W. with force of 4, and the tides normal. On the morning of the 22nd, the wind being nearly due south with force of 11, the tide rose to 20 feet 6 inches above Old Dock sill, or 29 feet 6 inches above L.W.S.T., and 6 feet 8 inches above the expected height. The evening tide was 13 inches below the expected height, making a difference of 7 feet 9 inches in the height of two succeeding tides.

Gale, November 1895.

During the early part of November (1st to 10th) there was a gradient of about half an inch on the English coast, the depression being in the north and the wind from south-east to south-west, blowing with the force of a gale on the 11th. The barometer was from about ½ to ¾ inch below the average, the mean being 29·85 at the North Foreland, 29·45 at Leith, and on the west coast 29·69 at the Scilly Islands, and 29·54 at Holyhead, the mean resultant being a gradient from the south of 0·40. The new moon was on the 16th.

At Leith the average force of the wind for 12 days was 3·41, and during this time the tides averaged 1·33 above the natural height. On the 11th, when the wind blew with force of 8 from S.W., the evening tide was 2 feet 10 inches above the natural height.

Lower down the coast at Grimsby the wind from the 5th to the 17th was blowing principally from the S.W. with force varying from 4 to 7. On the 12th the tide was raised 2 feet 6 inches in the morning and 1 foot in the evening; on the 13th 1 foot 5 inches and 1 foot 2 inches; on the 14th and 15th 1 foot and 1 foot 3 inches in the morning; on the 16th 1 foot 1 inch and 1 foot 5 inches; on the 17th 2 feet and 1 foot. The mean force of the wind for 7 days was 5, and mean increase of tides 1·30 foot.

At Hull the morning and evening tides were raised respectively on the 12th 2 feet 5 inches and 8 inches; on the 13th 1 foot 3 inches and 1 foot 4 inches; on the 14th 3 inches and 1 inch; on the 15th 1 foot 7 inches in the morning; on the 16th 11 inches and 1 foot 5 inches; and on the 17th 2 feet 1 inch and 1 foot 1 inch. The mean force of the wind for the 6 days was 5, and the mean increase in the tides 1·10 foot.

At Boston S.W. wind had the effect of depressing the tides, the average force from 10th to 16th was 5·10. On the night of the 10th there was a S.W. gale with force of 10, and the two following tides were respectively 1 foot 3 inches and 1 foot 6 inches below the normal height; the morning tides of the 12th and 15th were raised 1 foot 4 inches and 1 foot, and the evening tide of 13th depressed 13 inches; the barometer was 0·43 below the average.

At Ipswich on the 11th the morning tide was depressed 3 feet 9 inches.

At Dover from the 10th to 17th the wind was from S.W., the average force being 4·80 and the barometer below the mean. On the 10th and 11th the tides were depressed from 1 foot 3 inches to 1 foot 8 inches, the morning tide of the 12th was raised 2 feet 1 inch, the wind blowing with force of 7 from S.W., the tides from the 12th to 15th averaging about 10 inches above normal height.

At Sheerness on the 10th the morning tide was raised 13 inches, and the morning tide of the 11th depressed 23 inches, the evening tide being about normal. On the 12th the morning tide was raised 1 foot 8 inches, and the following tides respectively 2 feet 3 inches, 1 foot 8 inches, and 2 feet 5 inches.

At Portsmouth on the 13th, with N.W. wind, force 5 to 6, the morning tide was raised 13 inches and the evening tide 10 inches; on the 15th both tides were raised 13 inches.

At the west end of the Channel at Avonmouth on the 15th, with wind from S.W. to S.E. with force of 5 to 8, the evening tide of the 15th was 3 feet 4 inches above the normal height and the next tide 1 foot 11 inches above; the former tide flowed for 58 minutes after the calculated time of high water.

On the west coast on the 6th at Liverpool, with wind blowing force of 5 from S.W., the morning tide was 2 feet 4 inches and the afternoon tide 3 feet 4 inches above the normal height. The barometer stood at 29·26, or 0·59 below the average. On the evening of the 14th the tide was raised 2 feet, and the following afternoon tide 3 feet 11 inches, and next morning 2 feet 5 inches, the wind during this time being from S.W. with force varying from 3 to 7. Barometer about half an inch low, the gradient on the west coast between Scilly and Holyhead being 0·16, the depression being in the north.

At Holyhead the tides from the 10th to the 16th averaged $1\frac{1}{2}$ foot above normal, the wind being from S.W. with average force of 5·60, and mean barometer reading 29·44, or 0·40 low. The afternoon tide on the 15th was 3 feet above normal, and that of the following morning 2 feet 10 inches above, the force of wind varying from 5 to 8.

At Belfast from 10th to the 16th the tides averaged 1·40 above normal height, wind principally from S.W., with mean force of 5·50, mean barometer 29·19. The P.M. tide of the 15th was 4 feet 6 inches above the normal height, being the highest tide of which there is any record. The two following tides were raised 1 foot 5 inches and 1 foot 11 inches.

At Glasgow the wind from the 11th to the 16th was principally from the S.W., blowing with force of 8 on the 11th to 6 on the 16th, the barometer averaging 1·26 below the mean, and the lowest reading being 28·31 on 11th. On the 11th high water occurred three hours before the proper time, and rose 6 feet above the natural height; on the following day the tide was raised 2 feet 1 inch. On the 16th the tide reached high water $2\frac{1}{2}$ hours before the proper time, it then ebbed 2 feet 6 inches and flowed again 3 feet, the height reached being 5 feet above the natural height.

Gale, December 1895.

From the 1st to the 7th the wind was blowing from the S.W. with a mean force of 5, increasing to a gale on the 5th and 6th, the force on the west coast being from 8 to 9 and on the east from 5 to 6. The mean barometer on the east coast was 29·87 at the North Foreland, and 29·44 at Leith, showing a gradient of 0·43; and on the west coast 30·04 at the Scilly Islands, and 29·10 at Ardrossan, a gradient of 0·94, the mean resultant being a S.W. gradient of 0·60.

At Leith on the 3rd, 4th, and 5th the wind was from the S.W., the average force was 4·83, the maximum on the 5th being 6. The average increase in the height of the tide was 1 foot 3 inches, the maximum increase being 2 feet 6 inches on the 5th. On the 6th and 7th the wind was from the N.W., mean force 3·75, mean increase of tide 2 feet, greatest force of wind 5, and greatest increase of tide 2 feet 5 inches.

It will thus be seen that at this station the tides were increased both by S.W. and N.W. winds.

At Grimsby, near the mouth of the Humber, the wind from the 1st to the 5th was from the S.W., blowing with a mean force of 5, increasing to a gale with a force of 8 on the 5th. From the 6th to the 8th the direction was from the N.W., with force of 6 to 7; and from the 8th to the 10th S.W., with force of from 3 to 6. The mean force for the whole period was 5. On the 1st the tides were raised at Grimsby 1 foot 3 inches and 8 inches; on the 2nd, 1 foot 9 inches and 3 inches; on the 3rd, 2 feet and 2 feet 2 inches; on the 4th, 11 inches in the morning; on the 5th the morning tide was depressed 5 inches and the evening tide raised 2 feet 9 inches; on the 6th the tides were raised 3 feet 3 inches and 1 foot 8 inches; on the 7th, 3 feet 1 inch and 3 feet; on the 8th, 1 foot and 1 foot 1 inch; on the 9th the morning tide was depressed 8 inches and the evening tide raised 2 feet 7 inches; and on the 10th the morning tide raised 1 foot 6 inches, the mean increase for 16 tides being 1·80 foot.

At Hull, the force and direction of the wind being the same, the mean increase for 15 tides was 1·57 foot. On the 1st the tides were raised

10 inches and 8 inches; on the 2nd the morning tide 1 foot 4 inches; on the 3rd the increase was 1 foot 9 inches and 2 feet; on the 4th the morning tide was raised 7 inches and the evening tide depressed 5 inches; on the 5th the morning tide was depressed 1 foot 6 inches and the evening tide raised 2 feet 7 inches; on the 6th the tides were raised 3 feet and 1 foot 4 inches; on the 7th both tides 3 feet; on the 8th, 10 and 11 inches; on the 9th the morning tide was depressed 1 foot, and that of the 10th raised 1 foot 9 inches.

At Boston the wind on the 4th from W.S.W., force 5 to 10; the evening tide of the 4th was depressed 1 foot 8 inches and the succeeding tide 1 foot 10 inches. From 5th to 7th, with wind from W.N.W. to N.W. mean force 7, the mean increase of the tide was 1·82 foot, the maximum increase being 2 feet 8 inches.

At Yarmouth from the 6th to the 8th the wind was from W.N.W. with mean force of 5·55. The tides were increased about 3 feet.

At Ipswich on the 6th and 7th, with wind W.N.W. force 7 to 8, the tides were increased above the expected height from 3 feet 2 inches to 3 feet 11 inches.

At Dover on the 6th and 7th, wind W.N.W., force 4 to 7. Mean increase of tide 2 feet 11 inches, maximum increase 3 feet 6 inches.

At Sheerness on the 6th the morning tide was raised 3 feet 5 inches, and the evening tide 2 feet 9 inches; on the 7th the morning tide was not recorded, the evening tide was raised 4 feet 7 inches and the next morning 1 foot 11 inches and evening 1 foot 8 inches.

At Flushing, where the mean range of tides is 11 feet 9 inches, the tides from the 4th to the 9th were increased above the mean range, an average of 2·78 feet, the greatest increase being on the 7th, 5 feet 1 inch. At Ymuiden, the entrance to the North Sea Canal, where the mean range of tide is 5·4 feet, the maximum increase was 5·31 feet, and at the island of Schokland in the Zuyder Zee, where the mean range is only 0·72 foot, the increased height was 7·70 feet.

At Portsmouth on the 6th and 7th the tides rose to about their normal height, wind on the 7th blowing from N.W. with force 4 to 6.

At Avonmouth on the 6th and 7th, wind W. to N.W., force 7 to 10, the mean increase in the tides was only 9 inches, the maximum increase being 13 inches.

At Liverpool, from the 2nd to the 7th, the tides were all high, the mean increase being 2 feet 8 inches and the maximum 3 feet 5 inches. The wind was from W.S.W. to W., mean force 6·80 and maximum 9.

At Holyhead, 2nd to the 7th, wind from W. to S.W., mean force 6·40, maximum 7, mean increase of tides 1·14 foot, maximum increase 2 feet 1 inch.

At Belfast, 1st to 6th, wind W.S.W., mean force 6·80, maximum 8, mean increase of tides 1 foot 4½ inches, maximum increase 3 feet 1 inch.

At Glasgow, on the 4th, the wind was from the W.S.W., with force of 6, increasing to a gale on the 5th, with force of 8 and continuing to blow a gale from S.W. on 6th. The average increase in the height of the tides for the three days was 3 feet 9 inches, the maximum increase being on the 5th, when high water was raised 6 feet 2 inches, the normal rise above low water of spring tides being 10 feet 10 inches, and the actual rise 17 feet. The barometer fell 0·72 inch below the average reading.

Screw Gauge.—Report of the Committee, consisting of Mr. W. H. PREECE (*Chairman*), Mr. CONRAD W. COOKE (*Secretary*), Lord KELVIN, Sir F. J. BRAMWELL, Sir H. TRUEMAN WOOD, Major-Gen. WEBBER, Mr. R. E. CROMPTON, Mr. A. STROH, Mr. A. LE NEVE FOSTER, Mr. C. J. HEWITT, Mr. G. K. B. ELPHINSTONE, Mr. T. BUCKNEY, Col. WATKIN, Mr. E. RIGG, *and* Mr. W. A. PRICE, *appointed to consider means by which Practical Effect can be given to the Introduction of the Screw Gauge proposed by the Association in* 1884. (*Drawn up by the Chairman.*)

CONTENTS

I. THE PAST.

A UNIFORM system of screw threads was first proposed by the late Sir Joseph Whitworth in 1842, and his thread, a compromise of the numerous threads then in use, has become of almost universal use for all large screws—that is, screws of over ¼ in. diameter—in the United Kingdom.

Mr. William Sellers in 1864 introduced another thread in the United States of America, which has come into very general use in that country, and this thread has recently been accepted by the French.

In 1881 the British Association formed a committee to determine a gauge for the manufacture of the various small screws used in electrical apparatus, clock work, and for other analogous purposes; and after three years of unremitting labour this committee, in 1884, recommended a screw gauge which has come into very general use in this country. It was based on the metrical system, and with one slight modification on the system adopted in 1880 by the Swiss watchmakers.

The series of screws recommended is given in the following table:—

British Association Screw Gauge.

Number	Dimensions in Millimetres		Dimensions in Thousandths of an Inch		Threads per inch
	Diameter	Pitch	Diameter	Pitch	
I	II	III	IV	V	VI
0	6·0	1·00	236	39·4	25·4
1	5·3	0·90	208	35·4	28·2
2	4·7	0·81	184?	31·9	31·4
3	4·1	0·73	162?	28·7	34·8
4	3·64	0·66	142	26·0	38·5
5	3·2	0·59	126	23·2	43·0
6	2·8	0·53	110	20·9	47·9
7	2·5	0·48	98	18·9	52·9
8	2·2	0·43	87	16·9	59·1
9	1·9	0·39	75	15·4	65·1

Number	Dimensions in Millimetres		Dimensions in Thousandths of an inch		Threads per inch
	Diameter	Pitch	Diameter	Pitch	
I	II	III	IV	V	VI
10	1·7	0·35	67	13·8	72·6
11	1·5	0·31	59	12·2	81·9
12	1·3	0·28	51	11·0	90·7
13	1·2	0·25	47	9·8	101·0
14	1·0	0·23	39	9·1	110·0
15	0·90	0·21	35	8·3	121·0
16	0·79	0·19	31	7·5	134·0
17	0·70	0·17	28 ?	6·7	149·0
18	0·62	0·15	24	5·9	169·0
19	0·54	0·14	21	5·5	181·0
20	? 0·47	0·12	19	4·7	212·0
21	0·42	0·11	17	4·3	231·0
22	0·37	0·098	15	3·9	259·0
23	0·33	0·089	13	3·5	285·0
24	0·29	0·080	11	? 3·152	317·0
25	0·25	0·072	10	2·8	353·0

The form of thread adopted was triangular, the sides forming an angle of $47\frac{1}{2}°$, with the top and bottom rounded off to $\frac{2}{11}$ths of the pitch.

The diameter (D) is related to the pitch (P) by the formula $D=6\,P^{\frac{6}{5}}$, all measurements being in millimetres, and P having successively the values :—

1 (or $0{\cdot}9^0$) millimetre ; $0{\cdot}9^1$ millimetre ; $0{\cdot}9^2$ millimetre ; $0{\cdot}9^3$ millimetre ; . . . $0{\cdot}9^n$ millimetre. The index (n) thus becomes a convenient number designating the screw.

The reasons supporting these recommendations were fully given in the Report submitted by the Committee at the Montreal meeting of 1884. Experience has justified the adoption of this gauge, which is almost universally used by the electrical trade, and is very considerably employed by the clock and instrument makers in the United Kingdom.

It is not proposed to modify it, but there has been great difficulty in obtaining accurate gauges. No official system has yet been adopted by which manufacturers can compare their gauges with the standards, nor has a home been selected to deposit authorised standards for easy reference. British Association screws bought to-day from any screw manufacturer are not necessarily of the same dimensions as those supplied by the same maker a month ago. Screws supplied by different makers vary considerably from each other. Measuring gauges now existing, both male and female, differ largely from one another, and do not give correctly the true form of thread specified in the original Report. The essential element of the value of screws made to a standard gauge—their interchangeability—has thus never been fully realised.

The British Association, having had their attention called to these anomalies at their last meeting (Ipswich, 1895), appointed a committee to consider the subject, which has now the pleasure to submit its first Report.

II. The Present.

The Committee were formed 'to consider means by which better practical effect can be given to the introduction of the Screw Gauge proposed by the Association in 1884.' They have held many meetings. They have added Colonel Watkin, C.B., R.A., Mr. E. Rigg, and Mr. W. A. Price to their number. They have received great assistance from the Pratt and Whitney Company of Hartford (Connecticut, United States of America), who supplied each member of the Committee with a copy of their book on 'Standards of Length and their Practical Application.' They were unfortunately deprived of the services of Mr. Hewitt, who was seized with a very severe illness after the first meeting, but they received from him his paper 'On the Manufacture of Standard Screws for Machine-made Watches,' read before the Institution of Mechanical Engineers in October 1894; a paper which has been of great service. Mr. Griffith, representing the Council, attended regularly, and took advantage of his presence in the United States of America to visit the Pratt and Whitney works.

Evidence was taken by the Committee from large users of the screws. Mr. Willmot, of the Post Office Factory, stated that the Post Office had used some tens of millions of screws made to the British Association gauge, and he had never received a single complaint.

Various apparatus for measuring screws and different methods of testing their accuracy were carefully considered and discussed.

The Committee came to the conclusion that it was necessary to consider the subject from the three points of view of the Standards Office, the Works Manager, and the Workman.

1. *The Standards Office.*

This must include, not only the custody of recognised and authenticated standards, but also a scientific mode of measuring the dimensions of commercial gauges and screws themselves, and of comparing their accuracy with the authorised standards. The peculiarity of the British Association gauge is this, that material standards are not imperatively necessary. The table of dimensions given at page 527, together with the formula, enables any draughtsman to reproduce the form and pitch to any desired scale on paper. Colonel Watkin has shown to the Committee how to throw side by side, for purposes of very accurate comparison, a photographic image of—

(*a*) The screw to be examined.

(*b*) The standard with which it is to be compared.

(*c*) A scale which may be divided to $\frac{1}{10000}$th of an inch, the images of these three objects being so close to one another that a comparison to a very high degree of accuracy can be made. The Appendix to this Report contains a description of Colonel Watkin's method.

Mr. Price submitted to the Committee a microscopical method of measuring screws. The screw to be measured is attached to the stage of the microscope, the traversing slide of which is provided with a vernier and scale, while a vertical cross-hair in the eye-piece forms the index of the instrument. When the microscope has been adjusted for clear focus the screw is traversed across the field until the cross-hair intersects the thread of the screw at the desired point. The traversing screw of the slide is then turned until the corresponding point of the next thread is intersected by the cross-hair, and the reading of the vernier on the scale gives the measurement of the pitch with great accuracy. Mr. Buckney showed also how the angle of the thread could be accurately verified by this method by having suitable hairs.

2. *The Works Manager.*

The Committee, after considering various methods, came to the conclusion that male gauges for ordinary workshop use were best tested, as regards pitch and form of thread, by a template or 'comb' for each number, the accuracy of which has been verified by the photographic method. The screw to be tested is placed against the teeth of the comb, and the correctness of its fit verified by the eye against a light background.

The external dimensions of the screw can be obtained by any good micrometer gauge, and the internal diameter or core by a gauge such as that which is described in the Appendix by Mr. Stroh.

The Committee have failed to discover any very reliable method of testing, to any degree of accuracy, a female standard gauge. No clearance was allowed in the original definition of the system between the male and female standards. Hence a mathematically accurate male gauge cannot be screwed into a mathematically accurate female gauge. But by allowing a certain margin—a maximum and minimum diameter—an internal compatibility of dimensions is allowed in the workshop gauges, which is of a sound, practical character. The female screw must always be a little larger than the standard male gauge, but this must never exceed what is known as a 'good fit.'

A working margin is given in Appendix III. by a table prepared by Mr. Le Neve Foster.

Mr. Price, on behalf of the Committee, has made a series of measurements of certain sizes of B.A. screws which show the limits within which they are obtained in practice. His measurements indicate that the variation from the full diameter, which must be allowed for necessary inequalities in manufacture, is not a function of the diameter, but is rather in the nature of a constant quantity. This quantity appears to be approximately 1 mil. below the full diameter for all brass screws of sizes Nos. 0 to 11, and 1·3 mil. for all iron and steel screws of the same sizes.

3. *The Workman.*

The measuring gauge, available to the workman as well as to the foreman, is one that need not possess the mathematical accuracy of the standard gauges, but nevertheless it must not be allowed to deteriorate or to maintain false belief in its accuracy. Those that are subject to pressure and friction must necessarily wear, become distorted, and, in time, inaccurate. Hence the Committee were anxious to obtain a mode of comparison which would be free from this source of error. The most important measurement, whose accuracy should be easily verified by the workman is that of the pitch, and this is easily effected with the 'half-nut gauge' described in Appendix II.

The Committee are pleased to find that the result of their inquiry and discussion enables them to recommend for general use means of comparison which do not involve the wear and deterioration of the gauges. Deformation is confined to the taps and screw-plates, and as frequent verification of the manufactured screw is desirable continued accuracy is insured. With the introduction of simple methods of comparison and measurement errors in the screws issued and want of interchangeability are rendered improbable in a well-regulated shop, and unnecessary in any place.

There remains now to determine a place where material standard gauges are available for immediate comparison, and where the photographic and microscopic methods can be readily applied to verify gauges and to obtain a record of those submitted for examination. This means work to be done, expenses to be incurred, and fees to be paid, as is now done at the Kew Observatory for chronometers, thermometers, &c.

III. The Future.

The opinions formed by the Committee, after full and exhaustive discussions, for furthering the objects to be attained may be summarised as follows :—

(*a*) The Committee recommend the construction and housing of the comb form of gauges or templates of the B.A. screw thread, by comparison with which master gauges or templates may be exactly and conveniently verified.

(*b*) That, as no exact system of testing female threads has yet been devised, the Committee restrict themselves to recommending means for keeping male threads to gauge, and this they consider will be sufficient for the purpose of securing practical uniformity in female screws.

(*c*) Male threads can best be measured by the comb, combined with suitably arranged tests to give the correct diameters.

(*d*) That for purposes of verification or standardisation the gauges to be deposited for reference should consist of a complete set of these comb-pieces, and a complete corresponding set of male screws, so that new combs can be compared with those deposited, or male screws can be compared with the standard combs with great accuracy by the photographic or the microscopic method, and that these two methods may be conveniently used to check and corroborate each other.

(*e*) That in order to obtain interchangeability of these male screws for practical workshop use it is sufficient that they should satisfy the following tests :—

(1) There should be no appreciable difference in the fit of the screw with a standard comb having not less than twelve teeth.

(2) The diameter of the core must not exceed that laid down by the B.A. specification.

(3) The diameter of the screw measured over the thread must not exceed that laid down by the B.A. specification.

(4) The diameter of the screw measured over the thread must not fall short of that laid down by the B.A. specification by more than a certain amount, which amount depends on the class of work and purpose to which the screw is to be applied.

The amount referred to in (4) must be settled by the persons in control of the work for which the screws are to be used.

(*f*) They recommend for general use in the workshop the half-nut gauge, as described in Appendix II., combined with inside and outside diameter gauges.

The Committee, in printing the tables, Appendix III., for which they have to thank Mr. Le Neve Foster and Mr. Price, do not take the responsibility of recommending any limits, but publish the information as an indication of the limits of accuracy within which these screws may be expected to be produced in practice.

If the recommendations of the Committee be approved of, they further recommend that the Committee should be reappointed for the purpose of obtaining and verifying standard combs and male screws, and determining the future home of the gauges.

APPENDIX I.

Enlarged Shadow Photographs of Screws. By Col. WATKIN, *C.B., R.A., &c.*

The objects aimed at in producing enlarged photographs of screws are—

(*a*) To provide a means of verifying the accuracy of the shape of a thread.

(*b*) To provide a means of accurately gauging the dimensions of screw threads.

(*c*) To provide a record or certificate of a screw, in a similar manner to the certificate of accuracy given by Kew Observatory.

As in this process a standard scale is photographed at the same time as the screw, a direct reading to any desired accuracy can be obtained. There seems to be hardly any limit to the amount of enlargement, as the difficulties inherent to the enlargement of an ordinary negative do not apply to this process.

The question arises, Does the shadow photograph give accuracy as regards—

1. Dimensions ;
2. Shape of thread ?

To test (1) a No. 2 B.A. thread was enlarged 37·18 times. The linear dimensions could in this photo be measured to at least $\frac{1}{5000}$th of an inch.

The diameter, pitch, and angle of thread of this particular screw were gauged by a member of the Committee, and found to be :

By an Elliott gauge . . .	0·1818	} diameter
„ a Brown and Sharp gauge .	0·1820	} diameter
	0·03184	pitch
	54° 30′	angle of thread

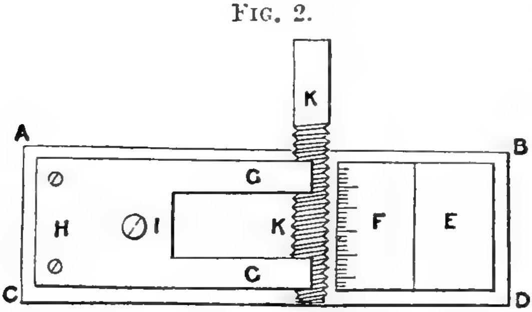
The photo gave the following :—

0·1818 diameter
0·03181 pitch
54° 30′ angle of thread

Fig. 1 shows a reduced copy of an actual photograph and scale.

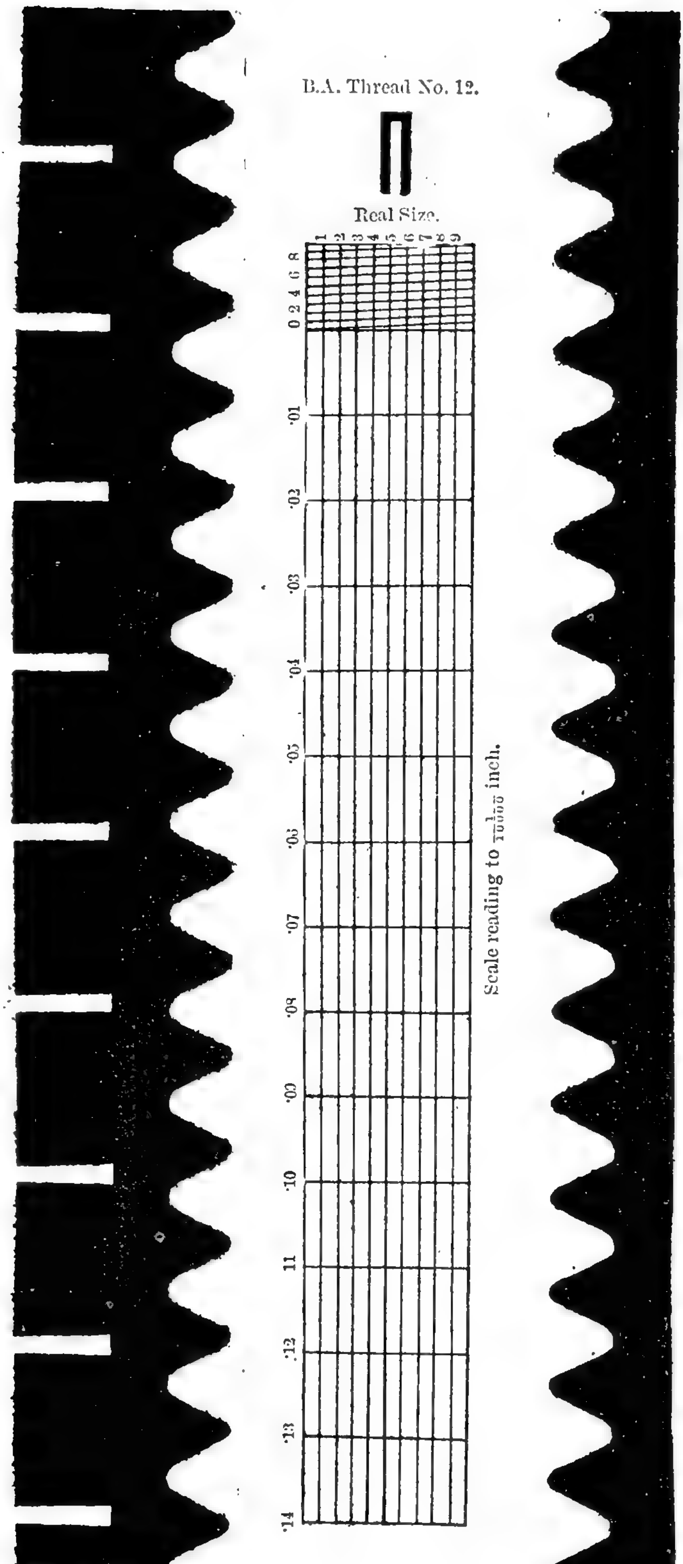
As regards (2) there has been considerable discussion as to whether the shadow photograph gave the true shape of the thread. There are two methods of obtaining a photograph of a screw thread : one in which the axis of the screw is at right angles to the beam of light ; the other in which the axis of the screw is inclined at an angle which differs from the right angle by the angle of the pitch of the screw.

FIG. 2.



As regards the first method, a mathematical consideration worked out by Mr. Price seems to show that a slight correction of about $\frac{1}{3}$ degree in the total angle of the screw thread would have to be made. I think, as regards the second method, no correction is required. In any

FIG. 1.—Standard Glass Scale, lines at intervals of ·02 inch.
(*Photograph magnified 34·415.*)



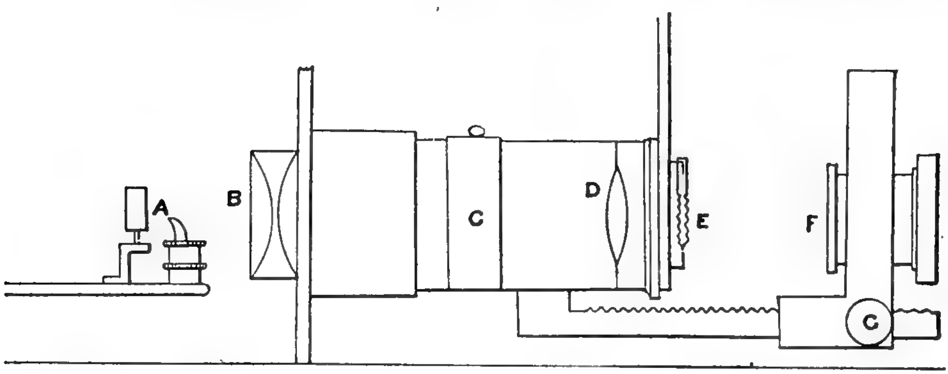
case the correction is so small that for practical purposes it might be neglected, as on a No. 2 B.A. thread it only represents about $\frac{1}{7000}$th of an inch, and proportionately less on the smaller sizes.

However, to determine practically whether this was the case, I suggested filing away a part of the screw to be photographed to make it a comb. There could be no doubt that the photo of such a comb would give the true shape of the thread. Mr. Stroh kindly supplied such a screw. From the photos it would appear that there is no practical difference in the shape, and that therefore the photograph of a complete screw gives a true record of the shape as well as the dimensions.

The following gives the detail of the method employed in photographing the screws :—

On a plate A, B, C, D, fig. 2, is a block, E, to which is secured a glass scale, F, which has been carefully etched with lines $\frac{1}{50}$ inch apart. A piece of spring brass, HG, serves to hold the screw KK to be photographed, with its axis parallel to the plate A, B, C, D. The distance of the screw from the plate can be adjusted by means of the screw I, so that when the scale

FIG. 3.



is sharply focussed on the screen the shadow of the screw may also be brought into focus.

The frame A, B, C, D, fig. 2, is adjusted in the same position as an ordinary microscopic slide in a magic lantern arranged for microscopic work ; only I found it desirable to employ a photographic lens of modern design instead of the usual objective.

The arrangement is shown in the accompanying diagram, fig. 3, where

A represents the limelight ; B the ordinary condenser ; C Alum trough to stop the heat rays ; D Small condensing lens ; E Screw, in its frame as described in fig. 2 ; F Photographic lens ; G Milled head screw for focussing the lens F.

APPENDIX II.

Gauges for Verifying the Accuracy of Screws (for Workshop Use only). By A. STROH.

In the gauge represented in fig. 4 the hole *a* is for the external diameter. It should be of exactly the diameter given in the table of sizes for B.A. screws. A screw should pass into this hole freely, but without much shake. The hole *b* is the minimum gauge, and the screw should *not* pass into this hole. The difference of diameter between the holes *a* and *b* has not yet been determined by the Committee; in the present case it is ·0015 in. *c* is a threaded hole or female gauge in which a screw should just turn freely. The hole *d* is for the diameter of the core, but as it is impossible, without turning down some of the threads of a screw, to pass the core of it into this hole, the gauge *e* is provided for gauging the core, or, in other words, the depth of the thread. It consists of a fork the inner edges of which are shaped so as to enter between the threads of a screw. The correctness of the pitch of a screw

FIG. 4.

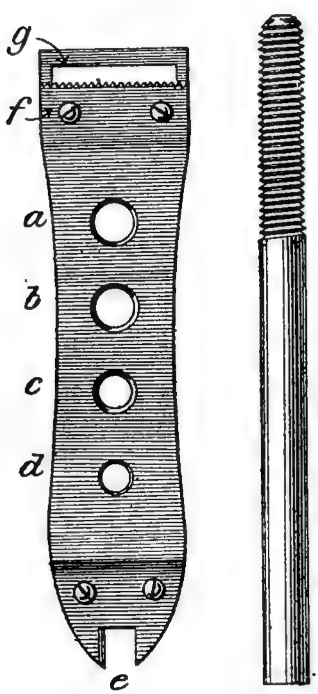


FIG. 5.

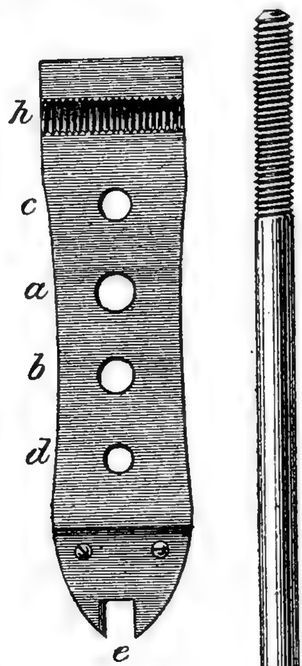
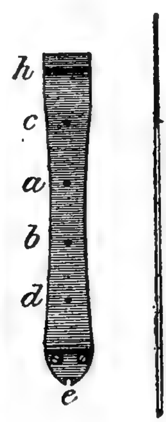


FIG. 6.

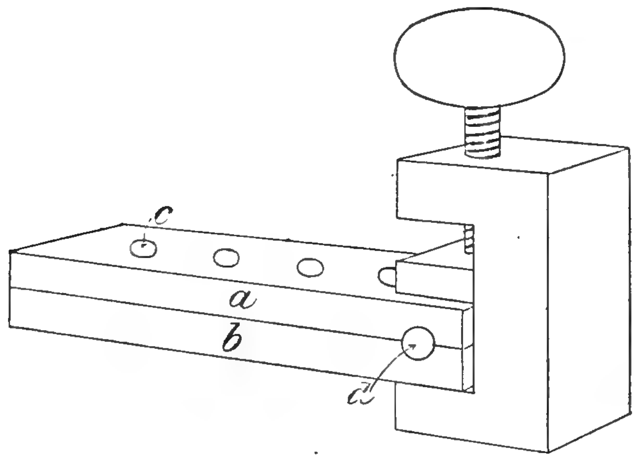


is ascertained by placing it in the comb *f* and against the back-rest *g*, and by holding the gauge against the light or a white paper.

It has been found by practice that there is considerable difficulty in making these combs with any degree of accuracy, and also that it would be almost impossible to carry out the above form of gauge for the smaller sizes. It is therefore suggested that the gauge represented in fig. 5 has certain advantages over the comb-gauge. With this the half-nut *h* is employed for verifying the pitch of screws instead of the comb. The half-nut can be carried out with greater certainty and ease, and is therefore less costly, and there is no difficulty in making it for the smaller sizes, as shown in fig. 6. Gauges on the principle of figs. 5 and 6 have also the advantage of being more compact and stronger for workshop use.

The process of making the half-nut gauges is the following:—Two have to be made at one time. When the two steel bars intended for the gauges are filed to shape they are placed together, as shown in sketch (*a* and *b*) ; a temporary rivet or bolt is put through the hole *c*, and the ends intended to receive the half-nut device are clamped together as shown. A hole of the diameter of the core is then drilled across the two

FIG. 7.



bars at *d*, so that each bar receives one half of it. The clamp is then unscrewed, the bars are slightly separated, the tap is inserted between them, and the clamp screw tightened again gently. Of course now the two steel bars cannot meet, being prevented by the insertion of the tap. But the smooth end of the tap is now fixed in a chuck on a lathe, and is rotated forwards and backwards, while the clamp screw is tightened from time to time. This is carried on till the threads forming the half-nuts are complete. It is only necessary towards the end of the operation to separate the bars once or twice for the purpose of removing the bur which is raised by the operation.

APPENDIX III.

Working Dimensions in Millimetres and Thousandths of an Inch.
By A. LE NEVE FOSTER.

No.	External Diameter		Diameter of Core		Difference of Diameter	Pitch		Working Margin	
	mm.	inches	mm.	inches	mm.	mm.	Threads per inch	mm.	mils.
0	6·0	·236	4·8	·189	1·2	1·0	25·4	·05	·002
1	5·3	·209	4·22	·166	1·08	·9	28·2	·05	·002
2	4·7	·185	3·72	·147	·972	·81	31·4	·04	·0016
3	4·1	·161	3·22	·127	·876	·73	34·8	·04	·0016
4	3·6	·142	2·8	·110	·792	·66	38·5	·04	·0016
5	3·2	·126	2·5	·0984	·708	·59	43·0	·03	·0012
6	2·8	·110	2·16	·085	·636	·53	47·9	·03	·0012
7	2·5	·098	1·92	·076	·575	·48	52·9	·03	·0012
8	2·2	·087	1·68	·066	·516	·43	59·1	·02	·0008
9	1·9	·075	1·43	·0565	·468	·39	65·1	·02	·0008
10	1·7	·067	1·28	·0505	·420	·35	72·6	·02	·0008

Mr. Foster informed the Committee that in the experience of his firm these limits are found to be convenient for all screws connecting ordinary pieces of mechanism.

Tests of B.A. Screws by Hervé Diameters. *By* W. A. PRICE.

Of the measurements given in the following table all, excepting the No. 8 steel and No. 11 brass screws, were made with a gauge of which the zero was out of adjustment, the measures to be reduced by ·0002 in the first 9 columns.

These measurements were made to ascertain within what limits a screw maker can work, not as chausson screws with their theoretical diameters.

It seems that 1·2 inch below the full diameter is all that is required for brass screws Nos. 0 to 11, and that the same is required for all sizes.

It is clear that steel screws are more troublesome than brass, but the lot of No. 4 steel examined were probably not made with sufficient care.

The margins are :

1·2	1·0 (1·6)	·9	1·1 (3·2)	·9	1·8 (3·0)	·8	1·2 (2·1)	1·0	1·2	·9 (1·5)

The figures in brackets in each case include the screws, even those that are clearly too small to pass.

No. 0 Brass	No. 0 Brass	No. 2 Brass	No. 2 Steel	No. 4 Brass	No. 4 Steel	No. 6 Brass	No. 6 Steel	No. 8 Brass	No. 8 Steel	No. 11 Brass
·2373	·2385	·1852	·1852	·1424	·1438	·1110	·1111	·0865	·0860	·0595
·2372	·2382	·1850	·1851	·1424	·1437	·1109	·1110	·0864	·0858	·0594
·2371	·2382	·1850	·1851	·1423	·1434	·1108	·1110	·0863	·0857	·0594
·2370	·2380	·1849	·1851	·1422	·1434	·1106	·1110	·0861	·0857	·0594
·2370	·2380	·1849	·1850	·1421	·1433	·1106	·1110	·0860	·0857	·0593
·2370	·2380	·1849	·1850	·1421	·1432	·1106	·1110	·0860	·0857	·0593
·2370	·2380	·1849	·1850	·1421	·1431	·1105	·1109	·0860	·0855	·0593
·2370	·2379	·1849	·1849	·1421	·1431	·1105	·1109	·0860	·0855	·0593
·2369	·2379	·1848	·1848	·1420	·1430	·1104	·1109	·0859	·0855	·0593
·2368	·2379	·1848	·1848	·1420	·1430	·1103	·1109	·0859	·0854	·0593
·2368	·2378	·1848	·1848	·1420	·1430	·1103	·1109	·0859	·0854	·0592
·2367	·2378	·1848	·1847	·1420	·1429	·1103	·1109	·0859	·0854	·0592
·2367	·2378	·1848	·1845	·1419	·1428	·1103	·1109	·0859	·0853	·0592
·2365	·2378	·1848	·1844	·1419	·1428	·1103	·1109	·0859	·0852	·0592
·2364	·2377	·1848	·1843	·1419	·1426	·1103	·1108	·0858	·0852	·0591
·2364	·2377	·1847	·1842	·1418	·1425	·1103	·1108	·0857	·0852	·0591
·2363	·2376	·1847	·1842	·1418	·1422	·1103	·1105	·0856	·0852	·0590
·2362	·2375	·1842	·1842	·1418	·1422	·1103	·1102	·0856	·0851	·0590
·2362	·2369	.1842	·1841	·1417	·1419	·1102	·1102	·0856	·0850	·0589
·2362	—	·1845	·1841	·1417	·1421	·1102	·1101	·0855	·0850	·0589
·2361	—	·1845	·1841	.1417	·1420	—	·1101	—	·0850	·0587
		·1845	·1832	·1416	·1412	Mean	·1100	Mean	·0849	·0586
Mean	Mean	·1843	·1830	·1416	·1412	—	—	—	—	--
2368	·2379	·1843	·1825	·1415	·1410	·1104	·1099	·0859	·0849	·0581
			·1820		·1410	—	·1094	—	·0848	·0580
			Omitting		·1409	—	·1090	—	·0848	—
		Mean ·18475	last four Mean ·1846	Mean ·14205	·1408 ·1408 ·1408 Mean Omitting last 8 ·1429		Omit- ting last 2 Mean ·1108		Mean ·0853	Omit- ting last 2 Mean ·0592

The No. 11 brass screws were a lot that Hervé had been asked to make with especial care.

Calibration of Instruments used in Engineering Laboratories.—Report of the Committee, consisting of Professor A. B. W. KENNEDY, *F.R.S.* (*Chairman*), Professor J. A. EWING, *F.R.S.*, Professor D. S. CAPPER, Professor T. H. BEARE, *and* Professor W. C. UNWIN, *F.R.S.* (*Secretary*). (*Drawn up by the Secretary.*)

IT was stated in the previous report, presented at Ipswich in 1895, that the Committee had decided initially to investigate the accuracy of instruments for measuring the tension coefficient of elasticity, or Young's modulus.

It was decided that sets of standard test bars should be prepared to be subjected to tension and the extensions measured by the instruments in use in different engineering laboratories. The forms of the test bars are shown in figs. 1 and 2. Two of the standard test bars of each set were cylindrical bars with screwed ends suitable for use with shackles having spherical seatings. The third bar of each set was a flat bar suitable for wedge grips. All the cylindrical bars were cut from a single bar of specially strong steel rolled for the Committee by the Blenavon Company. The flat bars were cut from a single plate of good mild steel. Four sets were prepared, of which two were used for most of the measurements. The bars were marked as follows :

Flat bars, A, B, C, D, of mild steel, approximately 2 inches by $\frac{1}{2}$ inch in section.

Cylindrical bars, E, F, G, H, of special steel, approximately $1\frac{1}{4}$ inch in diameter.

Cylindrical bars, K, L, M, N, of special steel, approximately $\frac{3}{4}$ inch in diameter.

The bars were carefully prepared by Mr. R. W. Munro. The cylindrical bars had marked gauge points suitable for extensometers 8 inches, 10 inches, 16 inches, or 20 inches in length. The flat bars had gauge points for extensometers 8 inches or 10 inches in length.

In order to obtain some preliminary information as to the mechanical properties of the standard bars, one round bar and one flat bar were tested in the testing machine at the Central Technical College. The following table gives the results obtained :

Preliminary Tests of Materials used for Standard Bars.

TENSION EXPERIMENTS.

Mark on Bar	Dimensions. Inches	Area. Sq. in.	Yield Point		Maximum Load		Breaking Load		Elongation on 8 in. per cent.	Contraction of Area per cent.	E. Tons per sq. in.
			Load. Tons	Tons per sq. in.	Tons	Tons per sq. in.	Tons	Tons per sq. in.			
D	2·000 × 0·507	1·014	16·19	15·97	23·725	23·40	19·75	19·48	32	62	13,113
N	0·750 diam.	0·4418	9·00	20·37	15·725	35·59	13·76	31·14	24·5	42	—

Bar D was exactly similar to the flat bars A, B, C.
Bar N was of the same steel as standard bars marked E, F, K, L, &c.

FIG. 1.

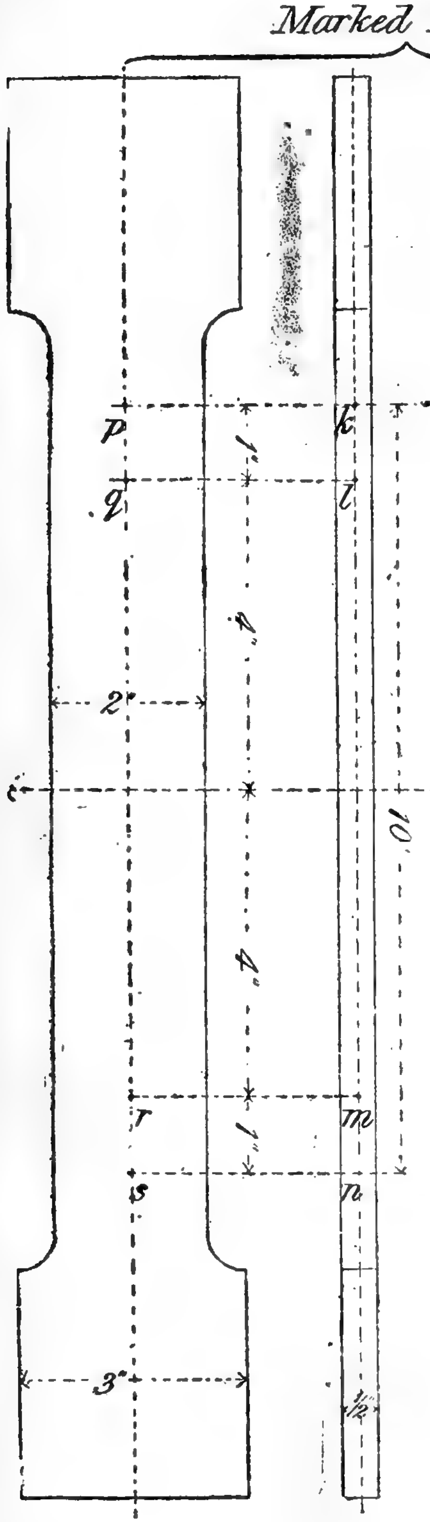
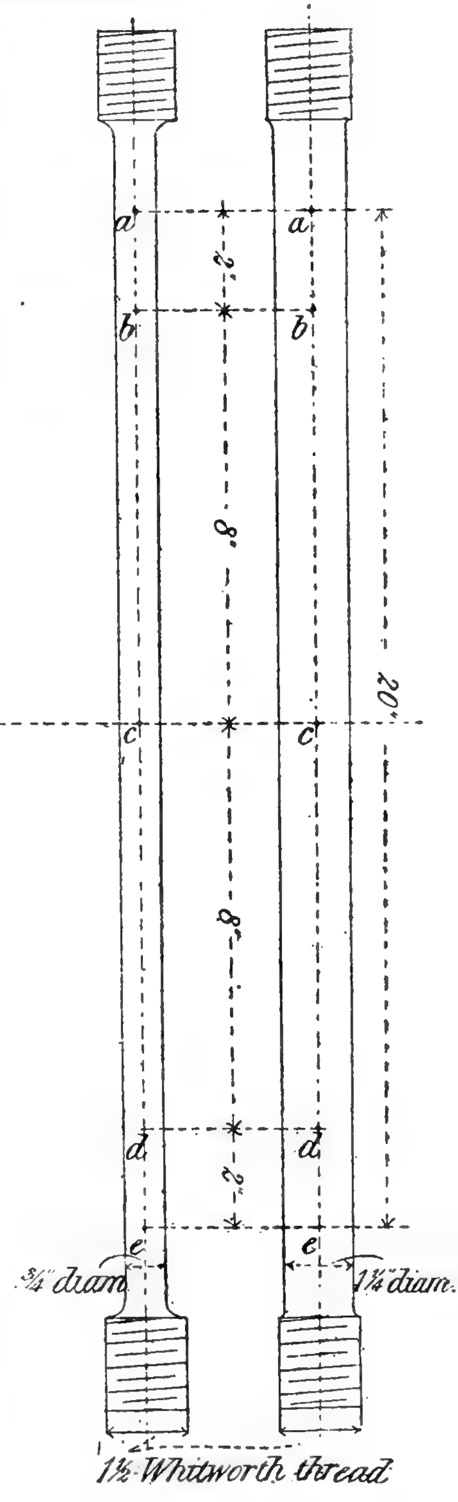

Marked End
p
q
r
s
k
l
m
n
1"
4"
4"
1"
2"
3"
10"
½"

FIG. 2.


a
b
c
d
e
2"
8"
8"
2"
20"
¾" diam
1¼" diam.
1½ Whitworth thread

Modulus of Elasticity (Tension). [See next page.]

[See next page.]

Date ______________ Round $1\frac{1}{4}''$ Bar, No. ______________

Measurements by ______________

With ______________ extensometer.

Gauge points used for measurement ______________ L = ______________ inches

Constant for extensometer reading (if required) ______________

Dimensions of bar ______________. Area = ω = ______________

Formula for $E = \frac{L.P}{\omega\lambda} = C\frac{P}{\lambda}$. C = ______________

Load in tons P	Temperature of Air near Specimen	Micrometer Readings	Differences	Differences in Inches λ	Temperature of Air near Specimen	Micrometer Readings	Differences	Differences in Inches λ	E for successive Intervals of $2\frac{1}{2}$ Tons. Tons per sq. in.	E for $2\frac{1}{2}$ to 20 Tons' Range. Tons per sq. in.	E for successive Intervals of $2\frac{1}{2}$ Tons. Tons per sq. in.	E for $2\frac{1}{2}$ to 20 Tons' Range. Tons per sq. in.
0												
$2\frac{1}{2}$												
5												
$7\frac{1}{2}$												
10												
$12\frac{1}{2}$												
15												
$17\frac{1}{2}$												
20												
$2\frac{1}{2}$			Set =				Set =					

Signed ______________

Test sheet forms were drawn up by the Committee, to be issued to different observers with the sets of test bars, on which the observations were to be recorded in a uniform manner. A sample of the form of observation sheet prepared by the Committee is printed on the opposite page.

In January 1895 two sets of test bars were sent out, to be circulated amongst those observers who had consented to make measurements for the Committee. A very large number of measurements have been made with great care, and the record forms have been returned to the Committee.

It is proposed in the present report to give an analysis of these results. The following short statement gives particulars, so far as they are stated on the forms received, of the extensometers used.

Extensometers used in Measurements made for the British Association Calibration Committee.

Observer	Instrument used
A. B. W. Kennedy .	Kennedy's Extensometer. Lever or mechanical multiplying arrangement.
J. A. Ewing . .	Ewing's Extensometer. Measurements taken by microscope with micrometer in eyepiece.
H. S. Hele Shaw .	Ewing's Extensometer.
J. Goodman . .	Goodman's Extensometer. A mechanical multiplying instrument of Kennedy type.
W. C. Unwin . .	Unwin's Mirror Extensometer. The extension of the bar deflects a mirror. A scale is placed at a distance, and by a fixed telescope the reading of the scale reflected in the mirror is taken. Also a lever extensometer with triple compound levers.
T. Hudson Beare .	Mechanical multiplying instrument of Kennedy type.
D. S. Capper . .	Bronze mechanical extensometer, Kennedy pattern.

I. *Variations in Measurement of the Area of the Test Bars by different Observers.*

The following table gives the measurements of the test bars by different observers. They are satisfactory as showing that the error of measurement of area of a test bar, by different observers, seldom exceeds about one-fifth of 1 per cent. That is the error reckoned from the mean value of the area given by several observers. The difference of measurement for any two observers may amount to 0·5 of one per cent.

TABLE I.—*Comparison of Measurements of Test Bars.*

Form of Bar	Distinguishing Letter	Observer	Observed area in sq. in.	Mean value of observed area in sq. in.	Deviation of observed area from mean value in sq. in.	Deviation in per cent. of mean value
Flat	A	W. C. U. .	1·0175		−·0002	−·02
		A. B. W. K.	1·0170		−·0007	−·07
		T. H. B. .	1·0190	1·0177	+·0013	+·13
		J. G. . .	1·0170		−·0007	−·07
		D. S. C. .	1·0180		+·0003	+·03

TABLE I.—*continued.*

Form of Bar	Distin-guishing Letter	Observer	Observed area in sq. in.	Mean value of observed area in sq. in.	Deviation of observed area from mean value in sq. in.	Deviation in per cent. of mean value
Flat	B	W. C. U. .	1·0157	1·0158	−·0001	−·01
		H. S. H. S.	1·0180		+·0022	+·22
		J. A. E. .	1·0120		−·0038	−·37
		D. S. C. .	1·0175		+·0017	+·17
Round	F	W. C. U. .	1·2230	1·2238	−·0008	−·07
		A. B. W. K.	1·2230		−·0008	−·07
		T. H. B. .	1·2262		+·0024	+·20
		J. G. . .	1·2230		−·0008	−·07
Round	E	W. C. U. .	1·2252	1·2232	+·0020	+·16
		H. S. H. S.	1·22125		−·0019	−·16
		J. A. E. .	1·2250		+·0018	+·15
		D. S. C. .	1·2213		−·0019	−·16
Round	L	W. C. U. .	0·4412	0·4403	+·0009	+·20
		A. B. W. K.	0·4394		−·0009	−·20
		T. H. B. .	0·4418		+·0015	+·34
		J. G. . .	0·4390		−·0013	−·30
		D. S. C. .	0·4400		−·0003	−·07
Round	K	W. C. U. .	0·4418	0·4418	0	0
		H. S. H. S.	0·44179		0	0
		J. A. E. .	0·4418		0	0
		D. S. C. .	0·4418		0	0

II. *Variations in each Observer's Results of the Measurement of Extension for a given Interval of Load.*

In the following table have been arranged the greatest and least measured extensions by each observer on each bar, for an increment of load of $1\frac{1}{4}$ ton in the case of some bars, and of $2\frac{1}{2}$ tons in the case of other bars. For the rectangular bars A, B, the extensions were measured for increments of $2\frac{1}{2}$ tons load, corresponding to stress increments of about $2\frac{1}{2}$ tons per sq. in. For the $1\frac{1}{4}$-in. round bars E, F, the load increments were $2\frac{1}{2}$ tons, corresponding to stress increments of about 2 tons per sq. in. For the $\frac{3}{4}$-in. round bars K, L, the load increments were $1\frac{1}{4}$ ton, corresponding to stress increments of nearly 3 tons per sq. in. For each observer's measurements on each bar the mean extension for the same increment in his set of observations is also given. By comparing each observer's maximum and minimum values with his mean value, an indication is obtained of the magnitude of instrumental or observational errors in each case.

As this comparison is not affected by error in the determination or the calibration constant of the instrument, it is an index of the observational or instrumental error of particular extensometer observations.

Table II.

Comparison of Observer's Greatest and Least Values of Extensions with his own Mean Values.

Observer	Bar No.	Greatest extension in Interval of 2½ or 1¼ ton	Least extension	Mean for all intervals by each observer	Deviation from mean of each observer's results	Per cent. deviation	Mean per cent. deviation for each bar
A. B. W. K .	A	·00200	·00140	·001775	+ ·000225 − ·000375	12·68 21·13	16·90
	L	·00225	·00205	·00214	+ ·000110 − ·000090	5·14 4·21	4·67
	F	·00160	·00140	·00150	+ ·000100 − ·000100	6·67 6·67	6·67
		·00160	·00140	·00151	+ ·000090 − ·000110	5·96 7·28	6·62
J. A. E. .	B	·00152	·00148	·00149	+ ·000030 − ·000010	2·01 0·67	1·34
	K	·00172	·00168	·00170	+ ·000020 − ·000010	1·18 1·18	1·18
	E	·00124	·00122	·00123	+ ·000010 − ·000010	0·81 0·81	0·81
T. H. B. . .	A	·00190	·00170	·00183	+ ·000070 − ·000130	3·82 7·10	5·46
	L	00220	·00190	·00208	+ ·000120 − ·000180	5·77 8·65	7·21
		·00220	·00190	·00210	+ ·000100 − ·000200	4·76 9·52	7·14
	F	·00165	00140	·00153	+ ·000120 − ·000130	7·84 8·50	8·17
		·00165	00140	·00153	+ ·000120 − ·000130	7·84 8·50	8·17
H. S. H. S. .	B	·001515	·001485	·001497	+ ·000018 − ·000012	1·20 0·80	1·00
	K	·0017316	·001672	·001716	+ ·0000156 − ·000044	0·91 2·56	1·73
	E	·001277	·0012102	·001242	+ ·000035 − ·0000318	2·82 2·56	2·69
J. G. . .	A	·00190	·00180	·00188	+ ·000020 − ·000080	1·06 4·25	2·65
	L	·00220	·00210	·00216	+ ·000040 − ·000060	1·85 2·78	2·31
	F	·00170	00150	·00156	+ ·000140 − ·000060	8·97 3·85	6·41
J. G.. . .	A	·00200	·00170	00184	+ ·000160 − ·000140	8·69 7·61	8·15
(Students) .	L	·00210	·00200	00207	+ ·000030 − ·000070	1·45 3·38	2·41
	F	·00170	00150	·00154	+ ·000160 − ·000040	10·39 2·60	6·49
W. C. U. . . . (Mirror extensometer)	B	·001891	·001788	·001843	+ ·000048 − ·000055	2·60 2·98	2·79
	K	·002182	·002038	·002105	+ ·000077 − ·000067	3·66 3·18	3·42

TABLE II.—*Continued.*

Observer	Bar No.	Greatest extension in Interval of $2\frac{1}{2}$ or $1\frac{1}{4}$ ton	Least extension in Interval of $2\frac{1}{2}$ or $1\frac{1}{4}$ ton	Mean for all intervals by each observer	Deviation from mean of each observer's results	Per cent deviation	Mean per cent. deviation for each bar
W. C. U. (Lever extensometer)	E	·001638	·001447	·001544	+ ·000094 − ·000097	6·09 6·28	6·18
	B	·001552	·001418	·001485	+ ·000067 − ·000067	4·51 4·51	4·51
	E	·001293	·001217	·001261	+ ·000032 − ·000044	2·54 3·50	3·02
D. S. C.	A	·00190	·00185	·001855	+ ·000045 − ·000005	2·43 0·27	1·35
	L	·00440	·00430	·004345	+ ·000055 − ·000045	1·27 1·04	1·15
		·00215	·00210	·002140	+ ·000010 − ·000040	0·47 1·87	1·70
		·00220	·00195	·002125	+ ·000075 − ·000175	3·53 8·23	5·88
	E	·00310	·00300	·003088	+ ·000012 − ·000088	0·39 2·85	1·62
		·00160	·00150	·00155	+ ·00005 − ·00005	3·23 3·23	3·23
		·00160	·00150	·00155	+ ·00005 − ·00005	3·23 3·23	3·23
	B	·0019	·0018	·001875	+ ·000025 − ·000075	1·33 4·00	2·66
	K	·0022	·0021	·002154	+ ·000046 − ·000054	2·13 2·51	2·32
		·0022	·00205	·002146	+ ·000054 − ·000096	2·51 4·47	3·49

It will be seen that the deviations of the maximum and minimum values of the extension for $1\frac{1}{4}$ ton (or $2\frac{1}{2}$ tons) from the mean value are somewhat considerable, and often exceed 5 per cent.

In considering the apparently large percentages of error in some cases in this table, it must be remembered that the extensions were measured for a comparatively small increment of stress; also that the greatest and least extensions of each observer are those probably affected by the largest accidental errors.

III. *Method of finding the Mean Extension for a given Increment of Load from which the Coefficient of Elasticity is calculated.*

If a series of extensions are observed for a series of equal increments of load, and if the coefficient of elasticity is constant for the whole range of stress to which the bar is subjected, then the arithmetical mean of the observed extensions is the true mean extension according to the observations for the given increment of load. It is this mean which should be used in calculating the coefficient of elasticity. Also, apart from mere observational errors, the value of the mean extension will in no way depend on the magnitude of the increments of load for which the extensions are observed.

If, however, the coefficient of elasticity is not constant for the range of stress to which the bar is subjected, then a different value of the mean extension will be found for different values of the increment of load for which the extension is observed.

Professor Kennedy suggested that the simple arithmetical mean of the observed extensions should be compared with the mean extension taken out in the following way.

Suppose six micrometer readings are taken for six equal increments of load. The extension is calculated for the first and fourth, the second and fifth, and the third and sixth loading; the mean of these is then taken. The following is a sample of this method for a single set of readings:

Load in Tons	Micrometer Reading	Differences for 7½ Tons	Mean Extension for 7½ Tons	Mean Extension for 2½ Tons
0	(40·41)			
2½	44·31	·005533		
5	48·15	005528	·005553	·001851
7½	52·17	·005599		
10	56·06			
12½	60·05			

The following table contains a comparison for some of the sets of observations of the simple arithmetical mean of the extensions observed, and the mean calculated by the method suggested by Professor Kennedy:

TABLE III.—*Comparison of Mean Extension.*

Observer	Bar	Loading	Increment of Load Tons	Mean Extension	
				Arithmetical Mean	Kennedy's Mean
A. B. W. K.	A	1st	2½	·00178	·00182
,,	,,	2nd	,,	·00177	·00181
,,	L	1st	1¼	·00214	·00215
,,	,,	2nd	,,	·00214	·00216
,,	F	1st	2½	·00150	·00152
,,	,,	2nd	,,	·00150	·00151
,,	F	1st	2½	·00151	·00153
,,	,,	2nd	,,	·00151	·00153
W. C. U.	B	1st	2½	·001851	·001851
,,	,,	2nd	,,	·001850	·001840
,,	K	1st	1¼	·002097	·002094
,,	,,	2nd	,,	·002113	·002106
,,	E	1st	2½	·001546	·001537
,,	,,	2nd	,,	·001542	·001539

As the differences are small between the means found by the two methods, compared with the variations due to other causes, the simple arithmetical mean has been used in the following comparisons.

As the modulus of elasticity is usually calculated for the whole range of stress, it does not seem to matter which method of getting the mean extension is adopted. But in a case like this, where the instrumental or accidental errors of single readings are obviously not inconsiderable when compared with the whole extension for small ranges of stress, it would seem that it is not desirable to take out the extensions for very small ranges of stress. Professor Kennedy's method averages the error over a longer range of stress.

IV. *Comparison of the Values of the Coefficient of Elasticity obtained by different Observers.*

The different values of the coefficient of elasticity calculated from the observations are affected by errors of measurement of the bars, errors of calibration of the testing machine and extensometer, errors of observation, and errors inherent in the construction of the extensometer.

TABLE IV.—*Values of Coefficient of Elasticity obtained by different Observers. (Tons per square inch.)*

Bar	Observer	Results by each observer	Mean results by each observer	Mean of all results on one bar	Mean of all results on bars of same material and size
E	J. A. Ewing . .	13290 13290	13290	13225	13249
	H. S. Hele Shaw .	13116 13160	13138		
	W. C. Unwin . .	13198 13231	13214		
	D. S. Capper . .	13260 13260 13200 13320 13260 13260	13260		
F	A. B. W. Kennedy .	13430 13430 13500 13500	13465	13273	
	T. Hudson Beare .	13050 13150 13070 13150	13105		
	J. Goodman . .	13250 13250	13250		
K	J. A. Ewing . .	13380 13350	13365	13274	13245
	H. S. Hele Shaw .	13310 13072	13191		
	W. C. Unwin . .	13495 13385	13440		
	D. S. Capper . .	13100 13040 13100 13160	13100		
L	A. B. W. Kennedy .	13200 13200	13200	13215	
	T. Hudson Beare .	13260 13420 13210 13160	13262		
	J. Goodman . .	13244 13244	13244		
	D. S. Capper . .	13120 13120 13210 13210 13130 13130	13153		

TABLE IV.—*continued.*

Bar	Observer	Results by each observer	Mean results by each observer	Mean of all results on one bar	Mean of all results on bars of same material and size
A	A. B. W. Kennedy .	13100 13200	13150	13182	13193
	T. Hudson Beare .	13160 13260	13210		
	J. Goodman . .	13110 13110	13110		
	D. S. Capper . .	13260 13260	13260		
B	J. A. Ewing . .	13260 13310	13285	13203	
	H. S. Hele Shaw .	13180 13060	13120		
	W. C. Unwin . .	13294 13302	13298		
	D. S. Capper . .	13110 13110	13110		

The foregoing table contains all the values of E calculated from the total range of stress to which the bars were subjected in the record sheets sent in to the Committee. The total range of stress in each case was about the maximum range which could safely be used without risk of straining the bar beyond its elastic limit.

It should be remembered that bars E, F, K, L were all cut from the same rolled bar, and of these E and F were approximately of 1·25 inch diameter and K L approximately 0·75 inch diameter. Bars A and B were cut from the same plate, and were approximately of the section $2 \times \frac{1}{2}$ inches.

V. *Variation of Individual Results from the Mean of all the Results.*

In the preceding table the means are given of all the results sent in for the pairs of bars of the same material and size. It cannot, of course, be assumed that these means are the true values of the coefficients of elasticity of the bars. Nevertheless, they furnish convenient reference numbers for estimating the probable magnitude of the differences of values of E determined by different observers with different instruments. In the following table this comparison of each observer's results with the mean of all the results is made. The percentage deviation from the mean is, of course, not necessarily the percentage error, but it is at least some indication of the probable magnitude of the error of the calibration constant as distinguished from error due to instrument or observer in individual determination of the extension.

TABLE V.

Variation of Values of Coefficient of Elasticity from the Mean Value of all the Observations on corresponding Bars.

Observer	Bar	Gauge Points	Mean Value of E from Two Loadings by One Observer	Mean Value of all Loadings by all Observers	Deviation from Mean per Cent.
A. B. W. Kennedy	A	p.s.	13150	13193	− ·33
	L	a.c.	13200	13245	− ·34
	F	a.c.	13500	13249	+1·89
	F	c.e.	13430	13249	+1·37
J. A. Ewing	B	—	13285	13193	+ ·70
	K	—	13365	13245	+ ·91
	E	—	13290	13249	+ ·31
T. Hudson Beare	A	p.s.	13210	13193	+ ·13
	L	a.c.	13340	13245	+ ·72
	L	c.d.	13185	13245	− ·45
	F	a.c.	13100	13249	−1·12
	F	c.d.	13110	13249	−1·05
H. S. Hele Shaw	B	l.m.	13120	13193	− ·55
	K	—	13191	13245	− ·41
	E	—	13138	13249	− ·84
J. Goodman	A	—	13110	13193	− ·63
	L	—	13244	13245	− ·01
	F	—	13250	13249	+ ·01
W. C. Unwin	B	k.n.	13298	13193	+ ·80
	K	a.c.	13410	13245	+1·47
	E	a.c.	13214	13249	− ·26
D. S. Capper	A	p.s.	13260	13193	+ ·51
	L	a.e.	13120	13245	− ·94
	L	a.c.	13210	13245	− ·26
	L	c.e.	13130	13245	− ·87
	B	p.s.	13110	13193	− ·63
	K	c.e.	13070	13245	−1·32
	K	a.c.	13130	13245	− ·87
	E	c.e.	13260	13249	+ ·08
	E	a.c.	13260	13249	+ ·08
	E	a.e.	13260	13249	+ ·08

On the Physical and Engineering Features of the River Mersey and Port of Liverpool. By GEORGE FOSBERY LYSTER, *M.Inst.C.E., Engineer-in-Chief to the Mersey Dock Estate.*

[Ordered by the General Committee to be printed *in extenso.*]

LIVERPOOL, with its river and docks, is such an important factor in the history of the world, and has so largely contributed towards England's commercial greatness, that, though doubtless the subject is well known, it would be out of place to allow the visit of so distinguished a body as the British Association for the Advancement of Science to the city and its surroundings to pass without briefly submitting to them something of the history, physical conditions, and progressive development of the port.

Although the Bay of Liverpool is open to the north and west, therefore at times subject to very heavy gales from those quarters, nevertheless, being sheltered by Ireland from the tumultuous and overwhelming seas of the Atlantic, and further guarded by the flanking coasts of Wales, Cumberland, South Scotland, and the off-lying Isle of Man, its position—as an examination of the map of the British Isles clearly shows—is assimilated more to a port situated within a large lake, like those of the North American Continent, than one on an open and exposed seaboard; while the numerous sheltered roadsteads, deep estuaries, and good harbours abounding along these coasts afford such facilities for economic interchange of traffic as nowhere else exist throughout the coasts of Great Britain.

To these peaceful advantages is to be added the invaluable feature of its unique position as regards safety in time of war, for, though modern battleships, by reason of their great speed and comparative invulnerability, are able to swoop down and make unlooked-for raids on an enemy's coast, it may be considered that, while England maintains her supremacy of the sea, a prudent hostile commander would scarcely risk annihilation by attacking a seaport such as Liverpool, approachable only through the well-guarded narrows of St. George's Channel, or the still narrower and more easily watched North Channel by the Mull of Cantire, and further protected by the mass of banks outside the port, the channels through which could be easily defended. Landward, Liverpool has a supreme advantage over the rest of England by being in close proximity to the chief centres of manufacturing industry, as well as to great coal-fields and salt-mines, which are most important adjuncts to its trade.

Further swelling the list of favourable elements are the unusual and peculiar characteristics of the river Mersey itself; namely, a deep, capacious, and sheltered roadstead close to its mouth, with shores suitable for the construction of docks and approached by easy sea channels, and so large a tidal range and other such physical conditions as to enable it to maintain its natural advantages without the aid of art—except as regards its bar, eleven miles seaward of its mouth, where nature is now being assisted by special dredging operations to improve its deep-water condition.

These salient advantages, now so briefly outlined, will readily account for the Mersey having been wisely selected as the best and most secure position for a great northern trading and distributing centre, to which the merchandise of the world now easily gravitates.

The foresight evidenced in such a selection has been more than amply justified, for, from a small beginning, less than 200 years ago, when the era of the manufacturing trade of the northern counties was commencing, Liverpool has expanded *pari passu* with that trade, from its position of an insignificant fishing village of a few hundred inhabitants to that of the second, if not the premier, commercial port of the world, and now has, with its surrounding urban districts, a population of upwards of 800,000.

This splendid and unrivalled progress, though in some degree owing to the foresight of its early founders and later administrators, is due primarily to the natural advantages before mentioned, and chiefly to the magnificent stretch of upwards of six miles of deep water which the Mersey presents and maintains immediately in front of the city and its suburbs, thus allowing docks of convenient form and size to be constructed along its foreshore, easy of approach, thoroughly sheltered, and in all respects suitable for ships of every class, both large and small.

In olden times, and while Liverpool was still in its infancy, the sea trade of this part of England was carried on through the ports of Preston and Chester, and that of the south-west of the country by Bristol and Milford Haven.

Preston was a prominent port of the Romans, but lost its value, even in the early days of light-draught vessels, by the deterioration and silting up of the river Ribble and the exposed condition of its estuary; while Chester, which chiefly commanded the trade and intercourse with Ireland, though also a favoured port with the Saxons and Romans, became obsolete from a like cause. It may, however, be remarked that the authorities of both the Ribble and the Dee have, in recent days, sought the aid of artificial works to improve the navigable condition of these rivers.

The precise origin of the name 'Liverpool' has for long been somewhat a difficulty to all inquirers, and, though a great variety of opinions have from time to time been under discussion, no definite conclusion has been come to, the meaning of the first portion of the name, 'Liver,' being the knotty point of contention.

Without having gone sufficiently into the question to justify more than a general opinion on the much-mooted point, it appears to the author sufficiently reasonable to suppose that, as the ancient seal on the old deeds of the Corporation, also on the present city arms, is emblazoned with a traditional bird called the 'liver,' generally accepted as the cormorant (though, as some suggest, it may have been originally intended for the more noble symbolic eagle of St. John, the patron saint of the guilds of that day), it is very probable that the first portion of the name is derived from that source, and that the creek or pool, evidenced by ancient maps as existing towards the centre of the old town, was the habitation of the cormorant, thus providing a fitting terminal for the ornithological puzzle.

As in the case of the doubtful origin of the name 'Liverpool,' and the variety of opinions that have been urged on the point, a difficulty exists, though probably not so prominently, as to the origin of the name 'Mersey,' though it is generally accepted that the river was so called from having been the northern boundary line of the kingdom of Mercia, and this appears to be a reasonable explanation.

It is stated by Picton, in his history of the district, that the earliest documentary evidence having reference to Liverpool is of the date 1004, when it is said to be mentioned in a deed of the reign of King Ethelred.

He also relates that King John, about the year 1170, founded the borough and port of Liverpool, and constructed a castle for their defence: this was chiefly with a view to facilitate the communication with Ireland, which was in a chronic state of disaffection and disturbance. rather than as a commercial enterprise, which in those days was little thought of.

The river Mersey first takes that name in Cheshire at a point four miles to the east of the town of Stockport, at the junction of the two small rivers Goyt and Etherow, which severally rise in the high lands bordering South Yorkshire, North Derbyshire, and Cheshire. They are insignificant streams, scarce worthy of the name of rivers, their courses being narrow, tortuous, and irregular.

The length of the river Mersey proper, from the point of junction above mentioned to its mouth between the north end of Liverpool on the Lancashire shore and New Brighton on the Cheshire shore, is 56 miles. It has, as tributaries, the Tame, running into it near Stockport, and the Irwell, one of its most important affluents, which has its source in

North Lancashire, and which, after receiving the waters of minor streams, passes through the city of Manchester, and joins the Mersey at Flixton, eight miles lower down. Between that point and Warrington the Mersey receives from the adjoining marshes the waters of several small streams. The aggregate drainage area of the combined catchment basins above Warrington is about 750 square miles. From Warrington downward to Runcorn, a distance of about ten miles, it partakes of the form of an ordinary narrow tidal river, passing through the low-lying marsh lands of the district with little fall.

At the town of Runcorn, where the name Runcorn Gap fitly describes the narrow and special configuration of its high and abrupt red sandstone shores, the Mersey is crossed by the high-level viaduct which carries the London and North-western Railway to Liverpool. From this point the river passes into the enlarged portion of the estuary, which at high tide assumes the appearance of a large inland lake. Reaching seaward to the south end of Liverpool, a distance of about 12½ miles, by from 2 to 3 miles wide, with an area of 30 square miles, it is filled to about half-tide level with a deposit of sand, which mostly becomes dry at low tide. This part of the river, owing to its form and size, plays an important part in maintaining the deep water abreast of Liverpool, as well as the sea channels.

About 2½ miles below Runcorn the river Weaver passes into the Mersey on its left bank, and, with its tributaries, forms its most important adjunct, being the chief drainage basin of mid-Cheshire, with a watershed of 550 square miles.

Below the mouth of the Weaver the adjoining part of Cheshire is drained by the Gowy and a few other insignificant streams, while on the Lancashire side minor streams of a like character drain that district.

The drainage of the city of Liverpool is effected by an ordinary system of sewers which pass into large intercepting culverts, carried at intervals through the Dock Estate into the river. Owing to the large volume of tidal water which daily passes backwards and forwards, the material from this source is swept away, leaving little or no trace of fouling along the foreshores.

The aggregate drainage area of these several rivers and streams is computed at 1,724 square miles. The total amount of up-river water discharging into the estuary in each twelve hours is estimated at from two to three million cubic yards, while the volume of tidal water on high springs is computed at about 710 million cubic yards, and on low neaps at 281 million cubic yards. It should not be inferred from this disparity in quantity between the volume of upland water and that of the tides that the former does not play an important part in the *régime* of the river—on the contrary, the river channel is formed primarily by the land water, and the wandering tendency which it displays in its downward course to the sea is the first step towards insuring the capacity of the estuary being fully maintained. This is effected by its action in grooving out the surface of the sandbanks, so forming minor channels to receive the in-flowing tide, which, running through them with great velocity, enlarges and extends them. This process, repeated in all the varying positions which the channels take, ploughs up the whole area of the estuary from shore to shore, so preventing the growth of the banks by accretion and the tidal displacement which would follow such accretion.

Near the point where the Mersey leaves the wide portion and enters the comparatively narrow channel abreast of Liverpool, it assumes the condition of a magnificent deep-water river passing shore lines largely in rock, and midway of its course of about six miles to the sea it gradually narrows to a width of 1,000 yards, widening again towards its mouth to about 1,800 yards. There is ample width in this deep reach of the river for the convenient handling and anchoring of a large number of the largest ships, the soundings at low water for the most part ranging from 40 to 50 feet, with considerable areas below 60 feet. It is here well sheltered by the high lands on the Cheshire shore from all winds from south to west, and by the Lancashire shore from south to north. The Bay, as has been said, is open to north and north-west gales, and these cause heavy seas on the banks, which, however, having their crests for the most part much above low-water level, act to a very considerable extent as breakwaters, and modify greatly the force of the waves through the sea channels as well as at the mouth of the river and along the line of docks. From the point where the river Mersey enters the sea at New Brighton on the Cheshire shore, that shore trends westerly in a straight line to the mouth of the Dee, a distance of about eight miles, and the Lancashire shore in a straight line northerly for a like distance. Within these coast-lines are contained about 23,000 acres of sand-banks, which dry at low tides, and form the formidable barrier fronting the port.

Doubtless a large proportion of this enormous mass of sand is brought from the adjoining coasts of Wales, by the action of the sea and currents, and deposited within this rectangular area, which it cannot pass, to which is added the large quantity that is necessarily brought down by the river from the continual wasting of its banks and foreshores, as also from the quantity of detritus that is constantly being conveyed seawards by floods and freshets.

Over and through these banks the flood and ebb tides force their way, maintaining, however, one large well-defined deep channel, used by all the important ships of the port, with two subsidiary channels of less value.

The main channel is known as the Crosby, and for the first six miles of its course it takes a straight and northerly direction, running parallel with the Lancashire coast, and at low tide skirting its extended sandy foreshore in front of the suburbs of Seaforth, Waterloo, and Formby, while the main body of the great Burbo Bank forms its seaward barrier and boundary. The continuity of the inner face of the Burbo is frequently broken by creeks, depressions, and shallow channels, evidencing the efforts of the ebb currents to find their way to the open sea through a shorter course than that of the main channel. At the end of the six-mile reach, which is marked by the Crosby Lightship, the Channel trends, with a gradual curve seaward, in a north-westerly direction to the Bar, which is about five miles from the Crosby Light, and thence forces and maintains its way through the enormous mass of sand, which forms the great Burbo and Taylor's Banks, and which, but for this severance, would present a solid unbroken mass, with a sea face in the form of an ordinary beach. The outer portion of the main channel is known as the Queen's Channel.

The Crosby Channel, considering its leeshore position, and its being flanked and almost surrounded by vast masses of mobile sand, has maintained its general conditions, both as regards position and capacity, with singular regularity, so that the conditions of navigation have remained practically uniform.

This indicates the value of the tidal volume flowing into and out of the Upper Estuary, and clearly points out the vital necessity of maintaining it undiminished and untrammelled to the fullest possible extent.

The Bar, as is doubtless well understood, is a sandy accumulation or ridge, with a long sloping foreshore on each side, stretching across the mouth of the main channel; on plan its form is that of an irregular curve, somewhat in the shape of a horseshoe with its convex side seaward, separating the deep water of the channel from that of the offing. It is the result of the loss of concentration of the current due to the channel departing from its regularity of form where it issues from the banks and meets their outer or sea slopes. It is joined up on its north flank to the tail or westernmost extremity of the most seawardly bank of the group known as the Zebra Flats, which forms an extension of Taylor's Bank under water, and on the south to the western spit of the Little Burbo.

The Bar is not constant in position, but has been found to be moving slowly seaward, in accord with the growth of the banks in a like direction, maintaining, however, its general characteristics. [Further on, the author refers to the works undertaken to give increased depth of water on the Bar.]

In addition to this main channel, there are two minor or subsidiary channels, viz.—the Formby Channel and the Rock Channel. The former is a prolongation nearly in the same direction as that of the inner reach of the main channel, which it leaves at a point abreast of the Crosby Lightship and continues in a northerly direction to the Formby Spit, after which it reaches the open sea, five miles from its junction with the Crosby Channel. It is narrow, shallow, and somewhat tortuous when it leaves the main channel, but is thoroughly buoyed, and is used by small vessels proceeding to and from the north, as it saves a détour of several miles.

The Rock Channel, so called from the rocks which crop up at the point at New Brighton, where it leaves the main channel, runs from that point westerly, nearly parallel to the Cheshire shore for a distance of six miles, when it turns to the north-west and passes into the Bay by an outlet known as the Horse Channel, between a spit of the Great Burbo and the East Hoyle Bank, which separates the water of the river Mersey from that of the river Dee.

Before the Crosby Channel with its bar entrance became stable and pronounced, the Rock was the chief channel to and from the port, owing to its position relative to the prevailing winds. Its main body was then wider and deeper than at present, it having considerably deteriorated of late years and come inshore, while the Horse entrance has become narrower and more difficult.

The whole of the entrances to the port are buoyed and lighted on the most approved system. Powerful distinguishing lights to serve both the Crosby and Rock Channels are placed on the land at the river mouth, at New Brighton and North Wall. In the main channel floating lightships are moored as follows:—the Crosby light at the point where the Crosby Channel changes its direction; the Formby light about halfway between the Crosby and Bar lights, the latter of which is moored about $1\frac{3}{4}$ mile outside the Bar. Out at sea, some eight miles from the Bar, a lightship known as the North-west Lightship is moored, this being the first floating light to be picked up by vessels making for the port. There are, however, along the north coast of Wales, to as far as Holyhead, several lighthouses maintained at the expense of the port of Liverpool. Each important station has its distinguishing light and fog-signal. In addition to the lightships in the main channel, there are also a number of lighted gas-buoys. The dredged cut at the Bar is also defined by two lighted buoys on each side.

The system of buoyage adopted in the sea channels of the Mersey is that approved in 1883 by the Conference on Buoyage in Ports of the United Kingdom, of which Captain Graham Hills, R.N., then Marine Surveyor to the Mersey Docks and Harbour Board, was a prominent member.

The width of the main channel varies in its several reaches, its deep-water fairway being outlined by the buoys referred to, which are moored to give a width of channel from 800 to 1,400 yards.

Doubtless the several features are well understood and appreciated by navigators, but they present such interesting characteristics as to render them worthy of the attention even of landsmen and laymen unacquainted with the locality. It will be evident from the foregoing necessarily very general description that the main sea-channels of the Mersey being wide, deep, thoroughly well buoyed and lighted, and provided with powerful fog-horns at all the leading points, there is no difficulty in entering or leaving the Mersey by day or night, which facility is essential in a sea-port used by such an enormous number of vessels, of all sizes and classes, as carry on its trade.

Until a few years ago vessels arriving at the approaches to the port occasionally ran some risk, and were, in some cases, subject to considerable inconvenience through being compelled to wait in the open bay outside the Bar until there was sufficient water over it to enable them to cross safely. By the very extensive dredging operations carried out in recent years, and to which the author now proposes to make some reference, this difficulty has practically been entirely removed.

It has been mentioned above that the main channel of the Mersey has maintained its general features with regularity, so that the conditions of navigation have remained practically uniform. This applies, amongst other features, to the depth of water over the Bar, which has generally under natural conditions been about 10 or 11 feet below low water of spring tides. Sometimes in the course of changes it has been somewhat greater or less. Assuming a depth on the Bar of 10 feet below low-water springs, then, with the range of tide obtaining in Liverpool Bay, the depth of water over the Bar at *high water* would scarcely ever be less than 30 feet, and would vary between that and about 40 feet, so that at high water (that is, about once every twelve hours) any vessel could enter or leave the port. Doubtless, therefore, the measure of inconvenience was not great when vessels were small and slow; but in recent years, where the size and speed of steamers have greatly increased, the detention at the Bar of vessels arriving at or about low water became a serious inconvenience, especially in the case of the ocean greyhounds carrying a large number of impatient passengers.

Previous to 1890 no attempt had been made to obtain by artificial works more than the natural depth of water on the Bar, except that about the year 1838, when the condition of the sea channels for navigation was below the normal efficiency as regards depth and otherwise, Captain Denham, the Marine Surveyor of that day, was authorised to harrow or rake across the Bar in the channel then forming in the course of natural changes at the outer end of the main channel. A sum of between 3,000*l.* and 4,000*l.* was spent in this work, the precise effect of which is uncertain, as in the course of nature a channel having the normal depth was formed in this position and was adopted for navigation.

It must not be inferred that the subject of the Bar obstruction was lost sight of through the period intervening between Captain Denham's experiment and the commencement of practical work. On the contrary, it had never ceased to be a source of anxiety to the authorities, and more particularly, in recent years, to the Dock Board, and the author as their engineer, and suggestions for its amelioration had from time to time been under consideration.

There was, however, a natural and wise hesitation to tackle a question that presented such formidable difficulties and responsibilities, both physical and financial, at all events unless and until there appeared a fair prospect of obtaining successful and satisfactory results within reasonable limits, both as regards time and expenditure.

At New York, the western terminus of the great Atlantic ferry, inconvenience arising from a similar cause had been felt, and after failure of certain expedients, experiments by dredging the obstructed channel, undertaken in 1885 and subsequent years, met with a considerable degree of success. Although the problems were by no means the same, the difficulties at Liverpool being infinitely greater than those at New York, the success at the latter port appeared to warrant an experiment on the Bar at Liverpool, and it was accordingly decided to undertake an experiment of some magnitude in dredging.

Had the lowering of the Bar been dependent on the old-fashioned bucket system of dredging, excellent as it is for some positions, experience teaches that in this instance costly failure would have been inevitable. The employment of the centrifugal pump as a dredger, which is a comparatively recent application, offered the best, and practically the only, means of removing the Mersey Bar, which consists of sand of various degrees of fineness. The author had made early experiments with the centrifugal pump as a dredger, these being carried out after an examination which he made in 1876 of a plan he saw in practice in the sandy bed of the river Loire in France, where he found a suction dredger at work in clearing out the foundations for a bridge over that river. His first attempt to adapt this principle to the work on the Dock Estate at Liverpool was by fitting up an old mud hopper barge with a centrifugal pump and trailing suction-pipe, for the purpose of testing its ability to remove the silty accumulation from the docks, and thus supersede the clumsy bucket system which was found very inconvenient to work in such confined spaces, and was costly.

This experiment, for the most part, failed by reason of the light flocculent character of the material to be dealt with, and consequent impossibility to retain it within the hoppers, as also from the frequency of foreign substances which had fallen into the docks, such as ropes, baskets, bags, mats, and the like, choking and breaking down the suction pipes.

The system, however, gave such evidence of ultimate success (provided the material was of a suitable character) that further experiments were successfully made at that time on the sandbanks within the river. When, therefore, there appeared a possibility of success warranting an experiment in dredging the Mersey Bar, the experience in pump-dredging indicated the method to be adopted, and the adaptation and use of two of the Board's 500-ton steam hopper barges, followed in course by the construction and setting to work of the gigantic dredger *Brancker*, novel in many features besides her size, of 3,000 tons capacity, and capable of filling herself in about three-quarters of an hour, resulted in a notable amelioration of the condition of the Bar.

From a channel, having in 1890 a minimum depth of 11 feet at low water of lowest tides between the fairway buoys, the Bar has now cut through it a channel 1,500 feet wide between its buoyed alignments, with a minimum depth of 24 feet—and so small a depth only in a few isolated patches over its area—by far the greater portion ranging to a depth of 28 feet.

It is fortunate that so important an improvement of the access to the port has been secured at a time when the enormous growth in the size of ships, the frequency of their voyages, and the urgency of trade competition absolutely demanded some advance of the kind. This achievement has not, of course, been attained without considerable expenditure, of which the cost of the two 3,000-ton dredgers (the *Brancker* above referred to having been followed by the *G. B. Crow*, of like capacity), which had to be specially designed and constructed for the purpose, forms an important item. The total quantity of sand removed to this date (September 1896) and deposited in a safe position, whence it cannot return to its old site, amounts to 15,511,390 tons, the actual cost of the operation being at the rate of $1\frac{1}{4}d.$ per ton. A description of this work has been so fully and exhaustively given in the paper read to the British Association last year by the author's son and chief assistant, Mr. A. G. Lyster, that it is unnecessary here to enlarge further on the subject beyond stating that since last year costly additions have been made to the plant, which, by minimising the chance of a breakdown, still better ensure a successful issue.

The subject of the tides may be considered as collateral to that of the channels. They are another important feature in the welfare of the Port, demanding some slight notice, and as a preliminary it may be well to explain the standard by which local tides are measured.

The datum level, long since arbitrarily adopted for all engineering work in connection with the Mersey, is that of the level of the sill of the first dock constructed, which has long since disappeared, but the level has been transferred to the bench mark on the wall of one of the more recently constructed pier-heads. This local datum is known as the 'Old Dock Sill.'

Several years ago a Committee of the British Association considered closely its relation to other standard levels, and its relation to Ordnance datum was then determined to be that the latter was 4·67 feet above Old Dock Sill. It may be noted in passing that the Ordnance datum was settled from observation taken by Royal Engineers of the mean level of the sea at Liverpool during a certain month in the year 1841. The relations of a number of important tidal levels to Old Dock Sill, mostly taken from the record of the self-registering tide-gauge at George's Pier, Liverpool, during ten years' observations, 1854–63, are as given below, viz.—

	Above datum Ft.	in.
An extraordinary high tide, as marked on the Leasowe Lighthouse	25	0
An extraordinary high tide, January 20, 1863	23	9
Average high-water mark of equinoctial spring tides	21	1
Average high-water of spring tides, including equinoctial tides	19	0½
Average high-water mark of ordinary spring tides, excluding equinoctial tides	18	10
Mean high-water level	15	6
Highest high-water mark of neap tides	14	8
Average high-water mark of ordinary neap tides	11	7
Lowest high-water mark of neap tides	8	7
Mean tide level	5	0
Ordnance datum level	4	8
Highest low-water mark of neap tides	4	1

	Below datum Ft.	in.
Average low-water mark of ordinary neap tides	1	5
Lowest low-water mark of neap tides	3	10
Mean low-water level	5	6½
Average low-water mark of ordinary spring tides, exclusive of equinoctial tides	8	8
Average low-water mark of spring tides, inclusive of equinoctial tides	8	10
Lowest low-water mark of equinoctial spring tides	10	4

The abnormally high range of tide in this locality, as shown by the foregoing figures, is sufficiently interesting to warrant a brief explanation of its causes. It is, shortly, due to the fact that a part of the great tidal wave, generated in southern latitudes, enters St. George's Channel round by the south of Ireland, and thence moves forward simultaneously in one vast current throughout, to a position in the Irish Sea abreast of the Isle of Man, where it meets that part of the ocean tide which passes by the north of Ireland and turns southwardly with great velocity through the North Channel by the Mull of Cantire. This meeting causes an upheaval of the tidal volume, which is transmitted laterally to such parts of the adjoining coasts as are within its influence, the Bay of Liverpool coming in for its share, and thus enabling it to project a tidal wave far up the river Mersey to Woolston Weir, 33 miles from the mouth of the river, and to Frodsham Bridge on the Weaver, 19 miles distant from the same point. At these points the tidal flow is barred by weirs on both rivers.

The gross volume thus sent into the estuary has been calculated at 710,000,000 cubic yards on springs, and 281,000,000 cubic yards on neaps.

It now remains to describe the share which man has taken to complete the benefits which Nature has so lavishly bestowed, and this may best be done by a brief and necessarily very general description of the works and docks which have brought Liverpool into such prominence and active touch with the outside world.

The major portion of the space upon which the Liverpool docks have been constructed has been gained from time to time by inclosing the foreshore of the river. Its width varies from 2,300 feet, where back land was low lying, at the mouth of the river, to 700 feet in the centre of the river frontage of the city, opposite the narrows of the river channel, and widening again to 1,100 feet at the southern extremity, where, however, width has only been won by excavation of the steep, rocky banks. The river wall fronting the Estate is continuous for six miles from the mouth of the river opposite New Brighton to the southern extremity of the developed portion of the Estate.

The enclosure thus effected with most of the works thereon, and the expenditure incurred thereby, have been authorised from time to time by Acts of Parliament.

Beyond this enclosure additional adjoining land and foreshore have been secured further south, and will admit of dock extensions when the necessities of trade demand increased accommodation. The total area of the Board's Estate on the Liverpool side is 1,105 acres, of which 950 acres are developed, the remaining area being brought only into partial use for dock purposes.

The first dock erected in Liverpool, already referred to, was towards the centre of the system as now existing, on the site of the Old Pool, and was constructed, under an Act obtained in 1708, from designs of Mr. Thomas Steers, an eminent engineer of that day. It was only four acres in area, and afforded accommodation for 100 small vessels. It was filled in about seventy years ago, and the group of buildings forming the Custom House, Post Office, and Dock Offices has been built on its site.

The earlier docks were all constructed in the vicinity of the Old Dock, but nearer to, and running parallel with, the river, and some of them exist to this day, partly in their original form. They were designed and carried out by Mr. John Foster and his son, who were then the Surveyors to the Corporation.

In 1824 the late Mr. Jesse Hartley took charge of the engineering of the Dock Estate, the business of which was in those days administered by the Corporation. Mr. Hartley occupied that honourable position with singular success for the long period of thirty-six years, and died in 1860. During the latter portion of his useful life he was assisted by his son, Mr. John Bernard Hartley, who succeeded him as Engineer, but who, owing to failing health, was shortly obliged to resign.

Undoubtedly the prominent position of Liverpool among the commercial centres of the world is largely due to the practical knowledge and ability of these eminent engineers and the success of their achievements, at a period when the science of engineering was but imperfectly understood. This is universally acknowledged both in and out of the profession.

In 1861 the author of this paper was appointed Engineer, and has remained so ever since. It is, however, but right to say that for the last six years Mr. A. G. Lyster has designed and carried out all the new works subsequent to those of the Canada, Huskisson, and Sandon improvements, which are the last with which the author has been prominently concerned.

The Hartleys designed and carried out most of that group of docks extending from the Prince's to the Canada on the north, and from the Salthouse to the Brunswick on the south, including the fine blocks of Albert and Stanley warehouses, for the storage of general produce. These docks all present features of great similarity, having been constructed to suit the special classes of shipping and trades which in those days were located in different positions along the Estate. They now require no special description.

Soon after the author took charge as Engineer, it became evident that the days of sailing ships were numbered, trade and steam developing on all sides, so that ships of greater size, with increased speed and draught, became the ruling requirements to ensure successful trading.

As a natural sequence, it was found that the older docks were rapidly becoming obsolete for this new class of ship, so that docks of improved type had to be specially designed and brought into use with all possible despatch. Fortunately the foresight of the Dock Board had provided for this contingency by the large enclosure—about 300 acres of foreshore—they had effected north of Canada Dock. An area of about 80 acres at the southern end of the Estate also had for some years been waiting for development.

These lands were handed over to the author in order to prepare designs for furnishing them in some form to meet the new conditions, the result being that the groups, north of Canada Basin, and known as the Alexandra system, at the North End, and the Herculaneum at the south, including the Harrington, Toxteth, and Union Docks, were carried out.

The Parliamentary Estimates for the whole of these works amounted to 4,100,000*l*. The main features of these schemes, both north and south, were such as to afford ample and convenient accommodation for ships of the largest class, in view at the time of their design, with facility of ingress and egress to and from the docks, and approaches with entrances as deep as the conditions of the river would safely justify; also abundant quay and water space, large shed accommodation, and all requisite appliances for the rapid discharge of goods, combined with wide roadways and convenient lines of railway in full connection with the main trunk lines of the country. Fortunately the large area of the enclosure at the north and the favourable condition of the river in the vicinity admitted of these desiderata being obtained.

The northern scheme comprised the extension and alteration of the Canada Basin and its pierhead, with the lowering of the level of its floor; the formation of the Langton Half-tide dock, which was to be the vestibule for the surrounding group; two graving docks, each 950 feet long; a branch dock for repairing purposes; a great steam dock with three branches, called the Alexandra; and a dock opening out of it called the Hornby, being the northernmost dock on the Estate. The total water area of this group amounts to 83 acres, having an aggregate quayage of 23,700 lineal feet. The Parliamentary Estimates for this section of docks amounted to 2,691,360*l*., within which they have been completed. They were opened for traffic on September 8, 1881, by their Royal Highnesses the Prince and Princess of Wales.

In designing works of this important character one of the difficult matters to successfully accomplish is that of effecting a simple and ready means of keeping the approaches, entrances, and dock sills clear of silt, with which the water of the Mersey is largely charged. This becomes all the more necessary where ships are large and valuable, and difficult where the sills are laid at abnormally low levels.

In the case of this group the sills were laid at twelve feet below datum, being the deepest in the river with the exception of those previously constructed at the northern entrances of the Birkenhead Docks. For the purpose of maintaining the required depth in the dock approaches a special arrangement of sluices of an elaborate character was designed and carried out, passing along and incorporated with the wing walls and pierheads of the entrances and basin, and continuing along timber piers projecting into the river, which structures, being of a heavy and substantial character, materially assist the passage of ships into and out from the docks. The result of this arrangement is that the fairway is daily swept clear of all sandy accumulation, and kept in perfect working order, while the entrances are thoroughly sheltered, even in heavy on-shore gales.

It may not be out of place to mention that one of the most important features of successfully working a dock system, particularly in a crowded port like Liverpool, is facility of ingress and egress, especially at times of heavy seas and bad weather, when big ships are difficult to handle and keep under control.

This matter received special attention, and the approaches and entrances were carefully designed to meet that end. The result has been satisfactory, no difficulty having been experienced with the new entrances, and no accident of any moment having occurred during the fifteen years that the docks have been in work. The responsible officer in charge of this division has informed the author that, no matter what the weather is, whenever a ship-master considers it safe to leave his moorings in the river, or his berth in the dock, he can enter or leave easily and safely by way of Canada Basin. This is all the more satisfactory as in the inception of this North End scheme it was freely predicted that in bad weather from the north-west the entrances would be dangerously exposed, if not unapproachable with any degree of safety. An instance may be quoted to illustrate the facility with which vessels are worked in and out of this group of docks. On February 13, 1889, twenty-three steamships of an aggregate of 34,197 tons and thirty-five smaller vessels passed in and out during the working tide of two and a third hours. This, though an excellent record, has no doubt been since exceeded, as during the seven years that have elapsed the docks have been largely overcrowded. Since their opening in 1881 they have accommodated an immense amount of the best steam shipping of the port.

That part of the works at the South End also included in the Act of 1873 consists of a chain of three docks, known as the Harrington, Toxteth, and Union Docks, extending from the Herculaneum Half-tide towards the north, up to the old Brunswick Dock. Their sills are laid at the level of 12 feet below datum throughout, and their main entrances and wing walls at Herculaneum are provided with an elaborate system of sluices, carried under a jetty on the river-side on the same principle as that at the North End, but alongside the river wall instead of projecting into the river. This has been the means of fully maintaining the sills and fairway open and free from silt and preventing the tail of the Estuary banks from approaching too near the entrances.

The Herculaneum Half-tide Dock, which in its original form, with two graving docks opening out of it southward, was constructed under the Act of 1863, was, under the Act of 1873, greatly extended eastwardly, and an additional graving dock was constructed alongside the other two. These docks were cut out of the solid red sandstone rock, which originally was much higher than the present quay level. Cliffs therefore exist on the east and south sides of the dock, and in the face of these have been excavated casemates separated by solid partitions of rock. These casemates were designed for the storage of petroleum in barrels, and are so used. Northward of the Herculaneum Dock the Estate is narrow, and consequently docks on the Alexandra system, of a great trunk with branches, could not be laid out; but the Harrington and Toxteth take the form of long docks of ample width, and are provided with sheds of the most modern type, double storey, of moderate width, on the eastern quays, and single storey, of exceptionally great width, on the western. The Union Dock forms a connecting link between the new deep-water dock and the older group having comparatively shallow sills.

The total area of the docks from Herculaneum to Union inclusive is 32 acres, 3,348 square yards, and the quayage 8,518 lineal feet, and the Parliamentary Estimate for the works was 1,408,640*l*.

At night the entrances and passages throughout the new north and south systems are lighted at tide-time by electric lights raised on tall lattice masts, placed on the pierheads and standing 80 feet above the quay level; these being amongst the first introduced into England or elsewhere for dock purposes, as far as the Author knows.

The sills of the older docks immediately north of the Union Dock, and extending as far north as George's Dock, are laid at a level of about six feet below datum—six feet higher than the Herculaneum-Union group. These older docks could not, on neap tides, be available for vessels of, say, more than 16 feet draught, and could therefore not be safely used on neap tides by deep-draught modern vessels. To meet this difficulty, the Author arranged that on such tides the water in the shallow group should be impounded at such a level as to afford ample draught for all vessels, the only disability from which they would suffer, and this is only of a trifling nature, being that, if required to pass between river and docks on neap tides, they would have to do so by way of the deep-water river entrances at Herculaneum Dock, the Union Dock being used as a lock between the old and new groups of docks. Inasmuch as there is a considerable loss of water by leakage at dock gates, and culverts, and for filling graving docks, such loss must be made good if the water is to be maintained at a constant level, and this is done by means of a powerful installation of centrifugal pumps, situate at the Coburg Dock, which are used to pump water from the River Mersey into the Coburg Dock, from which it distributes itself throughout the system. By these means the effective depth of the whole of the docks from Brunswick to George's, having an area of about 80 acres, is practically increased to that of the lowest sills leading to them, 12 feet below Old Dock Sill, and much detention of vessels and consequent loss are avoided, which could not be done in any other way, except by the reconstruction of the old docks, the cost of which would be immense, while that of the pumps is moderate, say, some 3,000*l*. per annum.

A pumping scheme of this character was first adopted by the Author in the case of the Sandon Graving Docks, of which there is a group of six, opening out of the Sandon Dock, constructed in 1851, and which, owing to the increase in the draught of ships, which prevented them entering the shallow graving docks on neap tides, had become much less useful to the Port than they formerly had been. Pumps were therefore provided of sufficient power to raise the water in the docks to such height as might be required by any individual ship, to pass her over the sill of any of the graving docks, and so the graving docks were made fully available for any ship which could enter the dock from which they opened, the sill of which was much lower than those of the graving docks. The success of this experiment warranted the extension of the system, and so it was applied to the Brunswick-George's group, and, afterwards, also adopted at Birkenhead, where the area to be deepened was about 150 acres, and the difference between the outer and inner sills three feet.

In the case of each of these installations it is necessary to do the pumping in a short time at and about high water, therefore the machinery is of a very powerful character. At the Sandon there are four pumps, each having suction pipes 36 inches diameter, and the Coburg and Birkenhead installations each consist of three pumps having 54-inch suction pipes. Some idea of the work done may be formed when it is noted that the discharge of each of the two last-named sets is about equal to that of the River Thames at Teddington. They have now been at work for many years without hitch of any kind. In referring to these schemes, only bare facts are given, details being purposely omitted as unnecessarily encumbering a Paper of this general character.

The works carried out under the Act of 1873 added about 44 per cent. to the dock accommodation previously existing on the Liverpool side of the River, and this of a class much better suited than the older docks for modern requirements; but, notwithstanding this fact, and that the pumping schemes above mentioned provided much additional accommodation for deep-draught vessels, the necessities of the largest class of steamers in the Port are ever pressing, and the Author is now, and has been for some time past, carrying out a design for very important alterations and additions to the group of docks immediately south of the Langton-Alexandra system. The works comprised in the complete scheme are as follows: the alteration by deepening and lengthening of the entrance from the Canada Basin into Canada Dock; straightening of the walls of Canada Dock and deepening of berths there; the construction of a new Branch dock out of Canada Dock as altered; a new Half-tide dock to serve as a vestibule to the improved system and having deep-water river entrances; and the construction of a new large and wide graving dock.

The work of altering Canada Lock, though apparently trifling, has in reality been of considerable magnitude and exceedingly difficult of execution. It meant the cutting out of the masonry at the bottom of a lock 600 feet long by 100 feet broad, and providing a new floor at a level of 6 feet 3 inches lower than before, without disturbing or letting in the side walls, which had to be underpinned for a depth of about 10 feet. The excellence of the granite masonry of which it had been constructed made it doubly difficult and costly, as it was the late Mr. Jesse Hartley's last work, and indeed his *chef d'œuvre*, and the Author, compelled to interfere with such a substantial model of excellent workmanship, did so regretfully. The work, however, has been substantially completed without accident, and ships are now daily passing to and fro through it.

Considerable and costly alterations have also been carried out within the Canada Dock, in taking down and rebuilding in straight and continuous form the old walls of contorted shape, originally built so as to allow of the construction of Huskisson Battery, and quite unsuited for the berthage of modern ships. The large Transatlantic steamers of the Cunard Line now berth at the straightened west wall.

This work was rendered more difficult and expensive in consequence of its being necessary to keep the water within the docks so as not to allow trade to be interfered with.

The new branch out of the Canada, giving a large amount of extra accommodation to the Port, has also been completed. This dock is 1,085 feet in length by 300 feet in width, and has an aggregate quayage of 2,469 feet, amply provided with single and double storey sheds of large size with improved crane appliances. The White Star Company occupy berths on the north and south sides of this dock, and there their largest steamers lie.

In connection with the Canada a new passage 90 feet in width, with a bridge over, has been constructed, to join up with the Huskisson system.

The new Half-tide Dock occupies the site of Sandon Basin and Wellington Half-tide Dock, and will afford room for a large number of great vessels. The sills of the river entrances are laid at a much lower level than any of the existing docks, viz., $20\frac{1}{2}$ feet below Old Dock Sill, so that vessels of the deepest draught will be able to enter and leave the Half-tide on any tide in the year. On neap tides this dock will be used as a lock for vessels passing between the River and docks, which latter will on such tides be maintained on the impounded system, powerful pumps being provided in positions near to the Half-tide dock.

The new Graving Dock, 920 feet long, will be constructed out of the east quay of Canada Dock immediately north of the Branch Dock.

Having now described the dock extensions most recently constructed and in hand at Liverpool, the Author will, before mentioning the accommodation provided for some of the most noteworthy trades, refer shortly to the history of that portion of the Mersey Dock Estate situate on the Cheshire shore at Birkenhead.

In 1855 the dock authorities of that day applied for Parliamentary powers to extend their docks on the Lancashire side of the river. This was only partially acceded to, and, in lieu of powers for their complete proposal, it was arranged that the Birkenhead Docks, then belonging to two independent authorities and only partially developed, should be purchased by the Liverpool Corporation, who in those days administered the affairs of the Liverpool Estate. Two years later the administration of the combined Liverpool and Birkenhead Estates was handed over to an independent Trust to be called 'The Mersey Docks and Harbour Board.' The Birkenhead system, therefore, now forms an integral portion of the Mersey Dock Estate, and is worked in complete unison with the Liverpool system.

The Birkenhead Docks are constructed on the site of a tidal creek, known as Wallasey Pool, which extended inland for about two miles from the left bank of the River, and formerly was the outlet of the drainage of the low lands of the Leasowes, lying between the Dee and the Mersey. The original design, by the late eminent engineer, Mr. James Meadows Rendel, F.R.S., having been partially carried out, was mainly completed on the same lines by Mr. John Hartley, who, however, introduced several important alterations when it came into Dock Board hands.

The main features of the scheme were two large docks, called the East and West Floats, of 120 acres in area, occupying a large portion of the pool, the connection between these docks and the River being by means of a lock, and a half-tide dock called the Alfred, the sills of which, at the Float end, are nine feet below datum, and at the River end twelve feet below.

On taking charge of the engineering of the Estate in 1861, the Author carried out these works to completion, but made several important alterations in Mr. Hartley's design, unnecessary now to particularise. In consequence of the entire area of the Float, East and West, being excavated only to a depth of nine feet below datum, it has been found inconveniently shallow for large modern ships on neap tides, to rectify which the pumping scheme before referred to has been adopted.

Towards the middle of the Liverpool Estate, the Author, about twenty-five years ago, designed and carried out an important system of docks, known as the Waterloo group. They consist of two docks, each running parallel with the river, and approached from the south through the Prince's Half-tide dock, which formed part of the design. The easternmost dock is surrounded on three sides by warehouses of a very extensive character, having a total length of 1,500 feet. They, with a similar group at Birkenhead, were especially constructed for the storage of grain, which at that time was beginning to come into the Port in large quantities. The combined floor area of the two sets of warehouses is twenty-three acres, and they are capable of storing upwards of 400,000 quarters. They are equipped with a novel and elaborate system of machinery, specially designed for facilitating the rapid discharge of ships, and for housing, transmitting, and delivering grain, not only in the warehouse, but also from ship to quay. This system has since everywhere become the recognised means of dealing with grain under similar conditions.

The import of live cattle from abroad, chiefly the United States and Canada, has of late years assumed very large proportions, and a Foreign Animals' Wharf, with extensive lairages and slaughter-houses, and other necessary adjuncts have been provided. These were the first constructions of the kind in the country, and have been increased from time to time until they now occupy twenty-two acres ; the lairages or stables are sufficient to accommodate about 8,000 head of cattle, and a vast number of sheep, the number of cattle which passed through the wharf last year having been about 200,000, and the number of sheep about 500,000. The landing of the cattle is effected at two floating stages, alongside of which cattle-ships can berth at most states of the tide. These stages are moored in the River abreast of the walls, to which they are connected by bridges formed of girders about 150 feet long. The accommodation thus afforded amounts to 850 feet of lie-by. Special cattle runs are laid from the stage to lead into the lairages.

At Liverpool, the Coal Trade of the Port is well provided for on a high-level structure, midway of the Estate, standing on and above the east quays of the Bramley-Moore and Wellington Docks, and north quay of the former. It is abundantly supplied with the most modern appliances, viz. hydraulic cranes, and an elaborate and extensive system of sidings and main lines in direct communication with the Lancashire and Yorkshire Coal-fields. The shipment by this Railway last year amounted to 809,000 tons. Recently a 25-ton hydraulic crane has been erected on the east quay of Herculaneum Dock, chiefly for Lancashire and Yorkshire coal for ships' bunkers.

At Birkenhead an important system of sidings and coal-hoists has been constructed on the south quay of the West Float. These are worked in connection with the coal-fields of North and South Wales, and add materially to the trade and commerce of the Port ; an average of 1,190,000 tons being annually brought to the docks for export and the use of steamships.

The petroleum trade has of late years become so important as to require a large amount of accommodation in the immediate vicinity of the docks. In addition to the storage space provided in the casemates excavated in the solid rock at Herculaneum Dock, to which reference has been made, and which afforded thoroughly safe accommodation for 60,000 barrels, extensive provision for the storage of petroleum in bulk has been made by the erection on some of the undeveloped land at the southern end of the Liverpool Estate of a group of five tanks, varying in capacity from 2,000 to 3,000 tons, and having a total capacity of 12,500 tons.

They are supplied from the ocean-going tank vessels, berthed alongside the west quay of the Herculaneum Dock, the connection being by means of pipes through which the oil is forced by the ships' pumps. Precautions against fire are taken, and each tank stands in a moat of capacity sufficient to hold the whole contents of the tank in case of accident. Railways are laid in connection with each installation.

At Birkenhead, on land belonging to the Dock Board, there are large depôts for the storage of petroleum in bulk close to the docks. They belong to the Anglo-American Oil Company, Limited, and have a total capacity of 18,000 tons. Precautions against fire, similar to those at the Liverpool depôt, have been adopted also in these cases.

Extensive warehouses for the storage of ordinary goods, also for the special storage of tobacco, have been erected in various positions along the Estate, the aggregate floor area of which is about ninety acres. Improved buildings of an extensive character for the storage and display of wool and tobacco are now in course of erection, from the designs of Mr. A. G. Lyster.

The Timber Trade of the Port is located at the north end of the Estate, where large areas are occupied as storage ground and enclosed yards.

The handling of the immense quantities of goods of all sorts in their transit across the Dock Estate is a very important matter, but scarcely more than a passing reference to the appliances required for this purpose and for working the bridges, gates, capstans, &c., can be given. It may be said, however, that in addition to a large amount of machinery worked by hand-power, and to the steam-power available on the steamers now forming the great majority of the sea-carriers, there are provided by the Dock Board a large number of steam and hydraulic cranes, including a 100-ton hydraulic crane, and a 90-ton steam crane, fixed on dock quays, a floating steam crane capable of lifting 100 tons under certain restrictions, and any load up to 30 tons freely, and another floating steam crane of 25-ton power. For the maintenance of the docks, and River channels, a large fleet of dredgers of all types, and hopper barges for carrying dredged material to sea, are provided.

Hydraulic power is largely made use of for working bridges, gates, capstans, &c.; centres of hydraulic power being established at a great many different points at Liverpool and Birkenhead.

The means of communication between the Dock Estate and the adjoining Towns, and between the several parts of the Estate itself, for goods and people, are various and ample.

The development of the City of Liverpool has steadily kept pace with that of the docks, and the interchange of traffic between them is carried on by means of a wide street traversing the whole length of the Estate from north to south, upon which the side streets abut. This thoroughfare is of sufficient width to allow of a double line of railway being laid along its margin throughout, communicating, where necessary, with lines along the dock quays, and also with several railway systems, which have their goods termini adjoining. There are in all about fifteen stations along this six-mile length, divided among the London and North-Western, Lancashire and Yorkshire, Cheshire lines, Midland, Great Northern, Manchester, Sheffield and Lincolnshire, and Great Western Railways, some of which, however, having no direct rail access to Liverpool, have depôts for the interchange of traffic with their fully developed systems at Birkenhead.

For many years a service of large omnibuses traversed the dock lines, from north to south and *vice versa*, every ten minutes throughout the day, and thus added considerably to the convenient working of the Estate.

As, however, the docks extended, this arrangement was found to be inconvenient and insufficient for the wants of the community, and the Author designed an Overhead Railway to be erected at the level of 16 feet above the street lines, with spans standing on slender wrought-iron columns, so as to offer as little impediment as possible to the underneath street traffic. Twenty-three stations, approached by easy stairs, were designed to be erected along the line in convenient positions to some of the side streets.

It was further designed that it should be worked by electricity, that being the simplest arrangement for a railway in such a situation. The plans were all matured for the construction of the work, and tenders were on the eve of being invited, when the Dock Board, as a final decision, concluded that, considering the great labour and responsibility of administering an Estate of such magnitude as that of the Docks, it would be somewhat anomalous to undertake in addition such duties as those of directing a passenger railway which was likely to develop to great magnitude. They therefore entered into an arrangement with a syndicate, who undertook the work, which, to the designs and under the able engineering direction of Sir Douglas Fox and Mr. James Henry Greathead, has been most satisfactorily carried out to completion, and now forms not only a most interesting engineering work, but a valuable public convenience, daily becoming of greater magnitude and importance.

The Mersey Tunnel railway, an important work which has added very materially to the facilities of the passenger cross-river traffic, as well as in effect linking up for passenger purposes the railway systems of the Lancashire and Cheshire sides of the River, was carried out from the designs of Sir James Brunlees and Sir Douglas Fox, and has since been in full and constant use.

The construction of the Tunnel presented considerable difficulties which were very successfully overcome by the Engineers.

Several canal systems, from up the River, work in connection with the Dock Estate, and are important adjuncts to the trade of the Port, the entrance to the docks being generally arranged to meet their special tidal requirements. The only one, however, which has a direct communication with the docks is the Leeds and Liverpool Canal, which traverses the country to the north of Liverpool, and is in direct communication with the manufacturing and mineral centres of Lancashire and Yorkshire.

In the foregoing sketchy narrative of the Mersey and its great Seaport, the Author has been unwillingly compelled, by the exigencies which a Paper of this description imposes upon him, to exclude many matters of great interest, even a descriptive outline of Garston, Widnes, Ellesmere Port, and, though last in time by no means least in magnitude, the Ship Canal, with its entrance at Eastham and great terminal dock system at Manchester, each and all of which not only add to the importance of the River, and the trade which it fosters in its ample embrace, but also give substantial evidence of the commercial activity of our common country, and, as such, are well worthy of enlarged, if not exhaustive, comment. Time forbids more than this passing notice, which the Author trusts will be sufficient apology for not dwelling upon them.

While ships generally, at Liverpool, are discharged, on account of the great range of the tide, in enclosed docks, which are open to the River only at high water, the necessary means of access to boats at all states of the tide, for communication between shore and shore, or with boats in the River, is for the most part afforded by the Floating Landing Stages, which form a striking feature of the riverscape. The first stage at Liverpool, the George's, 500 feet long, was constructed about 1847, and the Prince's, 1,000 feet long, was constructed about 1857; the stages on the Cheshire shore followed these.

The two stages on the Liverpool side, formerly separated from each other by a length of 500 feet for the purpose of retaining the entrance into the old George's Basin, are now joined together, and form one continuous structure, 2,463 feet in length, 400 feet having been recently added from the designs and under the superintendence of Mr. A. G. Lyster. The northern extremity of the stage abuts on to a timber jetty joined with the south pierhead of the Prince's Half-tide Dock, to be used to facilitate the landing of cattle from Ireland and other outside ports. The Liverpool stage is connected with the shore by a series of girder bridges, and also by a floating roadway in the form of a bridge of boats, constructed on the site of the George's Basin, and which, at low water, rests on a stone slipway, having an inclined surface of 1 in 20, enabling the bridge to be easily traversed by wheel traffic. At high water it is all afloat.

The additional 400 feet lately added to the stage has facilitated the arrangement of the Dock Board for berthing the great Atlantic liners alongside the stage for the purpose of landing or taking on board their passengers, which had been discontinued for some twenty years, and which can now be effected at practically all states of the tide, and in an expeditious and effectual manner. Thus the old and inconvenient method of landing by means of tenders has been done away with, to the great advantage of the travelling public.

Convenient examining rooms for the use of the Customs have long been erected at the back of the stage, adjoining these berths, so that little delay occurs in the transit of passengers and their baggage.

In connection with this a very important additional improvement has lately been carried out, in order to render passenger service as expeditious and convenient as possible, by the erection of a capacious railway station on the quay adjoining, and running parallel with, the stage, thus bringing the outgoing passengers alongside their ships, and the incoming *vice versa*. This station is in direct communication with the London and North-Western Railway. The arrangements have been designed and carried out by Mr. A. G. Lyster.

On the Birkenhead side of the River the Dock Board have constructed a landing-stage, known as the Woodside Stage, 800 feet in length, 300 feet of which is vested in the Birkenhead Corporation. The remainder is in use for general dock purposes, chiefly for the landing of cattle. Convenient bridges connected with the quays and a floating roadway, similar to that at Liverpool, have been provided for wheel traffic. A second stage, half a mile further north, has also been provided for general purposes, but is chiefly used by cattle ships.

A large amount of dredging is involved in keeping the docks on both sides of the River clear of silty deposit, and different kinds of dredgers are in use for that purpose. The material removed is chiefly composed of fine silt and mud, and is conveyed to the sea by steam hopper barges and deposited in positions indicated, on behalf of the Conservancy Commissioners, by their Acting Conservator, Admiral Sir George Richards, K.C.B., F.R.S.

The total area of the Estate, both at Liverpool and at Birkenhead, amounts to 1,611 acres, subdivided into 546 acres of water space, made up of docks, half-tide docks and basins, surrounded by 35 miles of quays, warehouses, and sheds, with an aggregate floor area of over 150 acres, the remainder being made up of timber-yards, shipbuilding-yards, open quays and streets, with a residue of undeveloped land and foreshore. The undeveloped portion of the Estate includes a large area of foreshore, amounting to about 200 acres at Tranmere, about one mile further up the river than Woodside. This has lately been acquired by the Board for future dock extension whenever the trade of the Port demands it.

The total number of graving docks belonging to the Mersey Docks and Harbour Boards is twenty-three, having an aggregate length of 14,920 feet of floor.

The total number of ships which entered the Port and paid tonnage rates for the year ending July 1, 1896, was 23,695, having a net tonnage of 11,046,459. In this figure the tonnage in or out only is represented.

The total revenue of the Estate from all sources is about 1,400,000*l.* per annum.

The affairs of the Dock Trust are administered by a body named the Mersey Docks and Harbour Board, with a number of members fixed by Act of Parliament at 28, of whom 24 are elected by the Dock ratepayers, the remaining four being nominee members appointed by the Mersey Conservancy Commissioners.

This important body consists of the First Lord of the Admiralty, the Chancellor of the Duchy of Lancaster, and the President of the Board of Trade, who are represented by an Acting Conservator. That position is now and has been for some years ably filled by Admiral Sir George Richards, K.C.B., F.R.S. The Commissioners are appointed under the authority of Parliament to preserve the navigation of the Mersey, from Warrington and Frodsham bridges to the sea.

In submitting a Paper of this general character, the Author has been compelled, from the extent and variety of the subjects he has touched upon, to do so in the briefest possible manner, with a view to explaining the general features of the Dock Estate and its surroundings, rather than dwell upon details and special works of interest with which the history of the Estate abounds, and which, to be properly dealt with and understood, would require a lengthy paper to themselves.

The North-Western Tribes of Canada.—Eleventh Report of the Committee, consisting of Professor E. B. TYLOR *(Chairman)*, Mr. CUTHBERT E. PEEK *(Secretary)*, Dr. G. M. DAWSON, Mr. R. G. HALIBURTON, *and* Mr. HORATIO HALE, *appointed to investigate the Physical Characters, Languages, and Industrial and Social Conditions of the North-Western Tribes of the Dominion of Canada.*

THE Committee were originally appointed at the Montreal Meeting of the Association in 1884, and, as indicated in the Tenth Report, presented last year at the Ipswich Meeting, it had been determined that that Report should conclude the series. When, however, it was decided to hold the meeting for 1897 in Toronto, it appeared to be appropriate that the work of the Committee begun at the first Canadian Meeting should be concluded at the second, and the Committee were accordingly continued. The concluding Report of the Committee to be prepared for the Toronto Meeting may afford the occasion of pointing out to the Government and public of Canada the necessity for further and systematic investigation of the ethnology of the country.

The Report presented herewith contains a number of observations by Dr. Franz Boas, through whose agency the greater part of the work has been done, chiefly supplementary to articles contained in the Fifht and Tenth Reports. Although the result of previous journeys by Dr. Boas, these have not been heretofore published.

It is now hoped to include in the final Report of 1897 the results of further field work in contemplation and to be directed toward the filling of some gaps still existing in our general knowledge of the tribes of British Columbia, particularly in respect to the anthropometric observations, which, in Dr. Boas' hands, have already yielded results of so much interest.

Sixth Report on the Indians of British Columbia. By FRANZ BOAS.

The following pages contain notes that were collected by me on previous journeys to the North Pacific coast. They supplement mainly the data on the Kwakiutl Indians, given in the Fifth Report of the Committee, and those on the Nass River Indians in the Tenth Report of the Committee.

There still remain two important gaps in our general knowledge of the ethnology of the North Pacific coast. In order to fill these, further anthropometric investigations on the Haida and Hē'iltsuk· and ethnological and linguistic researches among the Hē'iltsuk· would be required. When these have been added to the data gathered heretofore, it will be possible to give a fairly satisfactory general outline of the anthropology of British Columbia.

I. NOTES ON THE KWAKIUTL.

The Kwakiutl tribes speaking the Kwakiutl dialect call themselves by the general name of *Kwā'kwakyewak'*. The following notes refer to this group, more particularly to the tribes living at Fort Rupert.

THE SHAMANS.

The shamans are initiated by animals, supernatural beings, or by inanimate objects. The killer whale, the wolf, frog, and black bear are the most potent animals which have the power of initiating shamans. The cannibal spirit Baqbakuālanuqsī'waē (see Fifth Report, p. 850), the warrior's spirit Winā'lagyilîs, the fabulous sea bear Nā'nîs, the sea monster Mē'koatEm or K·elk·'ā'yuguit, the ghosts, the hemlock-tree, and the quartz may also initiate them. Shamans who were initiated by the killer whale or by the wolf are considered the most powerful ones. Only innocent youths can become shamans.

A person who is about to become a shaman will declare that he feels ill. For four days or longer he fasts in his house. Then he dreams that the animal or spirit that is going to initiate him appeared to him and promised to cure him. If he has dreamt that the killer whale appeared to him, he asks his friends to take him to a small island; in all other cases he asks to be taken to a lonely place in the woods. His friends dress him in entirely new clothing, and take him away. They build a small hut of hemlock branches, and leave him to himself. After four days all the shamans go to look after him. When he sees them approaching, he begins to sing his new songs and tells them that the killer whale—or whatever being his protector may be—has cured him and made him a shaman by putting quartz into his body. The old shamans place him on a mat, and wrap him up like a corpse, while he continues to sing his songs. They place him in their canoe, and paddle home. The father of the young person is awaiting them on the beach, and asks if his child is alive. They reply in the affirmative, and then he goes to clean his house. He must even clean the chinks of the walls, and he must take particular care that no trace of the catamenial flux of a woman is left in any part of the house. Then he calls the whole tribe. The singers arrange themselves in the rear of the house, while the others sit around the sides. For a few minutes the singers beat the boards which are laid down in front of them, and end with a long call: yoo. This is repeated three times. Then the new shaman begins to sing in the canoe, and after a short time he appears in the house, dressed in head-ring and neck-ring of hemlock branches, his eyes closed, and he dances, singing his song. Four times he dances around the fire. During this time the singing master must learn his song. After the dance the new shaman leaves the house again and disappears in the woods. In the evening the people begin to beat the boards and to sing the new song of the shaman which they had learned from him in the morning. Then he reappears and dances again with closed eyes. This is repeated for three nights. On the fourth night when the people begin to sing for him he appears with open eyes. He wears a ring of red cedar bark, to which a representation of the animal that initiated him is attached. He carries a rattle on which the same animal is carved. He looks around, and says to one of the people: 'You are sick.' It is believed that the shaman can look right through man and see the disease that is in him. Then he makes his first cure.

The power of shamanism may also be obtained by purchase. The intending purchaser invites the shaman from whom he is going to buy the power and the rest of the tribe to his house. There the people sing and the shaman dances. During his dance he throws his power into the purchaser, who falls down like one dead, and when he recovers is taken by the shaman into the woods, where both stay for four days. Then he returns, and the same ceremonial is performed that has been described before.

When the shaman has singled out a person whom he declares to be sick, he proceeds with the following performance: He carries a small bundle of bird's down hidden under his upper lip. He lets the sick person lie down, and feels his body until he finds the seat of the disease. Then he begins to suck at the part where the sickness is supposed to be seated, while the people beat the boards and sing his song. Three times he endeavours to suck out the disease, but in vain. The fourth time, after having sucked, he puts his hands before his face and bites the inside of his cheek so that blood flows and gathers in the down that he is carrying in his mouth. Then he takes it unnoticed from his mouth, and hides it in his hands. Now he begins to suck again, holding his hands close to that part of the body where the disease is supposed to be seated. Then he removes them, blows on them, and on opening his hands the bloody ball of down is seen adhering to the palm of the shaman. After a short while he closes his hands again, applies them once more, and shows one or four pieces of quartz, which he is supposed to have removed from the body of the sick person. Then he closes his hands again, and upon a renewed application produces the feathers, which he declares to be the soul of the patient. He turns his hands palm downward, so that the ball adheres to his hand. If it becomes detached and falls down, it signifies that the patient will die an early death. If the ball adheres, he will recover.

For four months the shaman continues to make cures similar to the one described here. Every fourth day he must bathe. After this time people whom he treats are expected to pay him for his services.

It is forbidden to pass behind the back of a shaman while he is eating, because it is believed that he would then eat the soul of the person passing him in this manner. The person as well as the shaman would fall in a swoon. Blood flows from the shaman's mouth, because the soul is too large for him and is tearing him. Then the clan of the person whose soul he has swallowed must assemble and sing the song of the shaman. The latter begins to move, and vomits blood, which he tries to hold in his hands. After a short time he opens his palms, and shows a small bloody ball, the soul which he had swallowed. Then he rises, while the person whose soul he had swallowed is placed on a mat in the rear of the house. The shaman goes around the fire, and finally throws the soul at its owner. Then he steps up to him, blows upon his head, and the person recovers. It is said that the shaman in this case also bites his cheek and hides some bird's down in his mouth, which soaks up the blood and is made to represent the soul. The person whose soul was swallowed must pay four or five blankets for the harm he has done to the shaman, and for his own cure.

The protector of a shaman informs him if an epidemic should be about to visit the tribe. Then he warns the people, and in order to avert the danger lets them go through the following ceremony. He resorts to a lonely place in the woods for one day. In the evening the people assemble in his house and beat the boards three times. When they begin to beat the boards the fourth time, he enters, wearing a large ring of hemlock branches. It is believed that the souls of unborn children and also those of deceased members of the tribe are hanging on the branches of the ring, ten to each branch. He talks to them, and brushes them off from the ring. When he enters another shaman goes to meet him, and strews bird's down on to the ring and on the shaman's head. Then the latter walks around the fire, and stays in the rear of the house. Now every member of the tribe must go to him, and he 'puts them through the ring.' The person who is thus cleansed must extend his right hand first, and put it through the ring, which is then passed over his head, and down along the body, which is wiped with the ring. When the ring has almost reached the feet of the person, the latter must turn to the left, and step out of it with his right foot first, turn on that foot, take out the left foot and turn once more to the left, standing on the left foot. Every member of the tribe is made to pass through the ring. It is believed that this is a means of preventing the outbreak of the epidemic. Sick persons must pass through the ring four times. Nobody is allowed to speak or to laugh during this performance. After the shaman has finished, he speaks to the people, making statements intended to show them that he knows even their most secret thoughts.

The shaman wears his neck-ring of red cedar bark all the time.

Powerful shamans are able to transform stones into berries.

Their dance is so powerful that the ground gives way under their steps, and they disappear underground.

Songs of Shamans.

1. *Song of Shaman, initiated by the Killer Whale.*

1. *K·oē'k·'ulagyīlakyastlōq hai'ligyaiūkoastlasa nau'alakuē wahai*
Making alive means of healing from this supernatural being wahai
ēhē' nau'alakuē.
ēhē' supernatural being.

2. *Gyilgyildōguilakyastlē hai'ligyaiūkoaqsō nau'alakuē wahai*
Making life long means of healing from this supernatural being wahai
ēhē' nau'alakuē.
ēhē' supernatural being.

3. *Gyū'gyayapalayūqdōq nau'alakuēkoaqsō nau'alakuē wahai*
Going along under water supernatural being from this supernatural being wahai
ēhē' nau'alakuē.
ēhē' supernatural being.

4. *Sī'sowapalayūqdōq nau'alakuē wahai ēhē' nau'alakuē.*
Made to paddle under water supernatural being wahai ēhē' supernatural being.

Translation.

1. He received the power of restoring to life from the supernatural being.
2. He received the power of lengthening life from the supernatural being.
3. His supernatural helper gave him the power to travel under water.
4. His supernatural helper gave him the power to paddle along under water.

2. *Song of Shaman, initiated by the Killer Whale.*

1. *K·oē'k·'ulagyīlakyastlōq nau'alakua.*
Life-maker real this supernatural being.
2. *K·ā'sElētlīlayatlōq nau'alakua.*
Making walk this supernatural being.
3. *Ts'ē'tltsāk'uēk·īlayatlōq nau'alakua.*
Making life short this supernatural being.

TRANSLATION.

1. My supernatural power restores life.
2. My supernatural power makes the sick walk.
3. My supernatural power cuts life short.

3. *Song of Shaman, initiated by the Wolf.*

1. *Laistalī'sElayūQdōQs gyi'lgyildōguilatlaiHdē k·auq nau'alak*
Made to go around the world by making life long past the supernatural being
hai tlō'koala.
hai magic.

2. *To-istā'lisElayūQdōQs gyi'lgyildōguilatlaiHdē k·auq nau'alak*
Made to walk around the world by making life long past the supernatural being
hai tlō'koala.
hai magic.

3. *Mā'tEla ōnō'guā'yask·ai gyi'lgyildōguilatlaiHdē k·auq nau'alak hai*
Ahead I the poor one making life long past the supernatural being hai
tlō'koala.
magic.

TRANSLATION.

1. The one who makes life long made me go all around the world, the supernatural being.
2. The one who makes life long made me walk all around the world, the supernatural being.
3. The one who makes life long placed my poor self ahead of all, the supernatural being.

4. *Song of Shaman, initiated by BaqbakuālanuQsī'waē.*

1. *Ai, hai'alikyilaamQdE nō'guaia k·'oā'nastēs BaqbakuālanuQsī'waē, dō'k·ula.*
Ai, healing all the time I wildness of BaqbakuālanuQsī'waē, behold!

2. *Ai, qoā'q'ulagyīyāitkyas ōnō'gua k·'oā'nastēs BaqbakuālanuQsī'waē, dō'k·ula.*
Ai, saving life I wildness of BaqbakuālanuQsī'waē, behold!

TRANSLATION.

1. Behold! I am able to heal by the power of the wildness of BaqbakuālanuQsī'waē
2. Behold! I save lives by the power of the wildness of BaqbakuālanuQsī'waē.

5. *Song of Shaman, initiated by the Echo.*

1. *Yāhau, hē'ilikyayatlōQ gyi'lgyildōguilaqs hēilikyayuqdē haus*
Yāhau, healing with making life long with means of healing of
tlō'koalakyas'ō.
the magician real.

2. *Hīyak·āyatlōQ gyi'lgyildōguilaqs Hēyak·ayōqda haus*
Blowing water with making life long with means of blowing water of
tlō'koalakyas'ō.
the magician real.

TRANSLATION.

1. Yāhau. The power that makes life long lets me heal with the means of healing.
2. Yāhau. The power that makes life long lets me blow water with the means of blowing water.

BIRTH.

The husband of an *enceinte* woman in the seventh month of pregnancy prepares to insure an easy delivery by collecting the following four medicines: four tentacles of a squid, a snake's tail, four toes of a toad, and seeds of *Peucedanum leiocarpum*, Nutt. If the birth should prove to be hard, these objects are charred, powdered, and drunk by the mother. The toad's toes are also moved downward along her back. This is called 'making the child jump' (*dâ'yuqstē*). It is worth remarking that *Peucedanum leiocarpum* is used as a powerful medicine also by the Salish tribes of Vancouver Island (see Sixth Report of the Committee, 1890, p. 577), who call the plant k·ᴇqmē'n, while the Kwakiutl call it *k·'aqmē'n*. Judging from the form of the word, I think that it is rather Salish than Kwakiutl. Certainly the belief in the power of this plant was transmitted from one tribe to the other.

During the period of pregnancy the husband must avoid to encounter squids, as this would have the effect of producing a hard delivery.

When the woman is about to be confined, she leaves the house accompanied by two of her friends who are to assist her. The latter dig a hole in the ground, and one of them sits down on the edge of the hole, stretching her legs across it so that her feet and the calves of her legs rest on the opposite edge. Then she spreads her legs, and the woman who is about to be confined sits down on her lap, straddling her legs so that both her feet hang down in the pit. The two women clasp each other's arms tightly. The third woman squats behind the one who is about to be confined, pressing her knees against her back and embracing her closely, so that her right arm passes over the right shoulder, her left arm under the left arm of her friend. The child is allowed to lie in the pit until after the afterbirth has been borne. Then the navel string is tied and cut, and the child is taken up.

For four days the afterbirth is kept in the house. A twig of yew wood about four inches long is pointed and pushed into the navel string, which is then tied up. Four layers of cedar bark are wrapped around the afterbirth. That of boys is in most cases buried in front of the house-door. That of girls is buried at high-water mark. It is believed that this will make them expert clam-diggers. The afterbirth of boys is sometimes exposed at places where ravens will eat it. It is believed that then the boys will be able to see the future.

The navel string is believed to be a means of making children expert in various occupations. It is fastened to a mask or to a knife, which are then used by a good dancer or carver, as the case may be. Then the child will become a good dancer or carver. If it is desired to make a boy a good singer, his navel string is attached to the baton of the singing master. Then the boy calls every morning on the singing master while he is taking his breakfast. The singing master takes his baton and moves it once down the right side of the boy's body, then down the left side; once more down the right side, and once more down the left side. Then he gives the child some of his food. This, it is believed, will make him a good singer.

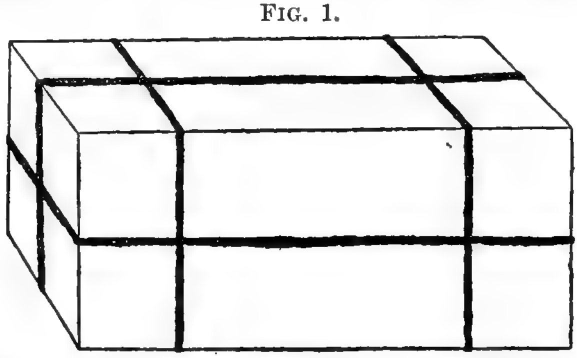
I referred in the Fifth (p. 847) and Sixth (p. 614) Reports to the beliefs in regard to twins. I have received the following additional information in regard to this subject. Four days after the birth of twins, mother and father must leave the village and resort to the woods, where they stay for a prolonged period. They separate, and each must pretend to be married to a log, with which they lie down every night. They are forbidden to touch each other. They must not touch their hair. Every fourth day they bathe, rub their bodies with hemlock twigs, and wipe them with white shredded cedar bark. Their faces are painted red all the time. For this purpose they do not use vermilion, but ochre. They are not allowed to do any work. These practices are continued for a period of sixteen months. During this period they must not borrow canoes or paddles from other people; they must use bucket and dishes of their own. If they should use the belongings of other persons, the latter would have also twin children. The woman must not dig clams and the man must not catch salmon, else the clams and the salmon would disappear. They must not go near a fire in which bracken roots are being roasted. It is believed that the birth of twins will produce permanent backaches in the parents. In order to avert this, the man, a short time after the birth, induces a young man to have intercourse with his wife, while she in turn procures a girl for her husband. It is believed that then the backache will attack them. A year after the birth of the twins the parents put wedges and hammers into a basket, which they take on their backs and carry into the woods. Then they drive the wedges into a tree, asking it to permit them to work again after a lapse of four months.

All the young women go to the pit over which the twins were born and squat over it, leaning on their knuckles, because it is believed that after doing so they will be sure to bear children.

BURIAL.

When a person is about to die, his friends spit water all over his body. After death the body is carefully washed, so that every particle of the bodies of the survivors that might adhere to the corpse may be removed. Even the places where their breath might have touched the body must be carefully washed. This is done in order to prevent that the survivors might accidentally bewitch themselves (see Sixth Report, p. 610). If the death occurs during the night, the body is left in the house until daylight; if it occurs during the day, it is removed at once. It must not be taken out of the door, else other inmates of the house would be sure to die soon. Either a hole is made in one of the walls, through which the

Fig. 1.



body is carried out, or it is lifted through the roof. It is placed behind the house to be put into the box that is to serve as a coffin. If it were placed in the coffin inside the house, the souls of the other inmates would enter the coffin too, and then all would die. The coffin is placed at the right-hand side of the body. Then a speaker calls the relatives of the deceased, saying: 'Let the dead one take away all the sickness of his friends.' Then they all come and sit down at the side of the corpse, wailing for a short time. Now they arise and give the body a kick. They turn once toward the left, and give the body another kick, repeating this action four times. This is called 'pushing away the love of the deceased,' that he may not appear in their dreams, and that his memory may not trouble them.[1] Then the wife of the deceased lets the children take off their shirts and sit down, turning their backs towards the corpse. She takes his hand and moves it down the backs of the children, then moving the hand back to the chest of the body. With this motion she takes the sickness out of the bodies of the children and places it into the body of the deceased, who thus takes it away with him when he is buried.

After this ceremony an olachen net is placed over the head of the body, his face is painted red, and the body is wrapped in a blanket. Then it is tied up, the knees being drawn up to the chin. Now four men of the clans of which the deceased was not a member lift the body to place it into the box. Four times they raise it. The fourth time they actually lift it over the box. Four times they move, but only the fourth time they actually let it down into the box. If the box should prove too small, they must not take it out again, but the body is squeezed in as best they can, even if they should have to break its neck or feet. The head is placed at the edge where the sides of the box are sewed up (see Fifth Report, p. 817) because the soul is believed to escape through the joint. The soul leaves the body on the fourth day after death, escaping through the place where the frontal fontanel of the child is located. The box is tied up, as indicated in fig. 1. As soon as the four men who carry the coffin to the burial-ground raise it the women cease to wail, because their tears would recall the deceased. The relatives are not allowed to attend the funeral, as it is believed that their souls would stay with that of their dead friend. Twelve women accompany the coffin. Children are not allowed to go with it. When the tree on which the body is to be deposited has been reached, four poor men are sent up to carry a rope by which to haul up the coffin. When they have reached the branch on which the coffin is to be placed, they lower the rope. The men who remained below pretend three times to tie the rope to the coffin. The fourth time they really tie it. Then the men in the tree pull up the rope. Three times they rest in pulling it up, so that the coffin reaches its final resting-place after having been pulled four times. It is placed on the branch and covered with a large board. Then the men climb down again, cutting off the branches for some distance under the coffin. When the men come down from the tree, the women resume their wailing. They scratch their cheeks with their nails. (The Koskimo use shells for this purpose.) After they have returned to the village the blankets and mats which the deceased used are burnt, together with the objects which he used. Food is also burnt for him. All this is intended for his use, and is burnt because the dead can use only burnt objects. If he has left a widow, she must use his blankets, mats, kettle, &c., once before they are burnt. After the death of a woman the widower must do the same. After four days a person belonging to another clan cuts the hair of the mourners. The hair is burnt. This service is paid for heavily, because it is believed to shorten the life of the one who has rendered it. The climbers receive a payment of two blankets each; those who placed the corpse in the coffin and carried it to the burial-ground receive one blanket each for their services.

[1] The widow and the children of the deceased wear strings made of mountain-goat wool and white cedar bark mixed, one around the neck, one around the waist, and two connecting ones down the chest; also strings of the same material around wrists, elbows, knees, and ankles.

Chiefs and common people were buried on separate trees. There is also a separate tree on which twins are buried.

Nowadays the bodies are mostly buried in small grave-houses. The custom of raising the coffin three times before it is placed in its final resting-place is still adhered to.

The customs of the Koskimo and Tlatlasiqoala differ somewhat from those of the Kwakiutl. They place the body in the box in the house. Before doing so the box is turned round four times. Then a hole is cut into the bottom of the box with an axe, which is raised three times before the hole is really cut. This is the breathing hole of the soul, which does not die or escape until the fourth day after the death of the body. The coffin, before it is carried to the burial-ground, is placed on the beach.

The Kwakiutl paint twins, before they are buried, red all over. Four feathers are attached to the coffin. Nobody is allowed to wail for them. A surviving twin is washed in the water with which the corpse of the dead one was washed.

When a person dies by an accident, and his body is not recovered, a grave is made for him, which consists simply of painted boards. The saying is that, if this were not done, it would be as though a dog had died. Nobody is allowed to walk behind such a grave, as by doing so he would indicate his desire to lie in a grave.

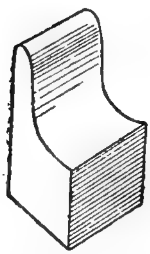
The widow, particularly if she has many children, must undergo a very rigorous ceremonial. On the evening of the third day after the death of her husband, her hair is cut. At the same time a small hut is built for her. It is made of the mats which were hanging around the bed of the deceased. The roof is made of the boards which were placed over his bed in order to keep the soot off. An old woman, preferably one who has been a widow four times, is appointed to assist her. On the fourth morning after the death of her husband, she must rise before the crows cry. She is not allowed to lie down, but must sit all night with her knees drawn up to her chest. She eats only four bites four times a day, and drinks only four mouthfuls four times a day. Before taking water or food she raises it three times. If she thinks that her husband has been murdered, she takes her food up, saying that it is the neck of her husband's enemy, and calling his name, she bites it four times. Then she throws it into the fire, saying : 'This will be your food when you are dead.' That means that the person whom she named must soon die. When she is tired she stretches her legs, first the one, then the other, naming her enemy. This is also believed to bring him death. After four days the old woman washes her and wipes her with a ring of hemlock branches, as described above. This is repeated four times in intervals of four days. After the last washing her old blanket is hung over the stump of a tree, and her hat, which she wears all the time, is hung on top of the stump. Then she is given new clothing, and is taken back to the house. There she must stay in one corner, where she has a small fire of her own. Her children are not allowed to see her. When she leaves the house, she must pass out of a small door of her own. Four times she must turn before putting her foot in the doorway. Four times she must put her foot forward before actually going out, and in the same manner she returns. The old woman now washes her every sixth day, and rubs her with the ring of hemlock branches. After the fourth washing she is permitted to come to the fireplace, but she must avoid going around the fire. Now the old woman washes her every eighth day, and then four times more every twelfth day. Thus the whole period extends over one hundred and twenty days.

If the woman is poor, and has many children, four washings in intervals of ten days are substituted for the washings of the last eighty days, thus reducing the whole period to eighty days. During all this time she must not cut her hair. She does not wail during the first sixteen days of the mourning period while she is confined in the small hut.

GAMES.

1. *Ēibayu.*—These dice have the shape indicated in fig. 2. The casts count according to the narrowness of the sides. This game is also played by the Tlingit of Alaska.

FIG. 2.



2. *Tl'ᴇ'mkoāyu.*—A stick, about three feet long, with a knob at its end, is thrown against an elastic board, which is placed upright at some distance. If the stick rebounds and is caught, the player gains four points. If it rebounds to more than half the distance from the player to the board, he gains one point. If it falls down nearer the board than one-half the distance, or when the board is missed, the player does not gain any point. The two players throw alternately. Each has ten counters. When one of them gains all the counters, he is the winner of the stake. When the stick falls down so that the end opposite the knob rests on the board, the throw counts ten points.

3. *Ā'laqoa*, the well-known game of lehal, or hiding a bone; played with twenty counters.

4. *T'ē'nk·oayu*, or carrying a heavy stone on the shoulder to test the strength of those who participate in the game.

5. *Mō'k·oa.*—This game was introduced from the Nootka. It is played between tribes. An object is given to a member of one tribe, who hides it. Then four members of another tribe must guess where it is. They are allowed to guess four times. If they miss every time, they have lost. This game is played for very high stakes.

VARIOUS BELIEFS AND CUSTOMS.

In seal feasts the chest of the seal is given to the highest chief; the feet are given to those next in rank. The young chiefs receive the flippers, and the tail is given to the chief of the rival clan, who must give a feast in return. The hunter, before returning home, cuts off the head of the seal and gives it to his steersman. He eats the kidney before going home, and cuts a strip three fingers wide along the back. These customs are said to have been instituted by *Ō'maqt'ā'latlē*, the ancestor of the clan *Gyī'gyilk·am* of the *K·'ō'moyuē*.

The lowest carving on a totem pole is that which the owner inherited from his father. The higher ones are those which he obtained by marriage.

The hunter, before going out to hunt seals or sea-otters, or other sea animals, rubs his whole canoe with the branches of the white pine, in order to take away all the bad smell that would frighten away the animals.

In order to secure good luck, hunters of sea animals bathe in the sea before starting. Hunters of land animals bathe in fresh water. Both rub their bodies with hemlock branches.

Of the first halibut caught in the season the stomach is eaten first, then the pectoral fins, next the head. The rest is divided. If this were not done, the halibut would disappear.

Hunters carve the figure of any remarkable animal that they have killed on the butts of their guns, or on their bows.

The souls of hunters are transformed into killer whales; those of hunters who pursue land animals become wolves. Only when a killer whale or a wolf dies can their souls return and be born again. Hunters have the bow seat of their canoes ornamented, and a hole cut in the centre of the seat. It becomes their dorsal fin when they become killer whales after their death. It is believed that, after the death of a hunter, the killer whale into which he has been transformed will come to the village and show itself. When a great number of killer whales approach a village, it is believed that they come to fetch a soul.

Not only hunters are transformed into killer whales. I was told that at one time a killer whale had been killed, the flipper of which showed a scar as though it had been burnt. Not long before this event a girl had died who had at one time burnt her hand. She was identified with the killer whale.

When a wolf has been killed, it is placed on a blanket. Its heart is taken out, and all those who have assisted in killing it must take four morsels of the heart. Then they wail over the body:

Âlawēstᴇns hēgyōsō qᴇns nᴇmōqtsēqdē—*i.e.*, Woe! our great friend.

Then the body is covered with a blanket and buried. A bow or a gun with which a wolf has been killed is unlucky, and is given away by the owner. The killing of a wolf produces scarcity of game.

Wolf's heart and fat are used as medicines for heart diseases (see Sixth Report, p. 613).

Women are forbidden to touch a wolf, as else they would lose their husbands' affections (see Sixth Report, p. 613).

The screech owl is believed to be the soul of a deceased person. The Indians catch them, paint them red, and let them free, asking for long life.

The root of the bracken (*Pteris aquilina*, L.) is believed to know everything that is going on in the house in which it is being roasted. It must be treated with great respect. If a person should warm his back at the fire in which it is being roasted, he will have backache. Parents of twins, and people who have had sexual intercourse a short time previously, must not enter a house in which the roots are being roasted.

When a person dreams that he goes up a mountain and the latter tilts over, it signifies that he will die soon.

The gum of the red pine is chewed. That of the white pine is not used by girls, because it is believed to make them pregnant.

The world is described as a house. The east is the door of the house; the west is the rear of the house. North is called 'up the river,' south 'down the river.' In the north of the world is the mouth of the earth. There the dead descend to the country of the ghosts.

The part of the beach immediately to the west of Fort Rupert, in front of the place where formerly the village of the sub-tribe Kuē'qa stood, is called the village of the ghosts, who are believed to reside there from time to time.

When there is an eclipse of the sun a man, named *Bā'wulē*, is required to sing :—

> Hōk·oai', hōk·oai', hōk·oalai', ā'tlas lalaq ts'ā'ya laqsgya Bāwulē'—
> Vomit it, vomit it, vomit it, else you will be the younger brother of Bāwulē'.

In order to gain the love of a girl the following philter is used : The tongues and gizzards of a raven and of a woodpecker are placed in a hollow stick, together with some saliva. They are mixed with the latter ; the tube is closed and worn under the blanket. The underlying idea was explained to me thus : The woodpecker and the raven are pretty birds ; therefore the girl will consider the man who wears them just as pretty and attractive.

The tongue of a snake or of a frog is also used as a philter. They are believed to make the wearer irresistible to everybody.

Another philter is as follows : The man wears a snake skin on his body for some time. About the month of August he gathers a root called *tl'ē'tayas*, which resembles in shape two people embracing each other. He procures four hairs of the girl whom he loves, which, together with four hairs of his own, he places between the two portions of the root which resemble the two people. The root is tied up with sinews taken from a corpse, and wrapped in the snake-skin which the man has been wearing. For four days after, the man must not look at the girl. Then she will call him, but he must not follow her. Finally she will come to him.

In order to bewitch a person it is necessary to obtain some of his soiled clothing, hair, or blood. I described some methods of witchcraft in the Sixth Report (p. 612). The following method is also used : The clothing of the enemy is placed in the mouth of a lizard, the head of which has been cut off. Then a snake's head is pulled over the lizard's head, so that the latter is in the mouth of the snake. The whole is placed in the mouth of a frog, which is then sewn up. This bundle is tied as tightly as possible with the sinews of a corpse, and placed inside a stick which has been hollowed out, and is then tied up again with the sinews of a corpse. The whole is then covered with gum. This package is placed on the top of a hemlock-tree which is growing at a windy place. In winter this method of witchcraft does not do much harm, but as soon as it grows warm the victim must die.

If a person is believed to be bewitched (*ē'k·a*) his body is rubbed with white cedar bark, which is then divided into four parts, and buried in front of four houses, so that the people when entering or leaving the house must step over it. This will break the spell.

If the children of a couple always die while very young, the little finger of the last child to die is wound with a string. A notch is cut in the upper rim of the burial box, in which the finger is placed. Then the cover is put on, and the finger is cut off. It is hidden in the woods that nobody may find it. The body of the child is placed on a new tree, not on the tree on which other children are put.

II. The Houses of the Tsimshian and Nîsk·a'

The houses of the Tsimshian and of the Nîsk·a' are square wooden structures, like those of the Haida and Kwakiutl, but they differ somewhat in the details of construction. While the house of the Haida (see

Fig. 3.

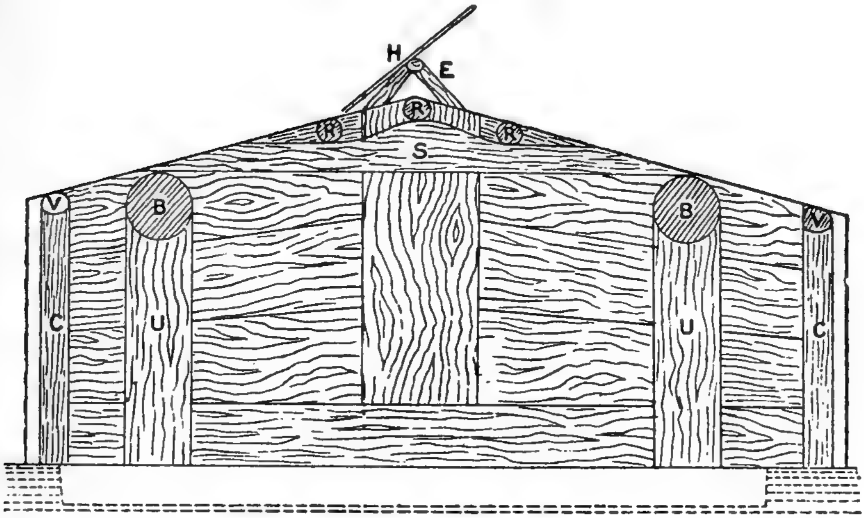
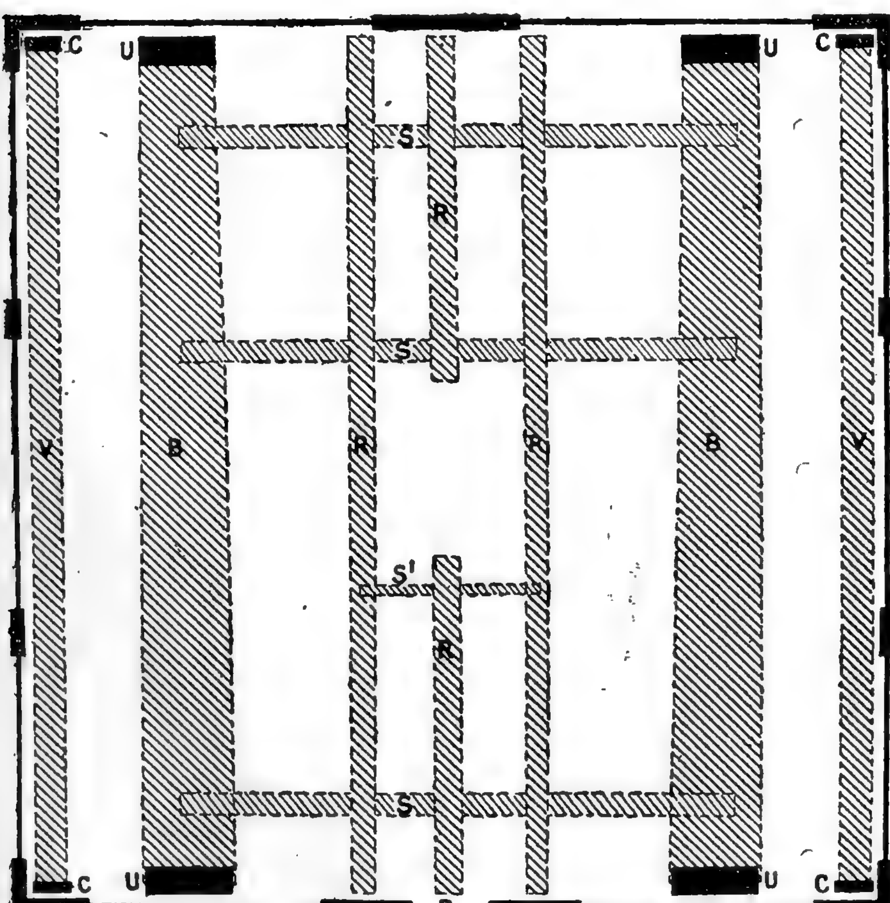
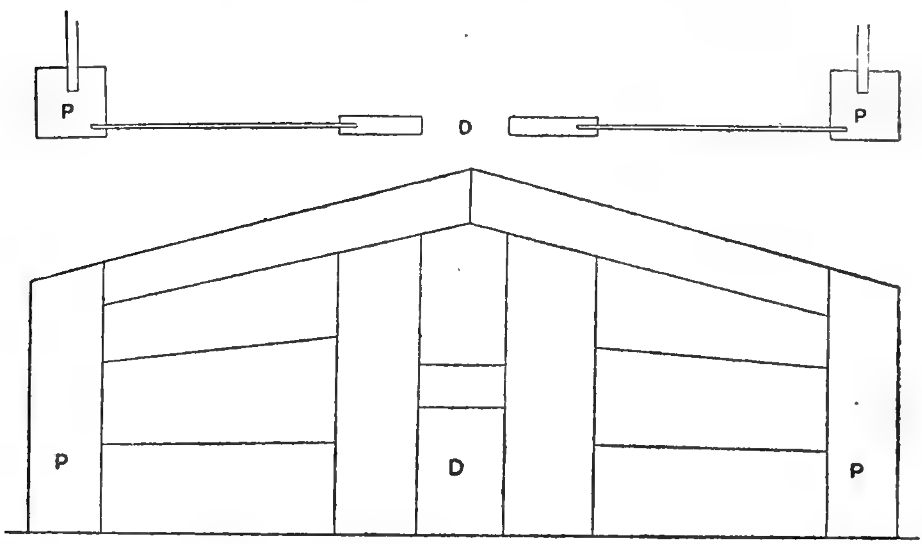


Fig 4.



Dr. G. M. Dawson, 'Report of Progress, Geol. Surv. of Canada,' 1878-79, Plates III., IV., and V.), generally has on each side of the central line three heavy beams which support the roof, the house of the Tsimshian and of the Kwakiutl has only one pair of heavy beams, one on each side of the doorway. In the Kwakiutl house these two beams, which rest on heavy posts, stand no more than 6 feet apart (see 'Proc. U.S. Nat. Mus.,' 1888, p. 210). In the houses of the Tsimshian and Nîsk·a' they stand about halfway between the central line and the lateral walls. This arrangement necessitates that provision is made for a ridge-beam. The heavy beams B rest on the uprights U, which are seldom carved. On top of the beams four supports S are laid, on which rests the ridge-beam R. The latter consists of two parts, leaving a space in the middle for the smoke-hole. Sometimes, but not regularly, two additional beams R rest on these supports. In a few cases the central ridge-beam is then supported by a smaller support S′. The lower end of the roof is either arranged as shown in figs. 3 and 4, or as indicated in fig. 5. In the former

FIG. 5.



case the roof-supports are separate from the walls; a beam V is laid on the uprights C, and the roof-boards rest on the beams R, B, and V. In the latter case (fig. 5) the corner-post P is connected with the rear corner-post by a square beam which supports the lower ends of the roof-boards. The walls of the old houses consist of horizontal planks of great width. The thick planks of the front, rear, and sides (figs. 4, 5) are grooved, and the thinner planks are let into these grooves. The two mouldings of the front are also thick planks, which are grooved. Over the door D is a short, heavy plank, on which rests a single thinner vertical plank. The construction of the back may be seen in fig. 3. Sometimes the houses are built on steep banks, so that only the rear half is built on the ground. In this case a foundation of heavy cedar-trees is built. A short log is placed with its end into the bank, the butt end standing out towards the beach, where the side wall is to be. Another log is placed in the same manner where the second side wall is to be. A third heavy log is placed over the butts of the two projecting logs. Then two more logs are put on top of the preceding one with their ends into the bank, and thus a foundation is built up to the level of the embankment. This is covered with a platform, and the house is built about eight or ten feet back from its outer edge, so that the platform forms the front portion of the floor of the house, and also a walk leading to the house-door.

III. The Growth of Indian Children from the Interior of British Columbia.

The table below shows the results of a compilation of the rates of growth of Indian children of the following tribes:—Ntlakyā'pamuq, Shuswap, Okanagan, Kalispelm, Yakima, Warm Springs. I have combined all these tribes, because the adults have very nearly the same stature, and because the geographical environment is very much alike. The numbers of individuals are rather small, but nevertheless a few results of general interest may be deduced from it.

It will be noticed that in the eleventh, twelfth, and thirteenth years girls are taller than boys. This agrees closely with the period during which the same phenomenon takes place among the whites, and is later than among the Indians of southern latitudes. The decrease in variability is not very well marked, probably because there is a considerable uncertainty in regard to the estimated ages of the children. Still, it appears that there is a distinct drop in the fifteenth year in boys, and in the thirteenth year in girls. Among the Mission Indians of Southern California this drop takes place between the thirteenth and fourteenth years in boys, between the ninth and eleventh years in girls. Among the white children of Massachusetts the drop takes place between the fifteenth and sixteenth years in boys, between the fourteenth and fifteenth years in girls—*i.e.*, nearly at the same time as, or a little later than, among the Indians of British Columbia.

Boys				Girls		
Age	Number of cases	Average variation	Average stature	Average stature	Average variation	Number of cases
		mm.	mm	mm.	mm.	
2	5	± 2·8	796	—	—	—
3	3	± 3·0	853	860	± 1·5	4
4	4	± 5·2	983	990	± 2 4	5
5	17	± 6·5	1,073	1,073	± 3·3	10
6	12	± 5·8	1,161	1,100	± 2·8	14
7	12	± 3·6	1 200	1,207	± 4·5	11
8	13	± 4·3	1,256	1,207	± 5·9	20
9	20	± 4·3	1,286	1,263	± 4·5	19
10	29	± 6·5	1,365	1,338	± 4·8	25
11	19	± 5·8	1,386	1,400	± 5·0	18
12	37	± 5·0	1,423	1,443	± 6·5	19
13	18	± 5·9	1,461	1,487	± 5·4	13
14	21	± 5·8	1,527	1,508	± 4·3	16
15	18	± 3·8	1,578	1,517	± 6·0	15
16	17	± 5·1	1,611	1,537	± 4·4	20
17	12	± 5·0	1,622	—	—	—
18	5	± 2·5	1,674	—	—	—
19	6	± 5 2	1,692	—	—	—

It is of interest to compare the rate of growth of Indian and white children. In the following table I give the statures of the Indian children of British Columbia and of the white children of Worcester, Mass. :—

Age: Years	Boys			Girls		
	Indian	White	Difference	Indian	White	Difference
5	1,073	1,097	−24	1,073	1,074	− 1
6	1,161	1,127	+34	1,100	1,113	−13
7	1,200	1,170	+30	1,207	1,175	+32
8	1,256	1,223	+33	1,207	1,216	− 9
9	1,286	1,270	+16	1,263	1,266	− 3
10	1,365	1,340	+25	1,338	1,328	+10
11	1,386	1,388	− 2	1,400	1,370	+30
12	1,423	1,429	− 6	1,443	1,447	− 4
13	1,461	1,476	−15	1,487	1,479	+ 8
14	1,527	1,543	−16	1,508	1,537	−29
15	1,578	1,622	−44	1,517	1,570	−53
16	1,611	1,658	−47	1,537	1,584	−47
17	1,622	1,685	−63	—	1,594	—
18	1,674	1,700	−26	—	1,591	—
19	1,692	1,713	−21	—	—	—

It appears from both tables, although more clearly in the case of boys, that the Indian child is taller than the white child, although in the adult the inverse relation of statures prevails. I have shown at another place that a similar relation prevails between full-bloods and half-breeds ('Verh. Berliner Anthr. Ger.,' 1895, p. 386). It is therefore probable that the difference in the laws of growth is a racial phenomenon.

NASAL INDEX OF SKULLS.

On p. 544 of the Tenth Report of the Committee I pointed out the difference of racial types found along the coast, and stated (p. 545) that the nose of the Kwakiutl represents a peculiar type which is not found in any other region of the coast. I have investigated the same question on a series of skulls, and have obtained the following results :—

Nasal Indices of Skulls

Index	Kwakiutl	Comox	Nanaimo and Sanitch	Songish, not deformed	Chinook
37	1	—	1	—	—
38	1	—	—	—	—
39	1	—	—	—	—
40	1	—	1	—	—
41	2	1	—	+	1
42	2	—	3	+	1
43	5	1	—	2	—
44	2	1	3	2	1
45	2	—	5	—	—
46	2	1	—	2	2
47	3	1	3	1	1
48	—	1	2	—	2
49	1	—	2	—	1
50	—	—	3	—	2
51	—	—	4	—	—

Nasal Indices of Skulls (continued).

Index	Kwakiutl	Comox	Nanaimo and Sanitch	Songish, not deformed	Chinook
52	—	—	—	1	—
53	—	—	3	—	—
54	—	1	3	2	1
55	—	—	2	—	—
56	—	—	1	—	—
57	—	—	—	—	—
58	1	—	1	—	—
59	—	—	—	—	—
60	—	—	—	—	—
61	—	—	—	—	—
62	1	—	—	—	—
⋮	⋮	⋮	⋮	⋮	⋮
71	—	—	1	—	—
Cases . .	25	7	38	10	12
Average .	45·1	46·6	49·6	47·8	47·6

It appears that the nasal index of the Kwakiutl is by far the lowest, and that it increases among the Coast Salish. The nasal bones are at the same time large and high, while among the Coast Salish they are small, decidedly flat, and sometimes synostosed.

IV. Linguistic Notes.

1. Kwakiutl.

I indicated on p. 659 of the Sixth Report of the Committee that there seemed to exist cases in Kwakiutl. I have since investigated this matter more fully, and find that cases clearly exist.

There is a definite article which has the following forms:—

Nominative: *da.*
Genitive: *sa*
Accusative: *qa.*
Locative: *laqa.*

The indefinite article is expressed only in the genitive and locative:—

Genitive: *s.*
Locative: *laq.*

The possessive pronoun has the following cases:—

	1st Person.	2nd Person.	3rd Person.
Nominative:	*—ᴇn*	*—ōs*	*—as.*
Genitive:	*sᴇn*	*sōs*	*sēs.*
Accusative:	*qᴇn*	*qōs*	*qēs.*
Locative:	*laqᴇn*	*laqōs*	*laqēs, laq—(a) s*

Examples: 1. Definite Article:—

Nominative: *Yā'k·'ēgyatlē da nᴇmō'k'uē bᴇguā'nᴇm.*
It said the one man.

Genitive: *Gyī'k·amaya sa mā'q'ēnôq.*
The chief of the killer whales

Accusative: *Aatltsā'la qa dō'weq.*
He tore the cedar twigs

Locative: *Lā'gyaa lā'qa ts'ᴇlā'tl.*
He arrived at the lake.

2. Indefinite article:—

Nominative: *Mā'q'ēnôq ky'ā'tama'ya sa gyōk'.*
Killer whale painting on front of the house.
Genitive: *tlEmā'îs s Tsā'qîs.*
the beach of Tsā'qîs.
Accusative: *K·'ā'qa wāp.*
He found water.
Locative: *Gyō'qwulsa sa gyō'kuē laq Ky'ā'k·a.*
He built a house of the house at Ky'ā'k·a.

3. Possessive pronoun:—

1st Person. Nominative: *Yî'qa g·u'nky'în k·'a'lkoa.*
This my nettle harpoon-line.
Genitive: *Iā'lak·EmEn sEn ō'mpē.*
I am sent by my father.
Accusative: *LamEn aq'ē't qEn likyā'yu.*
I took my hammer.
Locative: *Laē'tl lā'qEn gyō'kua.*
He entered in my house.

3rd Person. Nominative: *Gyō'kuas.*
His house.
Genitive: *Gyō'quat sēs gyō'kuē.*
He had a house of his house.
Accusative: *Dā'la qēs sē'ky'ak·anō.*
He took his staff.
Locative: *Nē'Hlat'a lāqēs ts'ā'yē.*
But he said to his younger brother.

I pointed out in the Sixth Report that these possessive forms may be modified according to the location, as near speaker, near person addressed, absent visible, absent invisible. I have not, so far, discovered these distinctions in the genitive, while they occur in all the other cases.

2. NÎSK·A.

As my treatment of the Nîsk·a language in the Tenth Report of the Committee was very brief, I give here some additional information in regard to it.

In the Fifth Report (p. 878) I have treated the formation of the plural in the Tsimshian, and Count von der Schulenburg has treated the same subject on pp. 9 ff. of his work ('Die Sprache der Zimshîan-Indianer.' Braunschweig, 1894). The principles underlying the formation of the plural will become clearer by the following remarks on the formation of the plural in the Nîsk·a dialect:—

1. Singular and plural have the same form.

This class embraces the names of all animals except the dog and the bear, trees, and a great many words which cannot be classified. I give here a list of some of these:—

sE, day.
yā'tsEsk', animal.
k·'Ek·'ā'H, wing.
misHk·'ā'H, down of bird.
g·îc, hair.
ōpq, forehead.
dz'ak·, nose.
ua'n, tooth.
iē'mk·, beard.
t'Emlā'niH, neck.
tlak·s, nail.
ban, belly.
mā'dz'ikys, breast.
nîsk·, upper lip.
tlātsq, tail of fish.
hawī'l, arrow.
lōatlgyā'ôtk', axe.
ts'awîk·sEtqa', moccasins.
lak', fire.
akyc, water.
pElî'st, star.
axk', night.
ia'ns, leaf.
mēq·'ā'ukst, salmon berry.
laq'amā'k's, prairie.
ts'aky, dish.
wā'ôs, dish.
k'ōtl, yes.
k·asā'eq, front.
ts'ēn, inside.
wuldi'gyît, warrior.
al'a'lgyîq, language.
lē'Elgyit, feast.
qtlk·aō'm, payment.
mī'ukc, sweet smelling.
hatlhā'tluks, lean.
tlana'k't, old.
lōcanā'tlk', to be astonished.
lEqlā'k·, to fall (rain, snow).
līya'k·, to hang (v. a.).
k·'â'mEqk', to wish.

iā'ky, to thunder.	*hasa'k·*, to want.
saanuwō'k·, to rebuke.	*tlmâ'ᴇm*, to help.
sîlg·auê'l, to accompany.	*hätk't*, to rush.
dē'lᴇmᴇqk', to reply.	*gyî'dᴇq*, to ask.
mē'lᴇk', to damn.	*k·alā'n*, to leave something.
lē'mîн, to sing.	*bak·*, to feel.
gyê, to see.	

2. The plural is formed by reduplication, the beginning of the word, as far as the first consonant following the first vowel, being repeated with weakened vowel. The accent of the word is not changed. The reduplicated syllable remains separated from the reduplicated word by a hiatus.

This is particularly evident in words beginning with a vowel. In these there is a distinct pause between the terminal consonant of the reduplication and the initial vowel of the reduplicated word:—

ôн	plural	*îн'ô'н*, to throw.	*a'lgyîq*	plural	*ᴇl'a'lgyîq*, to speak.
ām	„	*ᴇm'ā'm*, good.			

It seems to me that this method of forming the plural may be considered duplication affected by certain laws of euphony. Monosyllabic words beginning and terminating either with a vowel or with a single consonant, according to the rule given above, are duplicated. Monosyllabic words terminating with a combination of consonants drop all the elements of the terminal cluster of consonants, except the first one, because else there would be a great accumulation of consonants in the middle of the word. The same causes that bring about the elision of the terminal cluster of consonants probably affect polysyllabic words in such a manner that the whole end of the word was dropped. This seems the more likely, as the repeated syllable has its vowel weakened. If a polysyllabic word was thus repeated the effect must have been very similar to the repetition of a word with a terminal cluster of consonants. For instance, *wulā'н*, to know, duplicated with weakened vowels, would form *wulнwulā'н*. In this word, according to the rule governing the reduplication of monosyllabic words with a terminal cluster of consonants, the first н would drop out, so that the form *wulwulā'н* would originate.

A few euphonic changes of consonants take place:—

ky, *gy*, and *k*, following the first vowel of the word, are aspirated in the reduplication, and form н.

g· and *k·* are also aspirated, and form *q*.

y becomes the surd aspirate н.

ts becomes *s*.

The weakened vowels have a tendency to change into ᴇ or *î*. The variability and indistinctness of the vowels make it difficult to establish a general rule.

I classify the examples in order to bring out the points referred to above.

a. Monosyllabic words beginning and terminating either with a vowel or with a single consonant.

ôн	plural	*îн'ô'н*, to throw.	*t'aq*	plural	*t'aqt'a'q*, lake; also *t'ᴇt'a'q*.
us	„	*ᴇs'u's*, dog.	*dzôk·*	„	*dzîk·dzô'k·*, to camp.
ām	„	*ᴇm'ā'm*, good.	*t'ē*	„	*t'ᴇt'ē'*, valley.
ol	„	*al'o'l*, bear.	*mêtl*	„	*mîtlmê'tl*, to tell.
dan	„	*dînda'н*, hill.	*gyīc*	„	*gyîcgyî'c*, wrong.
d'ec	„	*d'îcd'e'c*, to push.	*(lō) nô'*	„	*(lō) nonô'*, hole.
tlap	„	*tlᴇptla'p*, deep.	*la'ôp*	„	*lᴇpla'ôp*, stone.
batl	„	*bᴇtlba'tl*, to lay down a flat thing.	*tsap*	„	*tsîptsa'p*, to do.
			ts'al	„	*ts'îlts'a'l*, face.
hap	„	*hapha'p*, to shut.	*ts'ē'ip*	„	*ts'ᴇpts'ē'ip*, to tie.
g·an	„	*g·ang·a'n*, tree.			

b. Monosyllabic words beginning with a vowel or a single consonant, terminating with a cluster of consonants.

sī'êpk'	plural	*sîpsī'êpk'*, sick.	*k·êck'*	plural	*k·ask·ê'ck'*, narrow.
ts'ēpk'	„	*ts'îpts'ē'pk'*, hard.	*dēlpk'*	„	*dêldē'lpk'*, short.
îsk'	„	*îs'î'sk'*, stench.	*(lō) dā'ltk'*	„	*(lō) dᴇldā'ltk'*, to meet.
g·ick'	„	*g·icg·î'ck'*, lean.	*tlantk'*	„	*tlᴇntla'ntk'*, to move.

mîtk'	plural	*mîtmî'tk'*, full.	*tlîntH*	plural	*tlEntlî'ntH*, to be angry.
gyîtk'	„	*gyîtgyî'tk'*, to swell.	*gyêpkc*	„	*gyîpgyê'pkc*, high.
gyatlk'	„	*gyîtlgya'tlk'*, to pierce.	*ētk'c*	„	*at'ē'tk'c*, to end.
hanH	„	*hanha'nH*, thin.	*maô'xkH*	„	*maxmaô'xkH*, meek.
			yāltk'	„	*yîlgā'ltk'*, to return.

c. Polysyllabic words beginning with a vowel or a single consonant.

sī'Eb'En	plural	*sîpsī'Eb'En*, to love.	*dē'lîH*	plural	*dîldē'lîH*, tongue.
had'a'qk'	„	*hadhad'a'qk'*, bad.	*lō'lak·*	„	*lEllō'lak·*, ghost.
wulā'H	„	*wulwulā'h*, to know.	*(qan)mā'la*	„	*(qan)mElmā'la*, bottom.
bā'siqk'	„	*bEsbā'siqk'*, to separate.	*a'lgyîq*	„	*El'a'lgyîq*, to speak.
wa'lîH	„	*wulwā'lîH*, load, to carry on bark.	*ma'lg·êksk'*	„	*mElmā'lg·êkysk'*, heavy.
			haQda'k'	„	*hîQhaQda'k'*, bow.
ā'd'îkysk'	„	*ad'ā'd'îkysk*, to come.	*hō'mts'îq*	„	*hamhō'mts'îq*, to kiss.
gyî'dEq	„	*gyîdgyî'dEq*, to ask.	*ha'qg·'at*	„	*haqha'qg·'at*, sweet smelling.
asā'H	„	*as'asā'H*, foot.			

d. Change of *ky*, *gy*, and *k* into H.

t'aky	plural	*t'înt'a'ky*, to forget.	*sakysk'*	plural	*sînsa'kysk'*, clean.
hakys	„	*hanHa'kys*, to abuse.	*tlēgya't*	„	*tlîHtligya't*, cripple.
ōkyc	„	*aH'ōkyc*, to drop.	*mōk'*	„	*mîHmō'k'*, to catch fish.
iâ'ōkys	„	*iH'iâ'ōkys*, to wash.	*gyukc*	„	*gyêHgyu'kc*, fish jumps.
âkys	„	*êH'âkys*, broad.	*hokck'*	„	*haHhō'kck'*, to join others.
dakytl	„	*dîHda'kytl*, to lie around.			

e. Change of *y* into H.

hō yîq plural *hîHhō'yîq*, just.

f. Change of *g·* and *k·* into *q*.

mag·ā'nsk'	plural	*mîqmag·ā'nsk'*, explanation.
g·äik·ck'	„	*g·Eqg·ä'ik·ck'*, to sit.
sō'uk·sk'	„	*sEqsō'uk·sk'*, to dive.
k·'äk·tl	„	*k·Eqk·'äk·tl*, to drag.
ak·k'tl	„	*aq'a'k·k'tl*, to arrive.

g. Change of *ts* into *s*, and of *dz* into *z*.

yats	plural	*yîs'ia'ts*, to chop.
k·'ôts	„	*k·'Esk·'ō'ts*, to chop a tree.
hē'îts	„	*hêshē'îts*, to send.
ā'dzîks	„	*az'ā'dzîks*, proud.
hē'tsumEq	„	*hashē'tsumEq*, to command.

h. Words beginning with combinations of consonants do not always reduplicate in the manner described above, as it sometimes results in an accumulation of consonants in the middle of the word. If such inadmissible clusters should result, only the first consonant of the word is repeated. In such cases initial *q* is transformed into *k·*.

ptô	plural	*pptô*, door.	*qtlkō'luq*	plural	*k·Eqtlkō'luq*, to scold.
qtlk·ô	„	*k·Eqtlk·ô*, to pray.	*qtsa'e*	„	*k·Eqtsa'e*, thick.

(See, however, the words with initial *ts*.

i. Words beginning with *hw* have in the plural *hūw*. When *hw* is considered as one syllable, the semi-vowel *w* standing for a weak *u* and *w*, the reduplicated form would be *hwhw*, which, when pronounced rapidly and with the following vowel, must naturally become *hūw*. I believe, therefore, that this plural must be included in the reduplications:—

hwa	plural	*hūwa'*, name.	*hwîl*	plural	*hūwî'l*, to do.
hwîlp	„	*hūwî'lp*, house.	*hwô*	„	*hūwô'*, to call.
hwât	„	*hūwâ't*, to sell.	*hwāH*	„	*hūwā'H*, paddle.

j. Irregular reduplications.

α. Elision of the consonant following the first vowel.

gyîn	plural	*gyîgyî'n*, to give food.
gyîk	„	*gyîgyî'k'*, to buy.
ts'aky	„	*ts'Ets'ā'ky*, dish.
t'aq	„	*t'Et'a'q*, lake.
ts'ēp	„	*ts'Ets'ē'p*, bone.
gyît	„	*gyigya't*, people.
māl	„	*mmāl*, canoe.

β. Introduction of (euphonic ?) H.

dEdā'lEk·	plural	*dîHdEdā'lEk·*, to talk to.
amō's	„	*aH'amō's*, corner.
t'ōtsk'	„	*t'îHt'ō'tsk'*, iron.
yinā'tsîq	„	*yiHinātsîq*, whip.
Endō'yEn	„	*aH'Endō'yEn*, garden.
Ensgyē'ist	„	*aH'Ensgyē'ist*, grave.
sā'atlk'	„	*sîHsā'atlk'*, weak.
hatlā'alst	„	*haHētlā'alst*, to work.
hatlEbîsk'	„	*haHētlEbî'sk'*, knife.
sanlai'dîkys	„	*sîHsanlai'dîkys*, sign.
ē'Esk'	„	*aH'ē'Esk'*, debt.
aqyâ'ôkysk'	„	*aq'îHyâ'ôkysk'*, to trust.
tg·aluwē'lEmtlk'	„	*tg·aluwîHwē'lEmtlk'*, servant.

Here may also belong

yō'tlmEq plural *hîHiō'tlmEq*, to command

γ. Introduction of consonants other than H.

dEdē'ls	plural	*dEldē'ls*, alive.
makysk'	„	*mEsmā'kysk'*.
k·Eg·ē'tk'	„	*k·Etg·ē'tk'*, difficult.
laqlē'lp'En	„	*laqlEplē'lp'En*, to roll.

δ. The reduplicated syllable amalgamates with the stem.

alî'ck' plural *allî'ck'* weak (instead of *al'alî'ck'*).
ane'st „ *anne'st* branch („ „ *an'ane'st*).

ε. The vowel of the reduplicated syllable is lengthened and the accent is thrown back upon the first reduplicated syllable, while the vowel of the stem is weakened.

lEk·s	plural	*lā'lEk·s*, to wash the body.
wôk'·	„	*wā wôk·'* to sleep.
caky	„	*cē'icîky*, to haul out.
tlaky	„	*tlē'tlîky*, to bend.
t'ôk·	„	*t'â't'Ek·*, to scratch.

3. The plural is formed by diæresis, or lengthening of vowels.

anā's	plural	*anā'Es*, skin.	*gwula'*	plural	*gūla'*, cloak.
gyî'nā'm	„	*gyē'nam*, to give.	*hala'it*	„	*hā'lait*, ceremonial dance.
kyîba'	„	*kyība'*, to wait.	*hanā'k·*	„	*hā'nak·*, woman.

4. The plural is formed by the prefix *k·a*—. In this class are included many names of parts of the body, adjectives expressing states of the body, such as blind, deaf, and also poor, words of location, and miscellaneous words which cannot be classified.

a. Parts of the body.

t'Emg·ē'c	plural	*k·at'Emg·ē'c*, head.	*an'ô n*	plural	*k·aan'ô'n*, hand.
ts'Emî'H	„	*k·ats'Emî'H*, ear.	*plnāQ*	„	*k·aplnā'Q* or *plnāQ*, body.
ts'Emā'k·	„	*k·ats'Emā'k·*, mouth.	*k·'ētlk·*	„	*k·ak·'ētlk·*, chest.
t'Emk·ā'H	„	*k·at'Emk·ā'H*, arm.	*g·âd*	„	*k·ag·â'd*, heart.
t'Emtlā'm	„	*k·at'Emtlā'm*, leg.	*tg·amâ'k·*	„	*k·atg·amâ'k·*, lip.
—	„	*k·atsuwē'Ent*, fingers.	*g·'ē'sEE*	„	*k·ag·'ē'sEE*, knee.

b. Adjectives expressing states of the body.

kyîba'	plural	*k·îkyîba'*, lame.
sîns	„	*k·asî'ns*, blind.
ts'äk·	„	*k·ats'ä'k·*, deaf.
mEwā'tsq	„	*k·amEwā'tsq*, crazy (= similar to a land otter).

Here may belong also

gwä'E	plural	*k·agwaä'E*, poor.
huQ·iō'nst	„	*huQk·a'iō'nst*, liberal.

c. Locations.

dāH	plural	*k·adā'H*, outside.
laq'ō	„	*k·alaq'ō'*, on top.
stô'ôkys	„	*k·astô'ôkys*, side of.

d. Other words, unclassified.

sEmō'tks	plural	*k·asEmō'tks*, to believe.
nō'd'En	„	*k·anō'd'En*, to adorn.
yicgu'sgyitk'c	„	*yisk·agu'sgyitk'c*, to rejoice.
lē'lukc	„	*k·alē'lukc*, to steal.
guîHsilē'Ensgut	„	*guîHk·asilē'Ensgut*, hunter.
wîst	„	*k·awî'st*, root.
k·ā'it	„	*k·ak·ā'it*, hat.

5. Terms of relationship from the plural by the prefix *k·a*— and the suffix —*(t)k'*.

niä'	plural	*k·aniä'Etk'*, grandfather.
ntsē'Ets	„	*k·antsē'Etsk'*, grandmother
nEquâ'ôt	„	*k·anEquâ'ôtk·*, father.
nEbē'p	„	*k·anEbē'pk'*, uncle.
waky	„	*k·awakyk'* (?), younger brother.

The following two have besides reduplication of the stem with lengthening of the reduplicated syllable:

nakys	plural	*k·anē'nîkysk'*, wife.
nôq	„	*k·anâ'nEqk'*, mother.

I found the following two without the prefix *k·a*—

waky	plural	*wakyk'*, younger brother.
gyîmudē	„	*gyîmHdē'tk'*, elder brother.

Irregular is

huQdā'eky'En	plural	*tluQdā'ek'Entk'*, grandson.

Here belongs also

mē'En	plural	*k·amē'Entk'*, master.

6. The plural is formed by the prefix *l*— with variable vowel. Words forming the plural in this manner have a tendency to form irregular plurals.

a. akys	plural	*laa'kys*, to drink.
yoxk'	„	*lēyô'xk'*, to follow.
gōksk'	„	*lEgō'ksk'*, to be awake.
d'äk·	„	*lEd'ä'k·*, to devour.
qbEts'aQ	„	*laqbē'ts'Eqt*, afraid.

b. Some words have the prefix *l*— combined with reduplication.

Qdan	plural	*luHdē'dîH*, hunger.

c. Initial *gy* and *k·* are elided when they follow the prefix *l*—

gyâkyc	plural	*lâkyc*, a bird swims.
gyıbā'yuk	„	*libā'yuk*, to fly.
k·ē'nEq	„	*lē'nEq*, a tree falls.

Here belong also the reduplicated plurals :—

gyamkys	plural	*lEmla'mkys*, to warm one's self.
gya'mgyitl	,,	*lEmla'mgyitl*, to warm something.

d. Irregular but related to this class are

yaQ	plural	*lī'lēQ*, to hide.
yîqya'k·	,,	*lîslī'sk'*, to hang (v. n.).
Qdak'	,,	*liduQ*, to shoot.
gyenē'tk'	,,	*lenêdEmk'st*, to arise.

7. Irregular plurals.

a. Singular and plural are derived from different stems.

gy'äqk'	plural	*hō'ut*, to escape.	*dā'utl*	plural	*sa'kysk'*, to go away.
yē	,,	*tlô*, to walk.	*malk'*	,,	*tqä'ldEt*, to put into fire.
iō'oqk'	,,	*tqô'oqk'*, to eat.	*maqk't*	,,	*cēntk'*, to go aboard.
iōk·'E'n	,,	*tqak·'E'n*, to feed.	*baq*	,,	*g·ôl*, to run.
d'a	,,	*wan*, to sit.	*ma'g·at*	,,	*t'atl*, to put.
lEksd'a'	,,	*lEkswa'n*, island.	*gyētl*	,,	*lā'tl*, to lie down.
dzak'	,,	*yêts*, to kill (pl. = to chop).	*ts'ēn*	,,	*la'mdziq*, to enter.
hētk'	,,	*mak·sk'*, to stand.	*nôE*	,,	*daq*, to die.
dEphē'tk'	,,	*dEpma'k·sk'*, short.			
wētk'	,,	*bak'*, form.	*qaE*	,,	*tltlē'ngyît*, male slave.
gō	,,	*dôk·*, to take.	*wat'ak'*	,,	*tltlē'ngyît*, female slave.
dô'qk'					
(qtlna)	,,	*(qtlna) sgyi'tk'*, to kneel.	*tlgō*	,,	*k'ōbE*, small.
kycaQ	,,	*ksitlô'* (*ksi*—, out. *tlô*, to walk), to go out.	*tlgôwī'lkycîtlk'*	,,	*k'ōpEwîlkycîtlk'*, nobleman.
mak·t	,,	*wîlk·t*, to carry.	*gyat*	,,	*ē'uQt*, man.
sk·ats'a'Q	,,	*alisgyī'da*, ugly.	*wī*	,,	*wud'a'q*, large.
			ts'ōsky	,,	*sEs'ō's*, small.

b. Singular and plural are formed from the same or related stems.

wuyī'tk'	plural	*si'ya'tk'*, to cry, to weep.
aiawā'tk'	,,	*alayuwā'dE*, to shout.
wīEme'E	,,	*wud'aq alEmē'd'E*, to shout.
lōmā'kysa	,,	*lōlē'dîkysa*, to wash clothing.
wīnak'	,,	*nnē'nEk'*, long.
wīd'ô'Q	,,	*d'EQd'ô'Q*, stout.
k'stak·s	,,	*lukstsā'dEk·s*, to leave.
q'aēma's	,,	*q'aēma'k·st*, young.
am'ama's	,,	*am'ama'k·st*, pretty.

Composition.

The composition of words in Tsimshian and Nîsk·a is remarkably loose. Although there are a great number of formative elements which have no independent existence they do not combine very intimately with the words to which they are prefixed. I pointed out before that the reduplicated syllable remains separated from the stem by a hiatus or pause. The same is true of all compositions, as the following examples will show :—

hagun'iē'E, to walk towards.
ts'Em'a'kys, in water.
lEg·Em'ōH, to throw into (from top).

This loose connection is also shown by the fact that in compounds the plural is formed from the stem alone.

k·alts'a'p	plural	*k·alts'Ets'a'p*, town.	*nsē'bEnsk'*	plural	*nsEpsē'b'Ensk'*, friend.
k·alhwī'lp	,,	*k·alhuwä'lp*, house			
daqgya't	,,	*daqgyigya't*, strong.			

There are very few cases of contractions.

SîyidEmna'k·, chieftainess; plural, *sîyidEmhā'nak·*. The end of this word was undoubtedly originally *hanak·*, woman.

Mental and Physical Deviations from the Normal among Children in Public Elementary and other Schools.—Report of the Committee, consisting of Sir DOUGLAS GALTON (*Chairman*), Dr. FRANCIS WARNER (*Secretary*), Mr. E. W. BRABROOK, Dr. J. G. GARSON, Dr. WILBERFORCE SMITH, *and* Mr. E. WHITE WALLIS.—(*Report drawn up by the Secretary.*)

THE Committee, acting in conjunction with a committee appointed for the same purpose by the International Congress of Hygiene and Demography, and the British Medical Association, is now able to give a further account of the 50,000 children examined individually, 1892–94, in sixty-three schools, together with some information bearing on the causation of defects in childhood.

The methods of examination and the points observed were described in our first report. The total number of boys and girls, with each class of defect, was given in 1894. In our last report the number of boys and girls, with the individual defects, was given as distributed in twelve divisions of schools, representing Board schools, Voluntary schools, the nationalities and social classes; also the primary classes of defect in proportions on the number of children seen and the number noted.

In each of the following tables the heading shows the division of schools dealt with. The cases are arranged first in school standards, secondly in age groups. Standard 0 contains children too old for the infant school and too dull or backward for Standard I. In Table VII. the column headed 'No standard' contains the boys in a high-class school which was not arranged in standards. The average ages as recognised for pupils in the standards respectively are:—Infants, five years and under; Standard I., six years, rising a standard a year, so that at twelve years of age the child may reach Standard VII.

The primary main classes of defect are indicated in the tables by symbols:—

A. *Defect in development only*: not in combination with other class of defect.

B. *Abnormal nerve-signs only*; not in combination with other class of defect.

C. *Pale, thin, or delicate only.*

D. *Reported as mentally dull or backward only.*

Six other primary groups are arranged by taking cases with two main classes of defect only.

Four primary groups present three main classes of defect only.

One primary group presents the four main classes of defect combined in each case.

The remainder—groups E, F, and G—contain the cases with defects not classed above as main classes; such as eye cases, children maimed or crippled, &c.

We thus show for each division of schools the children who presented an observed defect in development of body, in nerve status, in physical health and nutrition, and those reported by the teachers as dull or backward, arranged in primary groups presenting only the class of defect indicated by the formula. To obtain the total number of cases with any class of defect, whether combined with other class of defect or not, the numbers representing all the primary groups containing such defect must be added together. The total or compound group AB=primary AB+ABC+ABD+ABCD. It is also possible, for the purposes of research, to arrange from the tables the children in whom any class of defect is absent, and thus compare their conditions in contrast with the children in whom such defects were present. Such actuarial work is useful in seeking the causation of defects. Examples have been worked out by Dr. Francis Warner.[1]

This arrangement of our cases has afforded much information for the solution of certain problems, and the means of answering many questions concerning conditions of childhood. It has become possible to compare similar groups of children under varied environment and at different ages.

Comparison of the cases presenting some defect, as to their ages in relation to the standard in which they were placed, shows that 25·6 per cent. of the boys and 26·3 per cent. of the girls were over the average age recognised for the standard. Thus evidence is obtained of a lower mental status in children with the signs of defect, apart from the report of the teachers, while the value of the signs observed is indicated. Facts such as these can be arranged for any division of schools.

It is well known that developmental and congenital defect forms an appreciable cause in the high rate of infant mortality, especially among males; many children, however, with the lesser degrees of defect, survive to school age, and form 8·8 per cent. of the boys and 6·8 per cent. of the girls seen in schools. It was shown in our report of 1894 that conditions of defect are frequently associated in children; the tables now published make it possible to show that such conditions vary in boys and in girls respectively in the age groups.

Among the *children with developmental defects*, those who are seven years old and under have the lowest percentage association with additional or acquired defects. This is more marked among boys than girls. They have, however, a tendency to acquire nerve-disturbance, delicacy, and mental dulness under the continued action of their environment, as they grow older; this is specially marked with the girls. When eight to ten years of age the proportion of those children who have acquired additional defects has risen 7 per cent.; while at twelve years and older only 37 per cent. of the boys and 25 per cent. of the girls with developmental defects are free from additional or acquired delicacy, nerve-disturbance, or mental dulness. Further, among developmental defect cases, the signs of nerve-disturbance are more associated with other defect in boys under eleven years; while at all ages the association with low nutrition and mental dulness is greater in girls. At eleven years of age and over, developmental defect is most associated with nerve-disturbance, delicacy, and dulness in the girls.

The calculations upon which these statements are made, as founded upon the tables here given, will be found in the 'Statistical Journal,' March 1896.

Brain-disorderliness, as indicated by abnormal nerve-signs, is a more potent cause of mental dulness than congenital defect of development of

[1] See *Statistical Journal*, March 1896.

the body. Nerve-signs, whether they occur alone or in combination with defect in development or not, are more directly connected with low mental ability than congenital defect of the body. This is most marked in children seven years and under, particularly with girls; in the age-group eight to ten it is most marked with boys; while at eleven years and over it is about equal in the sexes. It should thus be an object, in training children, to prevent them from acquiring any abnormal nerve-signs.

In the London Board schools efficient physical training was given (these children are presented in Tables I. to IV.); in the Scotch Board school (see Table VI.) no physical training was given. The physical condition of the Scotch children was better—developmental cases, boys 8 per cent., girls 4·6 per cent.; and delicate children, boys 2·2 per cent., girls 3·3 per cent., as against, in the London schools—developmental cases, boys 8·5 per cent., girls 6·8 per cent.; and delicate children, boys 2·8 per cent., girls 3·4 per cent. When, however, we come to look to their brain status, we find, in the Scotch school, 13·6 per cent. boys and 10·3 per cent. girls with abnormal nerve-signs, while 9·8 per cent. boys and 6·2 per cent. girls are dull or backward pupils; as against, in the London schools, 9·7 per cent. boys, and 8·2 per cent. girls with nerve-signs, and 7·9 per cent. boys, and 7·1 per cent. girls reported as dull pupils. Further analysis of the cases shows the nerve-signs as probably connected with the larger proportion of dull pupils. The inference is that good physical training lessens the proportion of children with inco-ordinated brain action, and coincidently the proportion of dull pupils.

Many other points of interest might be dealt with on the basis of the facts arranged in the tables, and answers can be given therefrom to many questions raised from time to time. In the last two reports we have dealt mostly with the main classes of defects; in searching for the means of removing or preventing them it will be necessary to make further analysis and classification of the individual defects, especially as to the nerve-signs. Cases presenting each nerve-sign should be classified, as the main class of nerve-cases has been classified; we should thus obtain information as to the lines of causation of each, and their relative significance. As all our cases are recorded on separate cards, this can readily be done, but the work would involve much clerical labour.

The Committee desire to be reappointed, and ask a grant in aid of this work.

Description of Tables.

Each table is arranged for a division of schools as given in the heading. Cases are distributed into primary groups presenting only the class of defect indicated by the symbols. The numbers on the left hand refer to definition of the class, as given in the full report published.[1] In the first half of the table the groups are distributed according to educational standards. The numbers seen and the numbers noted are given at the bottom of this section of the table.

In the second half of the table the groups are distributed according to ages.

[1] 'Report on the Scientific Study of the Mental and Physical Conditions of Childhood. With particular reference to children of defective constitution; and with recommendations as to Education and Training, based on 100,000 children examined.' Published at Parkes Museum, Margaret Street, W.

TABLE I.—*Seven London Board Schools; Upper Social Class; English Children.*

—		No Standard		Infants		Standard 0		Standard I.		Standard II.		Standard III.		Standard IV.		Standard V.		Standard VI.		Standard VII.		Standard Ex. VII.		Total Number	
Group	Symbol	B.	G.	B.	G	B.	G.	B.	G.	B.	G.	B.	G	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	—	—	50	30	1	—	28	13	16	13	20	12	18	10	10	7	15	2	3	1	3	—	164	88
14.	B	—	—	26	11	1	—	19	17	23	20	32	30	31	22	19	11	14	29	5	16	1	3	171	159
15.	C	—	—	6	3	—	—	7	4	1	2	1	2	1	2	—	2	1	—	—	1	—	—	17	16
16.	D	—	—	10	7	3	—	8	5	4	7	11	13	5	2	2	4	3	1	1	—	1	1	48	40
17.	A B	—	—	9	5	2	2	6	11	14	4	12	6	7	5	9	5	1	—	4	—	1	1	65	39
18.	A C	—	—	5	3	—	—	3	6	6	5	—	4	3	3	1	2	1	1	1	—	—	—	20	24
19.	A D	—	—	16	15	2	4	8	5	11	9	12	9	4	5	5	4	3	—	5	1	—	2	66	54
20.	B C	—	—	2	1	—	—	4	6	1	2	3	5	4	3	3	—	—	—	—	4	—	1	17	22
21.	B D	—	—	11	6	7	1	8	10	21	11	21	22	13	10	7	2	4	4	1	1	1	—	94	67
22.	C D	—	—	2	2	1	1	1	2	1	1	—	2	—	3	—	—	—	—	—	—	—	—	5	11
23.	A B C	—	—	4	3	—	—	4	5	1	1	1	1	—	2	2	—	—	—	—	—	—	—	12	12
24.	A B D	—	—	10	4	4	1	8	4	7	3	7	9	4	3	3	3	1	—	1	1	—	1	45	29
25.	A C D	—	—	5	3	3	—	1	8	2	3	1	2	2	1	—	—	—	1	—	—	—	—	14	18
26.	B C D	—	—	4	—	1	—	2	1	1	—	1	4	—	1	—	—	—	—	—	—	—	—	9	6
27.	A B C D	—	—	3	2	1	1	2	5	1	—	3	—	—	—	—	—	—	—	—	—	—	—	10	8
56.	E F G	—	—	22	16	—	—	11	8	4	10	10	9	6	9	9	9	8	11	6	10	5	4	81	86
Number noted		—	—	185	111	26	10	120	110	114	91	135	130	98	81	70	49	51	49	27	35	12	13	838	679
Number seen		—	—	1207	1022	66	55	684	625	583	537	642	576	506	479	475	387	329	317	210	218	98	100	4830	4316

Age last birthday		3 and under		4		5		6		7		8		9–10		11–12		13		14 and over		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	2	2	6	4	14	17	34	11	22	10	11	10	37	18	27	14	10	2	1	—	164	88
14.	B	3	—	2	1	8	5	15	5	17	13	20	18	51	43	48	53	5	12	2	9	171	159
15.	C	—	—	—	1	6	2	6	—	1	3	1	2	2	3	1	4	—	1	—	—	17	16
16.	D	—	—	—	1	8	2	5	2	8	2	2	4	7	15	9	11	5	1	4	2	48	40
17.	A B	—	—	—	1	5	—	6	7	4	4	12	9	25	11	10	5	3	1	—	1	65	39
18.	A C	1	1	—	—	1	2	3	—	3	7	5	4	3	8	3	2	1	—	—	—	20	24
19.	A D	—	—	2	4	9	5	7	4	5	7	8	11	14	10	16	9	3	2	2	2	66	54
20.	B C	—	—	—	—	2	—	1	3	2	—	3	5	6	9	2	1	1	1	—	3	17	22
21.	B D	—	—	1	—	4	2	8	2	6	8	12	10	35	24	23	14	4	5	1	2	94	67
22.	C D	—	—	1	—	1	2	—	—	1	1	1	1	1	3	—	2	—	2	—	—	5	11
23.	A B C	—	—	1	2	1	—	2	3	1	—	4	3	1	2	1	2	1	—	—	—	12	12
24.	A B D	—	—	2	—	1	1	4	2	10	3	8	4	10	6	8	9	1	2	1	2	45	29
25.	A C D	—	—	1	—	3	2	1	4	3	2	3	4	2	4	1	2	—	—	—	—	14	18
26.	B C D	—	—	—	—	2	—	3	—	2	—	1	1	—	4	—	1	1	—	—	—	9	6
27.	A B C D	—	2	1	1	—	5	1	—	3	—	—	—	4	—	1	—	—	—	—	—	10	8
56.	E F G	5	1	5	1	5	8	9	7	4	9	3	4	23	17	16	24	8	9	3	6	81	86
Number noted		11	6	22	16	70	53	105	50	92	69	94	90	221	177	166	153	43	38	14	27	838	679

TABLE II.—*Eleven London Board Schools; Average Social Class; English Children.*

Group	Symbol	No Standard B.	No Standard G.	Infants B.	Infants G.	Standard 0 B.	Standard 0 G.	Standard I. B.	Standard I. G.	Standard II. B.	Standard II. G.	Standard III. B.	Standard III. G.	Standard IV. B.	Standard IV. G.	Standard V. B.	Standard V. G.	Standard VI. B.	Standard VI. G.	Standard VII. B.	Standard VII. G.	Standard Ex. VII. B.	Standard Ex. VII. G.	Total Number B.	Total Number G.
13.	A	—	—	40	35	—	—	37	13	22	11	10	14	22	7	23	7	10	5	1	3	—	1	165	96
14.	B	—	—	17	5	3	2	41	29	52	37	31	33	26	32	22	16	12	15	6	4	1	1	211	174
15.	C	—	—	9	8	—	—	8	5	4	7	2	—	1	3	—	2	1	3	—	4	—	—	25	32
16.	D	—	—	22	21	—	4	20	17	17	20	13	8	13	8	3	10	3	—	1	—	—	—	92	88
17.	A B	—	—	9	3	4	2	24	15	22	11	7	7	7	3	7	4	5	1	3	—	1	—	89	46
18.	A C	—	—	14	15	—	—	6	4	7	4	4	3	—	3	—	3	—	1	—	—	—	—	31	33
19.	A D	—	—	23	20	3	11	23	11	14	18	14	14	8	5	5	5	1	2	—	—	—	—	91	86
20.	B C	—	—	5	3	—	1	6	6	5	4	1	1	1	4	1	5	0	1	1	—	1	—	21	25
21.	B D	—	—	27	8	11	11	31	33	38	32	41	22	25	16	10	9	4	—	—	—	—	—	187	131
22.	C D	—	—	11	5	—	3	2	2	2	3	4	—	1	2	1	—	1	—	1	—	—	—	23	15
23.	A B C	—	—	4	7	—	—	2	1	3	5	1	6	3	—	—	—	—	2	—	—	—	—	13	21
24.	A B D	—	—	6	6	8	7	23	15	16	12	12	8	8	2	4	2	1	1	1	1	—	—	79	54
25.	A C D	—	—	10	14	—	2	5	5	5	2	3	6	—	2	—	1	—	—	—	—	—	—	23	32
26.	B C D	—	—	7	3	—	1	9	6	4	5	3	4	1	1	—	2	—	1	—	1	1	—	25	24
27.	A B C D	—	—	4	5	—	1	10	8	2	1	3	1	—	1	—	—	—	—	—	—	—	—	19	17
56.	E F G	—	—	17	20	—	2	15	3	9	6	4	9	11	12	3	5	4	7	2	6	—	—	65	70
Number noted		—	—	225	178	29	47	262	173	222	178	153	136	127	101	79	71	42	39	16	19	4	2	1159	944
Number seen		—	—	1659	1329	102	110	1035	971	934	884	773	867	658	646	508	460	323	256	109	99	12	6	6113	5628

Group	Symbol	3 and under B.	3 and under G.	4 B.	4 G.	5 B.	5 G.	6 B.	6 G.	7 B.	7 G.	8 B.	8 G.	9–10 B.	9–10 G.	11–12 B.	11–12 G.	13 B.	13 G.	14 and over B.	14 and over G.	Total Number B.	Total Number G.
13.	A	1	9	8	7	15	12	22	7	24	9	17	11	32	22	39	13	7	3	—	3	165	96
14.	B	1	—	1	1	4	3	14	3	31	17	37	32	59	54	51	52	12	8	1	4	211	174
15.	C	—	—	1	—	3	4	6	4	3	6	5	3	5	5	2	5	—	5	—	—	25	32
16.	D	2	1	3	4	4	4	10	12	7	7	8	14	22	19	29	16	4	8	3	3	92	88
17.	A B	1	—	—	2	4	1	8	2	21	6	15	14	20	11	17	8	2	2	1	—	89	46
18.	A C	3	2	5	5	3	3	5	6	1	1	7	6	7	5	—	5	—	—	—	—	31	33
19.	A D	3	3	2	5	8	3	11	9	10	7	13	14	23	23	16	19	5	3	—	—	91	86
20.	B C	1	—	—	—	—	—	2	4	5	5	6	2	4	7	2	6	1	1	—	—	21	25
21.	B D	—	—	6	—	12	2	8	6	15	15	26	20	70	35	44	41	4	12	2	—	187	131
22.	C D	2	1	1	—	4	—	4	5	1	4	—	—	6	3	4	2	1	—	—	—	23	15
23.	A B C	—	1	—	2	1	1	2	3	3	4	2	3	4	5	1	1	—	1	—	—	13	21
24.	A B D	—	—	2	2	1	2	2	4	12	9	17	7	22	13	19	12	4	4	—	1	79	54
25.	A C D	1	2	1	1	4	4	4	6	2	6	3	2	7	6	—	4	—	1	1	—	23	32
26.	B C D	—	—	—	—	3	2	4	1	3	4	6	1	7	9	1	6	—	1	1	—	25	24
27.	A B C D	—	—	—	2	—	—	4	3	3	4	7	2	4	4	1	2	—	—	—	—	19	17
56.	E F G	2	1	3	6	4	9	11	5	10	3	4	5	15	19	12	17	4	5	—	—	65	70
Number noted		17	20	33	37	70	50	117	80	151	107	173	136	307	240	238	209	44	54	9	11	1159	944

TABLE III.—*Fourteen London Board Schools; Poorer Social Class; English Children.*

—		No Standard		Infants		Standard 0		Standard I.		Standard II.		Standard III.		Standard IV.		Standard V.		Standard VI.		Standard VII.		Standard Ex. VII.		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	—	—	50	47	4	1	40	22	23	21	24	16	15	3	13	6	12	3	3	—	1	—	185	119
14.	B	—	—	22	13	9	2	35	36	46	34	31	28	28	19	11	8	9	6	2	3	1	—	194	149
15.	C	—	—	6	11	4	1	7	8	3	5	1	1	3	1	—	2	1	—	—	—	—	—	25	29
16.	D	—	—	17	11	6	11	18	17	12	21	11	7	10	6	4	5	4	1	—	—	—	—	82	79
17.	A B	—	—	12	6	3	1	24	16	17	7	12	4	9	1	3	1	1	—	—	—	—	—	81	36
18.	A C	—	—	22	27	1	1	6	13	4	5	—	—	1	—	1	1	1	—	2	—	—	—	38	47
19.	A D	—	—	18	16	6	10	22	12	14	12	16	5	10	5	7	2	7	—	1	—	—	—	101	62
20.	B C	—	—	4	4	2	—	5	5	5	10	2	3	3	—	—	1	2	—	—	—	—	—	23	23
21.	B D	—	—	24	9	11	9	46	34	33	27	15	14	22	12	7	6	3	2	—	—	—	—	161	113
22.	C D	—	—	5	2	2	2	4	3	1	2	2	1	—	—	—	—	1	—	—	—	—	—	15	10
23.	A B C	—	—	6	2	1	1	3	5	5	5	1	1	—	3	—	1	—	—	—	—	—	—	16	18
24.	A B D	—	—	13	9	7	6	21	15	16	10	11	8	2	3	2	—	2	—	—	—	—	—	74	51
25.	A C D	—	—	6	14	6	2	5	11	6	1	2	3	1	—	—	—	—	—	—	—	—	—	26	31
26.	B C D	—	—	9	2	2	3	5	9	5	4	2	2	2	—	—	—	—	—	—	—	—	—	25	20
27.	A B C D	—	—	9	8	4	3	10	12	3	2	—	—	—	—	1	1	—	1	—	—	—	—	27	27
56.	E F G	—	—	20	12	2	—	12	4	9	9	13	8	14	10	7	4	4	1	1	1	—	—	82	49
Number noted		—	—	243	193	70	53	263	222	202	175	143	101	120	63	56	38	47	14	9	4	2	—	1155	863
Number seen		—	—	1814	1577	171	99	1094	1053	956	766	847	740	658	509	404	308	291	137	93	23	14	1	6342	5213

Age last birthday		3 and under		4		5		6		7		8		9–10		11–12		13		14 and over		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	6	5	6	8	17	23	20	10	26	21	18	15	48	22	42	12	2	3	—	—	185	119
14.	B	2	—	6	1	1	2	13	12	25	21	34	22	61	51	42	35	10	3	—	2	194	149
15.	C	—	—	2	2	3	3	2	6	7	6	3	5	5	4	2	3	1	—	—	—	25	29
16.	D	1	1	4	3	7	2	5	6	9	14	10	9	23	19	19	21	3	4	1	—	82	79
17.	A B	—	—	2	1	4	3	7	5	13	7	14	7	18	8	17	5	6	—	—	—	81	36
18.	A C	4	2	4	4	3	11	10	8	2	10	5	6	4	2	4	1	1	—	1	—	38	47
19.	A D	2	—	4	4	5	10	8	4	9	10	14	9	23	17	31	6	4	2	1	—	101	62
20.	B C	—	—	—	—	2	2	2	2	4	6	5	4	5	5	4	4	1	—	—	—	23	23
21.	B D	—	—	—	1	7	1	14	8	21	15	28	15	38	36	33	29	18	8	2	—	161	113
22.	C D	—	—	1	—	2	—	1	4	4	2	2	1	2	2	2	1	1	—	—	—	15	10
23.	A B C	—	1	1	—	1	—	3	3	4	4	3	3	3	4	1	3	—	—	—	—	16	18
24.	A B D	—	—	—	3	4	2	3	1	14	7	15	10	13	20	19	7	4	1	2	—	74	51
25.	A C D	—	1	1	—	1	6	4	8	5	7	6	2	5	5	4	2	—	—	—	—	26	31
26.	B C D	—	—	3	—	2	1	4	—	2	4	4	7	7	6	3	1	—	1	—	—	25	20
27.	A B C D	2	—	1	2	4	1	2	5	3	9	8	2	4	3	1	4	2	—	—	1	27	27
56.	E F G	2	3	2	—	5	3	7	5	6	2	11	5	23	19	24	8	2	2	—	2	82	49
Number noted		19	13	37	29	68	73	105	87	154	145	180	122	282	223	248	142	55	24	7	5	1155	863

TABLE IV.—*Three London Board Schools; Poor Social Class; Jewish Children.*

—		No Standard		Infants.		Standard 0		Standard I.		Standard II.		Standard III.		Standard IV.		Standard V.		Standard VI.		Standard VII.		Standard Ex. VII.		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	—	—	11	5	—	2	7	4	3	4	4	2	5	1	6	—	—	1	2	—	—	—	38	19
14.	B	—	—	7	9	—	5	9	2	6	6	4	2	4	5	5	4	—	—	1	1	—	—	36	34
15.	C	—	—	4	6	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	4	8
16.	D	—	—	7	7	—	2	12	6	2	4	2	2	1	2	—	—	—	1	—	—	—	—	24	24
17.	A B	—	—	3	5	—	2	4	—	1	2	2	1	1	—	2	—	1	1	—	—	—	—	14	11
18.	A C	—	—	5	10	—	—	1	—	2	2	—	—	1	—	—	—	—	—	—	—	—	—	9	12
19.	A D	—	—	10	13	—	1	10	3	6	4	—	2	3	3	—	1	—	1	—	—	—	—	29	28
20.	B C	—	—	3	4	—	1	—	—	—	1	1	—	—	1	—	—	—	—	—	—	—	—	4	7
21.	B D	—	—	13	8	—	5	13	11	5	1	2	2	6	1	3	—	—	—	—	—	—	—	42	28
22.	C D	—	—	2	1	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	2	3
23.	A B C	—	—	3	4	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	5
24.	A B D	—	—	9	5	—	5	6	2	3	—	3	1	1	4	2	—	—	—	—	—	—	—	24	17
25.	A C D	—	—	1	2	—	—	3	1	—	1	—	—	—	—	—	—	1	—	—	—	—	—	5	4
26.	B C D	—	—	3	1	—	—	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	5	2
27.	A B C D	—	—	2	2	—	—	—	2	—	—	—	1	—	—	1	—	—	—	—	—	—	—	3	5
56.	E F G	—	—	3	5	—	—	—	1	1	—	—	2	1	1	1	4	—	3	—	—	—	—	6	16
Number noted		—	—	86	87	—	25	67	33	30	27	18	15	23	18	20	9	2	8	3	1	—	—	249	223
Number seen		—	—	544	602	—	59	258	239	153	231	146	165	137	131	77	83	40	50	13	21	—	—	1368	1581

Age last birthday		3 and under		4		5		6		7		8		9–10		11–12		13		14 and over		Total Number	
Group.	Symbol.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	—	—	—	1	3	2	6	2	4	2	5	3	8	6	10	2	1	1	1	—	38	19
14.	B	—	—	—	—	3	3	2	4	2	6	10	2	9	8	9	8	1	2	—	1	36	34
15.	C	1	—	1	1	1	2	1	1	—	—	—	—	—	3	—	—	—	1	—	—	4	8
16.	D	—	—	1	1	3	4	2	2	6	3	2	4	7	5	3	4	—	1	—	—	24	24
17.	A B	—	—	—	—	2	1	1	3	3	—	—	3	3	1	4	2	1	1	—	—	14	11
18.	A C	—	2	—	2	2	5	2	1	—	—	1	—	3	2	1	—	—	—	—	—	9	12
19.	A D	—	—	2	—	4	6	4	7	3	3	5	2	6	4	3	4	1	2	1	—	29	28
20.	B C	—	—	—	—	2	2	1	1	—	1	—	—	1	2	—	1	—	—	—	—	4	7
21.	B D	1	1	1	—	4	2	5	4	5	7	6	2	9	5	10	6	1	1	—	—	42	28
22.	C D	—	—	—	—	1	1	1	—	—	1	—	—	—	—	—	1	—	—	—	—	2	3
23.	A B C	—	—	1	—	1	2	1	1	—	1	—	—	1	1	—	—	—	—	—	—	4	5
24.	A B D	—	—	—	—	2	3	2	1	5	—	2	2	9	4	2	6	2	1	—	—	24	17
25.	A C D	—	—	—	—	—	1	1	2	3	—	—	—	—	1	1	—	—	—	—	—	5	4
26.	B C D	1	—	—	—	—	—	—	—	2	2	1	—	—	—	1	—	—	—	—	—	5	2
27.	A B C D	—	—	1	—	1	1	—	1	—	—	—	1	—	1	1	1	—	—	—	—	3	5
56.	E F G	—	1	1	—	1	4	1	—	—	—	—	—	2	3	—	7	—	1	1	—	6	16
Number noted		3	4	8	5	30	39	30	30	33	26	32	19	58	46	45	42	7	11	3	1	249	223

TABLE V.—*Two Country Board Schools of Average Social Class ; English Children.*

—		No Standard		Infants.		Standard 0		Standard I.		Standard II.		Standard III.		Standard IV.		Standard V.		Standard VI.		Standard VII.		Standard Ex. VII.		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A . .	—	—	3	3	—	—	3	—	4	—	2	1	1	1	2	—	2	—	—	1	—	—	17	6
14.	B . .	—	—	6	4	—	—	4	2	3	1	9	—	3	1	3	1	—	—	—	—	—	—	28	9
15.	C . .	—	—	—	1	—	—	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	2	2
16.	D . .	—	—	1	2	—	—	—	1	—	—	2	—	—	—	1	—	—	—	—	—	—	—	4	3
17.	A B . .	—	—	2	1	—	—	2	—	3	3	2	1	—	1	3	1	—	—	—	—	—	—	12	7
18.	A C . .	—	—	2	1	—	—	1	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	3	3
19.	A D . .	—	—	—	3	—	—	—	1	—	2	2	—	2	1	1	—	—	—	—	—	—	—	5	7
20.	B C . .	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—
21.	B D . .	—	—	4	3	—	—	4	3	1	3	3	2	—	2	2	—	—	—	—	—	—	—	14	13
22.	C D . .	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
23.	A B C .	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
24.	A B D .	—	—	—	1	—	—	2	1	—	2	1	1	1	1	1	—	1	—	—	—	—	—	6	6
25.	A C D .	—	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2
26.	B C D .	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
27.	A B C D .	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
56.	E F G .	—	—	3	1	—	—	1	—	—	2	2	2	1	1	2	—	—	1	—	—	—	—	9	7
Number noted .		—	—	23	26	—	—	21	9	12	14	23	9	8	8	15	2	3	1	—	—	—	—	105	70
Number seen .		—	—	184	163	—	—	27	84	68	80	69	69	66	56	46	19	42	9	26	2	—	—	528	482

Age last birthday .		3 and under		4		5		6		7		8		9–10		11–12		13		14 and over		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A . . .	—	—	2	—	—	2	—	—	1	1	5	—	5	1	3	1	1	1	—	—	17	6
14.	B . . .	—	—	—	—	—	3	4	1	4	1	3	1	9	1	7	2	1	—	—	—	28	9
15.	C . . .	—	—	—	—	—	—	—	1	—	—	1	—	1	1	—	—	—	—	—	—	2	2
16.	D . . .	—	—	—	—	—	1	1	1	—	—	—	—	2	1	1	—	—	—	—	—	4	3
17.	A B . . .	—	—	—	—	—	—	2	1	—	—	2	1	3	4	5	1	—	—	—	—	12	7
18.	A C . . .	—	—	—	—	—	1	1	—	2	—	—	—	—	2	—	—	—	—	—	—	3	3
19.	A D . . .	—	—	—	—	—	3	—	—	—	—	—	1	2	1	2	2	1	—	—	—	5	7
20.	B C . . .	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	2	—
21.	B D . . .	—	—	—	—	1	—	3	2	1	2	3	3	2	2	4	3	—	1	—	—	14	13
22.	C D . . .	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	1	1
23.	A B C . .	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
24.	A B D . .	—	—	—	—	—	—	—	—	1	1	—	1	2	1	2	2	1	1	—	—	6	6
25.	A C D . .	—	—	—	—	—	—	1	1	—	1	—	—	—	—	—	—	—	—	—	—	1	2
26.	B C D . .	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	2
27.	A B C D . .	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—
56.	E F G . .	—	—	—	—	1	—	2	1	1	—	—	1	1	2	2	—	2	2	—	1	9	7
Number noted . .		—	1	2	—	2	11	14	9	10	8	18	8	27	16	26	11	6	5	—	1	105	70

TABLE VI.—*A Board School; Upper Social Class; Scottish Children; Edinburgh.*

Group	Symbol	No Standard B.	No Standard G.	Infants B.	Infants G.	Standard 0 B.	Standard 0 G.	Standard I. B.	Standard I. G.	Standard II. B.	Standard II. G.	Standard III. B.	Standard III. G.	Standard IV. B.	Standard IV. G.	Standard V. B.	Standard V. G.	Standard VI. B.	Standard VI. G.	Standard VII. B.	Standard VII. G.	Standard Ex. VII. B.	Standard Ex. VII. G.	Total Number B.	Total Number G.
13	A	—	—	5	3	—	—	2	1	3	—	2	2	1	—	2	—	1	—	—	—	—	—	16	6
14	B	—	—	6	2	—	—	6	1	9	3	6	12	6	2	1	11	2	2	2	4	1	1	39	38
15	C	—	—	2	4	—	—	—	—	—	—	1	1	—	—	—	—	—	1	—	1	1	1	4	8
16	D	—	—	3	2	—	—	2	—	2	2	—	—	1	—	2	—	—	1	—	—	—	—	10	5
17	A B	—	—	1	1	—	—	—	1	2	1	1	3	5	—	3	—	1	—	1	—	—	—	14	6
18	A C	—	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	2	3
19	A D	—	—	8	1	—	—	—	3	2	2	—	—	3	1	—	—	—	—	1	—	1	—	15	7
20	B C	—	—	2	—	—	—	—	—	3	—	—	2	—	—	—	—	1	2	—	—	—	—	6	4
21	B D	—	—	10	7	—	—	—	4	11	3	1	—	3	1	—	2	4	2	—	1	—	1	29	21
22	C D	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
23	A B C	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
24	A B D	—	—	5	2	—	—	1	1	3	1	—	—	—	1	2	1	2	—	—	1	—	—	13	7
25	A C D	—	—	1	3	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	5
26	B C D	—	—	—	3	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	4
27	A B C D	—	—	1	1	—	—	—	—	—	—	1	1	—	—	—	—	1	—	—	—	—	—	3	2
56	E F G	—	—	1	—	—	—	—	—	1	—	3	3	—	4	2	2	1	1	—	1	1	—	9	11
Number noted		—	—	48	32	—	—	11	13	36	13	15	24	19	9	12	16	14	10	4	8	4	3	163	128
Number seen		—	—	173	165	—	—	87	102	150	103	107	125	117	103	88	98	50	59	20	33	11	19	803	807

Group	Symbol	3 and under B.	3 and under G.	4 B.	4 G.	5 B.	5 G.	6 B.	6 G.	7 B.	7 G.	8 B.	8 G.	9-10 B.	9-10 G.	11-12 B.	11-12 G.	13 B.	13 G.	14 and over B.	14 and over G.	Total Number B.	Total Number G.
13	A	—	—	—	—	2	—	1	2	4	2	2	1	4	1	3	—	—	—	—	—	16	6
14	B	—	—	1	—	2	—	1	1	6	2	6	4	12	11	9	15	—	4	2	1	39	38
15	C	—	—	—	—	—	—	1	2	1	2	—	1	1	—	—	2	—	—	1	1	4	8
16	D	—	—	—	—	—	2	—	—	2	—	1	—	3	1	4	1	—	1	—	—	10	5
17	A B	—	—	1	—	—	1	—	—	1	—	2	1	5	3	4	1	—	—	1	—	14	6
18	A C	—	—	—	—	1	—	1	1	—	1	—	—	—	—	—	1	—	—	—	—	2	3
19	A D	—	—	—	—	4	—	3	1	1	1	2	2	1	3	2	—	1	—	1	—	15	7
20	B C	—	—	—	—	—	—	1	—	1	—	—	1	3	—	1	2	—	1	—	—	6	4
21	B D	—	—	—	—	—	2	6	2	2	—	5	6	9	4	5	5	2	1	—	1	29	21
22	C D	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—
23	A B C	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
24	A B D	—	—	1	—	—	—	2	1	—	—	3	1	3	2	4	1	—	1	—	1	13	7
25	A C D	—	—	—	—	—	1	—	1	1	1	—	—	—	2	—	—	—	—	—	—	1	5
26	B C D	—	—	—	—	—	1	—	1	—	—	—	1	—	1	1	—	—	—	—	—	1	4
27	A B C D	—	—	—	—	—	—	—	—	—	1	—	—	1	1	2	—	—	—	—	—	3	2
56	E F G	—	—	—	—	—	—	1	—	1	—	—	1	3	4	2	5	2	—	—	1	9	11
Number noted		—	—	3	—	9	7	17	13	21	10	21	19	45	33	37	33	5	8	5	5	163	128

TABLE VII.—*Four Voluntary Schools; Upper Social Class; English Children.*

—		No Standard		Infants		Standard 0		Standard I.		Standard II.		Standard III.		Standard IV.		Standard V.		Standard VI.		Standard VII.		Standard Ex. VII.		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	6	—	5	8	—	—	1	1	7	1	7	1	5	2	4	3	4	3	1	1	—	—	40	20
14.	B	22	—	5	3	—	—	5	4	12	6	13	10	10	12	8	7	1	4	3	—	—	—	79	46
15.	C	—	—	1	—	—	—	—	—	—	—	1	2	1	1	—	—	—	—	—	—	—	—	3	3
16.	D	1	—	3	1	—	—	3	—	1	1	—	3	—	2	—	4	1	1	3	—	—	—	12	12
17.	A B	9	—	—	1	—	—	—	1	4	1	1	2	4	2	3	2	—	—	2	—	—	—	23	9
18.	A C	1	—	1	—	—	—	—	1	1	1	—	—	2	1	—	—	—	—	—	—	—	—	5	3
19.	A D	2	—	2	—	—	—	2	4	2	—	1	4	1	1	3	3	1	1	—	—	—	—	14	13
20.	B C	—	—	1	1	—	—	2	—	—	2	—	—	—	1	1	1	—	—	1	—	—	—	5	5
21.	B D	8	—	6	5	—	—	6	6	5	1	3	5	6	4	1	2	2	3	—	—	—	—	37	26
22.	C D	1	—	—	—	—	—	—	—	—	1	1	—	—	1	—	—	—	—	—	—	—	—	2	2
23.	A B C	—	—	—	—	—	—	—	—	1	—	—	1	1	1	—	2	—	—	—	—	—	—	2	4
24.	A B D	—	—	1	—	—	—	—	1	—	1	2	—	2	—	—	—	1	1	—	—	—	—	6	3
25.	A C D	—	—	1	1	—	—	2	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	5	1
26.	B C D	2	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	3	1
27.	A B C D	—	—	—	—	—	—	—	1	—	1	—	—	1	—	—	—	—	—	—	—	—	—	1	2
56.	E F G	5	—	1	1	—	—	—	3	1	1	4	—	—	3	—	3	2	1	—	—	—	—	13	12
Number noted		57	—	27	21	—	—	21	22	35	17	33	29	34	31	21	27	12	14	10	1	—	—	250	162
Number seen		228	—	255	226	—	—	133	161	149	117	127	121	124	128	96	92	64	56	54	37	2	1	1232	939

Age last birthday		3 and under		4		5		6		7		8		9–10		11–12		13		14 and over		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	—	—	2	2	3	4	—	2	3	1	4	2	12	3	8	4	3	—	5	2	40	20
14.	B	—	—	1	—	—	1	4	2	6	2	11	10	22	17	15	10	5	4	15	—	79	46
15.	C	—	—	—	—	—	—	1	—	—	—	—	1	2	2	—	—	—	—	—	—	3	3
16.	D	—	—	—	—	1	—	2	1	2	—	—	1	2	1	1	8	2	1	2	—	12	12
17.	A B	—	—	—	—	—	—	—	—	2	3	1	—	6	1	6	4	4	1	4	—	23	9
18.	A C	—	—	—	—	—	—	—	—	1	1	1	1	1	—	1	—	—	1	1	—	5	3
19.	A D	—	—	1	—	—	—	—	—	2	1	2	1	2	5	3	5	2	—	2	1	14	13
20.	B C	—	—	—	—	—	—	1	1	2	—	—	—	—	2	2	2	—	—	—	—	5	5
21.	B D	—	—	1	—	1	—	3	3	7	3	3	3	6	7	7	7	2	3	7	—	37	26
22.	C D	—	—	—	—	—	—	—	—	—	—	—	—	1	2	1	—	—	—	—	—	2	2
23.	A B C	—	—	—	—	—	—	—	—	—	—	—	—	2	2	—	2	—	—	—	—	2	4
24.	A B D	—	—	1	—	—	—	—	—	—	—	—	—	3	2	2	—	—	—	—	1	6	3
25.	A C D	—	—	—	—	—	—	1	1	1	—	1	—	2	—	—	—	—	—	—	—	5	1
26.	B C D	—	—	—	—	—	—	—	—	—	—	—	1	2	—	—	—	—	—	1	—	3	1
27.	A B C D	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	—	—	—	—	—	1	2
56.	E F G	—	—	1	—	—	1	—	—	—	3	—	1	4	3	3	2	—	2	5	—	13	12
Number noted		—	—	7	2	5	6	12	10	26	14	23	22	68	48	49	44	18	12	42	4	250	162

TABLE VIII.—*Five Voluntary Schools; Average Social Class; English.*

—		No Standard		Infants		Standard 0		Standard I.		Standard II.		Standard III.		Standard IV.		Standard V.		Standard VI.		Standard VII.		Standard Ex. VII.		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	—	—	6	9	—	—	3	—	5	4	7	3	3	—	2	2	2	—	1	1	—	—	29	19
14.	B	—	—	6	2	—	—	13	2	10	6	8	8	11	6	6	2	3	1	—	4	—	—	57	31
15.	C	—	—	1	—	—	—	1	2	—	—	2	1	2	1	—	—	—	1	—	—	—	—	6	5
16.	D	—	—	4	3	—	—	4	—	3	4	2	1	—	3	—	—	—	—	—	—	—	—	13	11
17.	A B	—	—	5	3	—	—	4	3	3	2	1	1	3	2	2	—	1	—	—	—	—	—	19	11
18.	A C	—	—	2	3	—	—	3	5	2	2	—	—	—	—	—	—	—	—	—	—	—	—	7	10
19.	A D	—	—	2	4	—	—	1	4	—	2	3	2	1	—	—	—	—	—	—	—	—	—	7	12
20.	B C	—	—	1	—	—	—	1	1	2	—	2	—	1	—	4	—	—	—	—	—	—	—	11	1
21.	B D	—	—	1	2	—	—	6	7	7	4	6	4	2	3	3	—	—	1	—	—	—	—	25	21
22.	C D	—	—	—	—	—	—	1	—	2	—	2	1	—	—	—	1	—	—	—	—	—	—	5	2
23.	A B C	—	—	4	1	—	—	1	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	6	2
24.	A B D	—	—	6	2	—	—	3	3	4	3	3	1	1	—	2	—	—	—	—	—	—	—	19	9
25.	A C D	—	—	—	3	—	—	1	1	1	—	—	—	—	—	—	—	1	—	—	—	—	—	3	4
26.	B C D	—	—	2	—	—	—	1	2	1	1	—	1	—	—	1	—	—	—	—	—	—	—	5	4
27.	A B C D	—	—	2	2	—	—	—	—	—	—	1	—	3	1	—	—	—	—	—	—	—	—	6	3
56.	E F G	—	—	3	6	—	—	—	1	2	2	1	1	4	1	—	—	—	—	—	2	—	—	10	13
Number noted		—	—	45	40	—	—	43	31	42	30	39	24	31	18	20	5	7	3	1	7	—	—	228	158
Number seen		—	—	256	246	—	—	169	201	151	192	149	143	114	97	86	69	37	18	6	22	—	—	968	988

Age last birthday		3 and under		4		5		6		7		8		9–10		11–12		13		14 and over		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	1	—	2	1	3	2	1	5	1	2	2	1	11	4	7	2	—	1	1	1	29	19
14.	B	—	—	1	—	1	1	6	2	7	—	9	1	17	15	14	8	2	2	—	2	57	31
15.	C	—	—	—	—	—	—	—	1	2	—	—	1	1	1	3	1	—	1	—	—	6	5
16.	D	—	—	1	—	1	—	2	2	5	1	—	1	3	3	1	1	—	1	—	2	13	11
17.	A B	1	—	1	—	1	1	2	2	1	2	4	—	2	4	4	2	2	—	1	—	19	11
18.	A C	—	1	1	2	1	—	1	—	2	3	1	2	1	2	—	—	—	—	—	—	7	10
19.	A D	1	—	1	—	—	—	—	2	—	2	—	4	1	3	4	1	—	—	—	—	7	12
20.	B C	—	—	1	—	—	—	—	—	1	1	—	—	2	—	6	—	1	—	—	—	11	1
21.	B D	—	—	—	—	1	1	1	2	—	3	7	1	6	6	7	3	3	1	—	4	25	21
22.	C D	—	—	—	—	—	—	—	—	1	—	1	—	2	1	1	1	—	—	—	—	5	2
23.	A B C	—	—	3	—	1	—	1	1	—	—	—	—	1	—	—	1	—	—	—	—	6	2
24.	A B D	—	—	3	—	3	—	—	2	—	2	3	3	6	1	1	1	3	—	—	—	19	9
25.	A C D	—	—	—	2	—	1	—	—	—	1	—	—	2	—	1	—	—	—	—	—	3	4
26.	B C D	—	—	—	—	—	—	2	—	—	—	—	3	2	1	1	—	—	—	—	—	5	4
27.	A B C D	—	1	—	1	—	—	1	—	1	—	—	—	2	—	2	—	—	1	—	—	6	3
56.	E F G	—	1	—	1	3	—	—	2	—	3	1	2	4	2	2	1	—	1	—	—	10	13
Number noted		3	3	14	7	15	6	17	21	21	20	28	19	63	43	54	22	11	8	2	9	228	158

TABLE IX.—*Two Voluntary Schools; Poor Social Class; English Children.*

Group	Symbol	No Standard B.	No Standard G.	Infants B.	Infants G.	Standard 0 B.	Standard 0 G.	Standard I. B.	Standard I. G.	Standard II. B.	Standard II. G.	Standard III. B.	Standard III. G.	Standard IV. B.	Standard IV. G.	Standard V. B.	Standard V. G.	Standard VI. B.	Standard VI. G.	Standard VII. B.	Standard VII. G.	Standard Ex. VII. B.	Standard Ex. VII. G.	Total Number B.	Total Number G.
13.	A	—	—	6	4	—	—	2	3	4	2	2	1	3	—	2	1	—	1	—	—	—	—	19	12
14.	B	—	—	1	2	—	—	10	3	2	6	5	1	4	1	4	1	—	1	—	—	—	—	26	15
15.	C	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
16.	D	—	—	5	1	—	—	—	1	—	—	3	—	—	—	—	—	—	—	—	—	—	—	8	2
17.	A B	—	—	3	1	—	—	1	—	—	—	1	—	—	—	2	1	1	—	—	—	—	—	8	2
18.	A C	—	—	1	5	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	6
19.	A D	—	—	5	2	—	—	4	—	3	1	1	1	1	1	—	2	—	—	—	—	—	—	14	7
20.	B C	—	—	3	—	—	—	—	—	1	1	—	—	—	—	—	1	—	1	—	—	—	—	4	3
21.	B D	—	—	1	4	—	—	13	3	3	3	8	4	2	2	1	2	—	—	—	—	—	—	28	18
22.	C D	—	—	1	1	—	—	3	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	4	2
23.	A B C	—	—	1	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1
24.	A B D	—	—	—	2	—	—	4	4	2	2	1	3	1	1	—	—	—	—	—	—	—	—	8	12
25.	A C D	—	—	3	1	—	—	2	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	5	2
26.	B C D	—	—	—	1	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2
27.	A B C D	—	—	—	—	—	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2
56.	E F G	—	—	3	1	—	—	1	—	—	3	—	1	4	1	—	1	—	2	—	—	—	—	8	9
Number noted		—	—	33	27	—	—	43	18	15	20	21	11	15	6	9	9	1	5	—	—	—	—	137	96
Number seen		—	—	141	169	—	—	169	149	105	121	100	93	80	86	74	60	19	35	7	3	2	4	697	720

Age last birthday: Group	Symbol	3 and under B.	3 and under G.	4 B.	4 G.	5 B.	5 G.	6 B.	6 G.	7 B.	7 G.	8 B.	8 G.	9–10 B.	9–10 G.	11–12 B.	11–12 G.	13 B.	13 G.	14 and over B.	14 and over G.	Total Number B.	Total Number G.
13.	A	—	2	1	1	3	—	3	1	1	3	2	2	3	1	6	1	—	1	—	—	19	12
14.	B	—	—	—	—	1	—	1	1	5	4	5	3	6	6	8	1	—	—	—	—	26	15
15.	C	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
16.	D	—	—	1	—	1	—	2	1	1	1	—	—	2	—	—	—	1	—	—	—	8	2
17.	A B	—	—	—	—	1	1	2	—	—	—	1	—	1	—	3	—	—	1	—	—	8	2
18.	A C	—	1	—	3	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	6
19.	A D	—	—	1	—	2	—	2	2	1	—	2	—	4	2	1	3	1	—	—	—	14	7
20.	B C	—	—	1	—	1	—	1	—	—	—	—	—	1	1	—	1	—	1	—	—	4	3
21.	B D	—	—	1	1	—	3	—	—	2	1	7	—	7	7	8	6	2	—	1	—	28	18
22.	C D	—	—	—	—	—	1	1	—	3	—	—	—	—	1	—	—	—	—	—	—	4	2
23.	A B C	—	1	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	2	1
24.	A B D	—	—	—	—	—	—	—	2	1	—	2	2	2	4	3	4	—	—	—	—	8	12
25.	A C D	—	—	—	—	1	—	2	—	2	1	—	1	—	—	—	—	—	—	—	—	5	2
26.	B C D	—	—	—	1	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	1	2
27.	A B C D	—	—	—	—	—	—	—	—	—	—	—	—	1	2	—	—	—	—	—	—	1	2
56.	E F G	—	—	—	1	—	—	3	—	—	—	1	1	3	3	1	4	—	—	—	—	8	9
Number noted		—	4	5	7	11	6	18	9	17	10	21	9	30	28	30	20	4	3	1	—	137	96

Table X.—*Ten Voluntary Schools in London; Poorer Social Class; Irish Children.*

Group	Symbol	No Standard B.	No Standard G.	Infants B.	Infants G.	Standard 0 B.	Standard 0 G.	Standard I. B.	Standard I. G.	Standard II. B.	Standard II. G.	Standard III. B.	Standard III. G.	Standard IV. B.	Standard IV. G.	Standard V. B.	Standard V. G.	Standard VI. B.	Standard VI. G.	Standard VII. B.	Standard VII. G.	Standard Ex. VII. B.	Standard Ex. VII. G.	Total Number B.	Total Number G.
13	A	—	—	22	20	—	—	20	6	15	5	12	4	9	3	10	—	3	1	3	1	—	—	94	40
14	B	—	—	17	3	—	—	30	8	20	17	19	7	17	13	12	6	8	2	—	—	—	—	123	56
15	C	—	—	6	2	—	—	4	2	—	—	3	—	—	1	1	1	—	—	—	—	—	—	14	6
16	D	—	—	9	1	3	—	3	5	2	3	5	3	1	1	—	—	—	—	—	—	—	—	23	13
17	A B	—	—	3	5	—	—	19	4	16	6	9	3	6	3	4	2	3	1	—	—	—	—	60	24
18	A C	—	—	5	6	—	—	4	4	—	2	1	—	1	2	—	1	1	1	—	—	—	—	12	16
19	A D	—	—	7	9	1	—	12	7	3	5	4	4	—	—	1	2	1	—	—	—	—	—	29	27
20	B C	—	—	4	4	—	—	4	3	2	2	1	3	1	2	—	—	—	1	—	—	—	—	12	15
21	B D	—	—	14	3	1	—	17	13	13	3	8	7	6	4	4	1	3	2	—	—	—	—	66	33
22	C D	—	—	2	—	—	—	—	2	1	—	—	1	—	—	—	1	—	—	—	—	—	—	3	4
23	A B C	—	—	3	2	—	—	2	3	—	2	1	—	—	1	—	—	—	1	—	—	—	—	6	9
24	A B D	—	—	4	5	—	—	15	9	8	5	4	2	4	3	1	1	1	—	—	—	—	—	37	25
25	A C D	—	—	4	3	—	—	2	6	—	1	—	—	—	—	—	—	—	—	—	—	—	—	6	10
26	B C D	—	—	6	—	—	—	1	1	2	—	1	—	—	2	—	—	—	—	—	—	—	—	10	3
27	A B C D	—	—	3	4	—	—	5	7	—	1	—	—	—	—	—	—	—	—	—	—	—	—	8	12
56	E F G	—	—	12	12	—	—	5	4	2	3	2	5	4	2	5	4	2	1	—	—	—	—	32	31
Number noted		—	—	121	79	5	—	143	84	84	55	70	39	49	37	38	19	22	10	3	1	—	—	535	324
Number seen		—	—	629	613	15	—	451	438	336	320	287	232	198	187	158	107	78	49	19	6	—	—	2171	1952

Group	Symbol	3 and under B.	3 and under G.	4 B.	4 G.	5 B.	5 G.	6 B.	6 G.	7 B.	7 G.	8 B.	8 G.	9–10 B.	9–10 G.	11–12 B.	11–12 G.	13 B.	13 G.	14 and over B.	14 and over G.	Total Number B.	Total Number G.
13	A	—	4	3	2	6	5	11	4	11	6	10	3	23	9	23	7	4	—	3	—	94	40
14	B	1	—	1	—	4	—	8	3	16	2	15	8	42	19	32	22	3	2	1	—	123	56
15	C	—	1	1	—	1	1	2	—	4	—	1	—	4	1	—	3	1	—	—	—	14	6
16	D	—	—	1	—	3	1	2	—	2	—	5	5	4	2	4	3	2	2	—	—	23	13
17	A B	—	—	—	—	—	3	2	3	8	2	12	2	17	6	17	7	4	1	—	—	60	24
18	A C	1	1	1	1	2	2	1	—	1	3	2	2	3	4	—	2	1	1	—	—	12	16
19	A D	—	—	2	—	1	4	2	3	4	4	6	4	11	6	3	4	—	1	—	1	29	27
20	B C	—	—	—	1	1	—	1	2	3	3	2	1	3	4	2	3	—	1	—	—	12	15
21	B D	—	—	2	—	1	—	7	2	8	4	9	2	15	13	21	8	3	4	—	—	66	33
22	C D	—	—	—	—	2	—	—	—	—	—	—	—	1	2	—	2	—	—	—	—	3	4
3	A B C	—	—	—	—	2	1	—	—	1	2	1	2	1	2	1	2	—	—	—	—	6	9
24	A B D	—	—	1	—	1	1	1	3	3	2	5	1	12	9	12	6	1	2	1	1	37	25
25	A C D	1	—	1	—	—	—	1	1	2	6	—	—	1	1	—	2	—	—	—	—	6	10
26	B C D	—	—	—	—	2	—	2	—	3	1	1	—	—	—	2	2	—	—	—	—	10	3
27	A B C D	1	—	—	—	1	—	1	3	1	3	1	2	1	4	2	—	—	—	—	—	8	12
56	E F G	—	1	—	3	2	4	7	3	6	2	1	2	6	8	8	8	2	—	—	—	32	31
Number noted		4	7	13	7	29	22	48	27	73	40	71	34	144	90	127	81	21	14	5	2	535	324

TABLE XI.—*Three Voluntary Schools in London; Average Social Class; Jewish Children.*

—		No Standard		Infants		Standard 0		Standard I.		Standard II.		Standard III.		Standard IV.		Standard V.		Standard VI.		Standard VII.		Standard Ex. VII.		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	—	—	6	4	—	—	3	3	4	2	2	2	1	3	2	—	—	—	—	—	—	—	18	14
14.	B	—	—	2	4	—	—	8	2	7	3	3	11	5	4	5	2	2	7	6	—	—	—	38	33
15.	C	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—
16.	D	—	—	2	1	—	—	—	—	—	1	—	1	1	1	1	—	—	1	1	—	—	—	5	5
17.	A B	—	—	4	1	—	—	3	2	2	2	1	2	3	1	—	1	2	—	2	—	1	—	18	9
18.	A C	—	—	1	1	—	—	—	1	1	3	—	—	—	—	—	—	—	—	—	—	—	—	2	5
19.	A D	—	—	12	1	—	—	—	2	1	—	2	—	2	2	—	—	—	—	—	—	—	—	17	5
20.	B C	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	2	1
21.	B D	—	—	2	4	—	—	3	3	1	—	1	—	3	—	—	—	—	—	—	1	—	—	10	8
22.	C D	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	2	—
23.	A B C	—	—	2	—	—	—	—	—	—	—	—	1	—	1	—	—	1	—	—	—	—	—	3	2
24.	A B D	—	—	2	3	—	—	2	1	2	1	1	2	—	—	—	2	1	—	—	—	—	—	8	9
25.	A C D	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
26.	B C D	—	—	—	—	—	—	—	1	1	—	1	—	1	—	—	—	—	—	—	—	—	—	3	1
27.	A B C D	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
56.	E F G	—	—	—	2	—	—	2	—	3	—	1	1	2	2	—	4	—	—	—	3	—	—	8	12
Number noted		—	—	36	21	—	—	22	15	25	12	13	20	18	14	8	9	6	9	9	4	1	—	138	104
Number seen		—	—	193	162	—	—	124	128	125	114	110	89	102	75	65	68	58	35	41	22	5	—	823	693

Age last birthday		3 and under		4		5		6		7		8		9-10		11-12		13		14 and over		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	—	—	—	1	3	3	2	—	3	2	2	1	4	6	4	1	—	—	—	—	18	14
14.	B	—	1	—	—	1	1	2	1	5	2	5	2	8	13	15	10	2	2	—	1	38	33
15.	C	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—	2	—
16.	D	—	—	1	—	—	1	—	—	—	—	1	—	—	1	1	3	2	—	—	—	5	5
17.	A B	—	—	1	—	1	—	1	—	3	2	3	2	1	4	4	1	3	—	1	—	18	9
18.	A C	—	—	—	—	—	1	—	—	1	—	—	3	1	1	—	—	—	—	—	—	2	5
19.	A D	—	—	6	—	2	1	3	—	1	1	—	—	3	1	2	1	—	—	—	1	17	5
20.	B C	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	1	—	—	—	—	2	1
21.	B D	—	—	1	—	1	—	—	2	1	1	—	1	5	3	1	—	1	1	—	—	10	8
22.	C D	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	2	—
23.	A B C	—	—	1	—	1	—	—	—	—	—	—	—	—	1	1	—	—	1	—	—	3	2
24.	A B D	—	—	1	1	1	—	—	—	—	3	4	—	1	3	1	2	—	—	—	—	8	9
25.	A C D	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
26.	B C D	—	—	—	—	—	—	—	—	—	1	—	—	3	—	—	—	—	—	—	—	3	1
27.	A B C D	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
56.	E F G	—	—	—	1	—	1	—	—	1	—	3	—	3	1	1	4	—	3	—	2	8	12
Number noted		—	1	12	3	11	8	9	3	16	12	20	9	31	34	30	23	8	7	1	4	138	104

TABLE XII.—*A Voluntary School; Poor Social Class; London; Jewish Children.*

—		No Standard		Infants		Standard 0		Standard I.		Standard II.		Standard III.		Standard IV.		Standard V.		Standard VI.		Standard VII.		Standard Ex. VII.		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	—	—	—	—	—	—	—	2	—	—	6	1	—	—	4	1	7	2	—	—	—	—	17	6
14.	B	—	—	—	—	—	—	—	1	—	—	24	4	—	—	12	4	21	9	—	—	—	—	57	18
15.	C	—	—	—	—	—	—	—	—	—	—	2	—	—	—	2	—	2	—	—	—	—	—	6	—
16.	D	—	—	—	—	—	—	—	4	—	—	2	6	—	3	5	2	3	—	—	—	—	—	10	15
17.	A B	—	—	—	—	—	—	—	2	—	—	7	4	—	1	2	—	3	—	—	—	—	—	12	7
18.	A C	—	—	—	—	—	—	—	—	—	—	2	—	—	—	1	—	1	—	—	—	—	—	4	—
19.	A D	—	—	—	—	—	—	—	2	—	—	3	3	—	—	3	1	—	—	—	—	—	—	6	6
20.	B C	—	—	—	—	—	—	—	1	—	—	3	1	—	—	3	—	2	1	—	—	—	—	8	3
21.	B D	—	—	—	—	—	—	—	—	—	—	6	6	—	1	4	1	—	—	—	—	—	—	10	8
22.	C D	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	1	—	—	—	—	—	3
23.	A B C	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	3	—	—	—	—	—	5	—
24.	A B D	—	—	—	—	—	—	—	1	—	—	4	1	—	—	—	—	—	—	—	—	—	—	4	2
25.	A C D	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	1	1
26.	B C D	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	1	—	—	—	—	—	2	1
27.	A B C D	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
56.	E F G	—	—	—	—	—	—	—	—	—	—	3	3	—	—	5	1	5	3	—	—	—	—	13	7
Number noted		—	—	—	—	—	—	—	14	—	—	64	31	—	6	43	11	48	16	—	—	—	—	155	78
Number seen		—	—	—	—	—	—	—	40	—	—	184	214	—	37	118	46	138	57	—	—	—	—	440	394

Age last birthday		3 and under		4		5		6		7		8		9–10		11–12		13		14 and over		Total Number	
Group	Symbol	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
13.	A	—	—	—	—	—	—	—	—	—	1	—	1	3	—	11	3	3	1	—	—	17	6
14.	B	—	—	—	—	—	—	—	—	—	—	—	1	14	1	34	14	7	2	2	—	57	18
15.	C	—	—	—	—	—	—	—	—	—	—	—	—	1	—	4	—	1	—	—	—	6	—
16.	D	—	—	—	—	—	—	—	—	—	2	—	—	2	6	5	7	3	—	—	—	10	15
17.	A B	—	—	—	—	—	—	—	—	—	—	1	1	3	2	6	4	1	—	1	—	12	7
18.	A C	—	—	—	—	—	—	—	—	—	—	1	—	—	—	3	—	—	—	—	—	4	—
19.	A D	—	—	—	—	—	—	—	—	—	1	—	1	2	2	3	2	1	—	—	—	6	6
20.	B C	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7	2	1	1	—	—	8	3
21.	B D	—	—	—	—	—	—	—	—	—	—	—	—	—	3	9	4	1	1	—	—	10	8
22.	C D	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	3
23.	A B C	—	—	—	—	—	—	—	—	—	—	—	—	2	—	2	—	1	—	—	—	5	—
24.	A B D	—	—	—	—	—	—	—	—	—	1	—	—	3	1	1	—	—	—	—	—	4	2
25.	A C D	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—	1	1
26.	B C D	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	1	—	—	—	2	1
27.	A B C D	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1
56.	E F G	—	—	—	—	—	—	—	—	—	—	—	1	3	1	10	4	—	1	—	—	13	7
Number noted		—	—	—	—	—	—	—	—	—	5	2	6	34	17	96	44	20	6	3	—	155	78

Ethnographical Survey of the United Kingdom.—Fourth Report of the Committee, consisting of Mr. E. W. Brabrook (*Chairman*), Dr. Francis Galton, Dr. J. G. Garson, Professor A. C. Haddon, Dr. Joseph Anderson, Mr. J. Romilly Allen, Dr. J. Beddoe, Professor D. J. Cunningham, Professor W. Boyd Dawkins, Mr. Arthur J. Evans, Mr. F. G. Hilton Price, Sir H. Howorth, Professor R. Meldola, General Pitt-Rivers, Mr. E. G. Ravenstein, *and* Mr. E. Sidney Hartland (*Secretary*). (*Drawn up by the Chairman.*)

1. As in previous years, the Committee have had the advantage of the co-operation of several gentlemen not members of the Association, but delegates of various learned bodies who are interested in the Survey. Mr. George Payne, one of the delegates of the Society of Antiquaries, and Mr. E. Clodd, Mr. G. L. Gomme, and Mr. J. Jacobs, the representatives of the Folklore Society, Sir C. M. Kennedy, K.C.M.G., representing the Royal Statistical Society, Mr. Edward Laws, the Ven. Archdeacon Thomas, Mr. S. W. Williams, and Professor John Rhys, representing the Cambrian Archæological Association, and Dr. C. R. Browne, a representative of the Royal Irish Academy, have continued their valuable services. Other members of the Committee are delegated by the Anthropological Institute.

2. In previous reports, the Committee presented a list of villages or places which, in the opinion of competent persons consulted by the Committee, appeared especially to deserve ethnographic study. They also recorded the commencement of such study in several parts of the United Kingdom by observers residing in the respective neighbourhoods. Since the last meeting of the Association the Committee have taken an important step in advance by commissioning the Rev. Dr. Walter Gregor to make a special visit to the district of Galloway for the purpose of the survey. He remained there during part of the months of October and November 1895, and paid another visit in the spring of the present year. On these occasions he collected a considerable amount of information on the current traditions and folklore of the district, and took measurements of a number of the inhabitants. The Committee have requested him to complete his observations on the people of Galloway, and to commence a similar systematic survey of Ayrshire, the results of which will, it is expected, be ready for insertion in their next Report. Dr. Gregor possesses special qualifications for this work, and his preliminary notes are appended to this Report, not merely as being of interest in themselves, but as indicating by example the manner of recording folklore.

3. The tabulation of the results of Dr. Gregor's physical measurements, and of those which the Committee have received from other sources,

is deferred to a future Report. The Committee hope also, if reappointed, in future Reports to supply bibliographical information.

4. The Committee have provided, for the use of observers of the physical characters of the people, a number of the following instruments graduated in millimetres :—

1. A two-metre tape.
2. A pair of folding callipers.
3. A folding square.
4. A small set-square.

Sets of these have been supplied to applicants in various parts of the country, who will communicate to the Committee the measurements they take. Others are still available for use by competent observers who may desire to borrow them, and those at present in circulation will be reissued as soon as returned. Several applications were made in consequence of an announcement on the matter inserted in the 'Academy,' 'Athenæum,' and 'Nature' by the courtesy of the editors of those journals.

5. The Committee have to thank the Rev. Fletcher Moss, of Didsbury, for a number of measurements and other observations.

6. The Committee are much indebted to Mr. G. Paul for undertaking to organise, through communications to the local papers circulating in Nidderdale, and communications with the local Naturalists' Club, a survey of that district, the results of which the Committee hope to receive in due course.

7. The Buchan Field Club has published a series of observations made by Mr. John Gray, B.Sc., and Mr. Tocher, secretary of the club, upon the anthropological characters of the people of East Aberdeenshire. It is proceeding with the work upon the lines laid down by this Committee.

8. The Irish Ethnographic Committee, consisting of Professors Cunningham and Haddon, members of this Committee, and Professors Haughton and Wright, is engaged in tabulating the results of the measurements of over 500 individuals taken during the last four years in the Anthropometric Laboratory of Trinity College, Dublin. It is intended to tabulate the statistics with reference to ethnography, to the occupation of the subjects, and to the success of the students. For the first of these the subjects will be grouped geographically, according to the districts from which their parents come, in probably a dozen groups. Dr. C. R. Browne, who co-operates with this Committee, has undertaken the work of tabulating the observations and calculating the indices. A Report from the Committee is appended.

9. The Cambridge Ethnographic Survey Committee have also commenced operations. They are at present investigating the villages of Barrington and Foxton, but as yet there are no results available for this Report.

10. The Committee have to thank the Congress of Archæological Societies in union with the Society of Antiquaries of London for printing and circulating among their members a large number of this Committee's code of instructions, with Mr. Hartland's explanatory paper appended thereto. At the Canterbury Meeting of the Royal Archæological Institute a discussion has taken place on the subject of an ethnographical survey of Kent.

11. Appended to this Report is an important communication made to this Committee by Mr. Laurence Gomme, on the method of determining

the value of folklore as ethnological data. The recommendations of Mr. Gomme will be found to be valuable when the stage arrives at which it is practicable and necessary to compare the collections made by the Committee in different localities.

12. The Committee have learned with much gratification from Mr. Griffith that the establishment of similar committees for the Dominion of Canada and the United States of America, working on the same lines as this Committee, is in contemplation.

13. The Committee look upon these several results of their work as encouraging, and ask to be reappointed for the purpose of continuing it. They also ask for a further grant of 50*l.*, having wholly expended the sum granted for the present year.

APPENDIX I.

The Ethnographical Survey of Ireland.—Report of the Committee, consisting of Dr. C. R. Browne, Professor D. J. Cunningham, Dr. S. Haughton, Professor E. Perceval Wright, *and* Professor A. C. Haddon (*Secretary*). (*Drawn up by the Secretary.*)

Last year the Royal Irish Academy published[1] a Report by Dr. C. R. Browne on 'The Ethnography of the Mullet, Inishkea Islands, and Portacloy, co. Mayo,' illustrated by three plates of photographs. This is the third Report issued by the Dublin Ethnographic Committee, and the investigation was carried out on the same lines as previously—that is, it embraces the physiography of the district, anthropography (physical characters and statistics, vital statistics—personal and economic, physiology, folk-names); sociology (occupations, customs, food, clothing, dwellings, and transport); folklore, archæology (survivals and antiquities); history, &c. The district investigated is a very wild and remote part of Ireland, and, in spite of great difficulties, Dr. Browne has produced a valuable and interesting memoir. A full series of observations were taken on sixty-two adult males, and the eye and hair colours of 494 individuals were recorded. The average stature of the men is 1·725 m. (about 5 ft. 8 in.); they are stoutly built and broad-shouldered. Over 80 per cent. of the adults have brown or dark hair, and about the same number have light eyes; but the eyes of the women run darker than those of the men. The cephalic index of the men is mainly (39) mesaticephalic, there being 20 brachycephals and only 3 dolichocephals; if two units are deducted (as is often done to compare with cranial indices), the numbers are 41 mesati-, 10 brachy-, and 11 dolicho-cephals. The mean cephalic index is 79·4, the facial is 111·9, and the nasal 64. Dr. Browne analyses the differences of the people from the various districts. Thus the North Inishkea and the Portacloy are the tallest (av. 1·727 m.=5 ft. 8 in.); but the former have the shortest arms, the proportion of span to height being 102·45; while at Portacloy it is 105·65, and intermediate elsewhere. The nigrescence index is as follows: Inishkea Islands 10·5, Mullet 62·3, Portacloy 77·5; thus the islands show a greater proportion of light hair. There is a greater tendency to brachycephalism in South Inishkea and Portacloy, and none of these men were

[1] *Proceedings* (3), vol. iii. pp. 587–649.

dolichocephalic. The reader is referred to the original paper for fuller details.

In 1895 Dr. Browne investigated the natives of Ballycloy, in the southern portion of the barony of Erris, in co. Mayo. This is an isolated district, being cut off by a semicircle of mountains from the rest of the county. The people, who are much intermarried, are largely descended from Ulster settlers. A statement, originally made by an anonymous writer, has somehow gained currency, and has been repeatedly quoted abroad, noticeably by M. de Quatrefages and by M. Devay, that the descendants of the Ulster people, driven two centuries ago into Sligo and Mayo, had dwindled into dwarfs of 5 feet 2 inches high, prognathous, and pot-bellied. Dr. Browne found that the average height of these people is 1·721 m. (5 feet $7\frac{3}{4}$ inches), and they exhibited no sign of physical degeneracy; they are very healthy, fond of music and dancing, given to joking, and sharp in business. Though there is a coast-line of forty-seven miles, nearly all the men are farmers. The houses are of a somewhat better order than those commonly found in the West of Ireland. Fifty men were measured, and the hair and eye colours of 298 individuals noted. The mean cephalic index is 80·5 (78·5), facial index 112·6, and nasal index 63·9. Full details, as in the last Report, will shortly be published in the 'Proceedings' of the Royal Irish Academy.

APPENDIX II.

Report of the Ethnographical Survey of Pembrokeshire. *By* EDWARD LAWS, Esq., *F.S.A.*

At the annual meeting of the Cambrian Archæological Association, held at Launceston in August 1895, Mr. Henry Owen, F.S.A., and myself were requested to institute an archæological survey of the county of Pembroke.

Mr. Owen undertook to compile a bibliography—no slight task, for though Pembroke is comparatively a small county it has perhaps been more freely ink-bespattered than any shire in Wales. Mr. Owen has now ready for press an annotated catalogue of printed books referring to the county. This list he will present to the committee appointed by the Cambrian Archæological Association at their meeting on the 7th September in Aberystwith. When the catalogue of printed books has been issued it is proposed to prepare and print a list of MSS. relating to the county of Pembroke. This is a work that cries aloud for the worker. The list of MSS. relating to the Welsh counties preserved in the British Museum was compiled just one hundred years ago, and other great libraries are equally behind the times.

I myself undertook to raise a company of Pembrokeshire men, and with their assistance archæologically annotate the 6-inch ordnance survey of the county of Pembroke. I have now ready for press thirty quarter sheets, and hope before the end of the month of August to receive twenty more.

The system we have adopted is as follows: I send out one or more quarter sheets to a volunteer worker, requesting that he will mark thereon with a pinhole the position of the following objects:—

Camps or spaces enclosed by earthworks.
Camps or spaces enclosed by stone wall.

Camps or spaces enclosed by banks or walls at right angles.
Earthworks which do not enclose a space.
Settlements as shown by hut foundations, animal bones, shells, &c.
Interments, barrows, graves.
Megalithic remains, cromlechs, rocking stones, menhirs, holed stones, stone circles.
Inscribed stones, with Ogam or Roman lettering, or carved.
Stone implements, or flint chips.
Bronze implements.
Pottery.
Coins.
Ecclesiastical buildings, or remains.
Military buildings, or remains.
Domestic buildings, manor houses, &c., or remains.
Battle-fields.
Holy wells.
Localities connected with legends.
Other spots of archæological interest.

Having marked these spots on the map with a pinhole, the assistant is requested to put a number on the back of the map by his pinhole, and a symbol on the face (for this purpose he has been supplied with a simple code of symbols, which seems to answer fairly well), and then on a separate piece of paper to write his remarks, measurements, &c.

On receipt of the quarter sheet with the accompanying notes, I schedule the latter thus :—

Symbol | No. | Locality | Object | Notes and References.

I look up former descriptions of the object already published and give them in the fifth column. If the object is technical, such as an Ogam or inscribed stone, I ask aid from an expert ; if something that seems to me important or incomprehensible, I personally inspect.

Of the thirty quarter sheets received two have proved barren ; on the remaining twenty-eight I find 246 objects marked, and of these 106 have escaped the Ordnance Surveyor.

The gentlemen to whom I am indebted for this valuable assistance are six in number : Lieut. Howorth, R.A. ; Lieut.-Col. Lambton ; A. H. Lascelles, Esq. ; Henry Mathias, Esq. ; Thos. Wall, Esq., M.D. ; Mr. Henry Williams, editor of the 'Pembroke County Guardian.'

These gentlemen still hold some sheets, and a good many more have been distributed among other friends, which I hope shortly to receive.

When finished each quarter sheet will be complete in itself, and, if my Committee think good, can be supplied to members and non-members of the Association at a cost very little exceeding the original price of the map.

Our associate, Mr. Williams, has been good enough to give up to the survey a column of newspaper in which to collect notices of the customs, traditions, and superstitions of the people. As the 'Pembroke County Guardian' is published at Solva, in the Welsh-speaking district of Pembrokeshire, this is a very valuable aid, for although the English-speaking portion of the county has been well exploited, the Welshery is still untrodden ground. We call this column 'Yn amsang ein Tadau'—*i.e.* in the footsteps of our fathers—and have collected therein a vast amount of matter which, when properly digested, we hope to reprint at the end of the year. Two notes I will give as specimens :—

1. The Vicar of Pontfaen draws attention to a custom called 'Y Wylnos,' or the Wake Night.

Formerly, the day before burial, the corpse was removed from the coffin, a rope passed under the arms, by which it was drawn up the chimney of the house, then lowered again and replaced in the coffin. This ghastly ceremony was common in the last century : the last recorded performance took place at the Old Mill on the glebe land of Pontfaen.

Several persons have corroborated the vicar's story as to this unnatural performance.

2. The hell-hounds, whist-hounds, or dandy-dogs, as they are called in different places, are still occasionally heard on the slopes of Precelli, but here they are termed 'Cwn bendith y Mamau.'

APPENDIX III.

Preliminary Report on Folklore in Galloway, Scotland.

By Rev. Walter Gregor, LL.D.

On October 16, 1895, I went, on the invitation of Sir Herbert Maxwell, to the Airlour, parish of Mochrum, Wigtownshire. He afforded me, during the time I was his guest, every facility to carry out the work entrusted to me. From one of his workmen, John Thomson, aged seventy years, I obtained the Folk-tale of 'Marget Totts' and the tale of Aikendrum the Brownie, along with a good many items of folklore, including the mode of cutting 'The Hare.' On Monday the 21st, on the invitation of Mr. Wright of Alticry, I went to Alticry House, and took measurements of three men, two farmers and Mr. Wright's gamekeeper, from the last of whom I got some rhymes and other items of folklore. In the parish of Mochrum seven sets of measurements were got, and one was obtained in the neighbouring parish of Glasserton. The best thanks of the Committee are due to Sir Herbert and Lady Maxwell, as well as to the Misses Maxwell for their helpful kindness. Mr. Wright showed great attention. On Tuesday, October 22, I went to Soulseat, the Manse of Inch, the residence of the Rev. Mr. Paton. He used every exertion to help me to carry out the wishes of the Committee. He took me to those of his parishioners whose ancestors had been for the longest period in Galloway. From this parish, Stranraer and Stoneykirk, were obtained eleven sets of measurements, nine males and two females. The difficulty met with in those parishes is the mixture of modern Irish. With the help of Mr. and Mrs. Paton those whose ancestors were Irish either on the father's or mother's side were avoided as much as possible in the parish of Inch, though it was not always convenient to do so. From Inch were obtained several rhymes and other items of folklore. I have to say that Mr. and Mrs. Paton were most kind, and without Mr. Paton's help not much could have been accomplished. On October 29 I went to the Manse of Minnigaff, and was most cordially received by Mr. and Mrs. Reid. Mr. Reid spared no pains to meet my wishes, both by driving me for miles through the wild Galloway moors and by taking me to those he considered able to help me both in Minnigaff and in Newton-Stewart.

Eleven measurements of males and ten of females were obtained, along with some folklore.

Some items of folklore have not been communicated to the Committee, as I wish to make further investigation into them. It will be seen that twenty-eight measurements of males and twelve of females—in all forty—have been obtained, along with a considerable amount of folklore. The items of folklore which follow are numbered for facility of reference, and the place where each was obtained is indicated at the commencement of the paragraph.

I have only to add that nothing could exceed the kindness and courtesy with which I was received by all, and the readiness with which all gave themselves to be measured, and that all were much interested in the survey.

1. *Mochrum.* 'Marget Totts.'—Once on a time a man was very hard towards his wife, and laid tasks on her no one could accomplish. He at one time gave her such a quantity of flax to spin within a fixed time that the work was beyond human power. As she was sitting in the house bemoaning herself, and thinking of what was to be done, a woman entered. Seeing her in great distress and perplexity, she asked her what was the matter with her. She told her of the task that had been laid on her by her husband. The stranger said to her: 'I'll tack awa' yir lint an spin't t' you, an bring't back t' you on such and such a day (naming the day), if ye can tell me my name.' The guidwife agreed at once, and gave the woman the lint. But she was now in as great straits as ever, and could in no way come to her apparent friend's name, and the day on which the lint was to be brought back was drawing near. As she was one day sitting at her wits' end in the house a man came in. He asked her what ailed her that she was looking so cast down and sad. She told him all her tale. Now near the house there was a small hill covered with thorn bushes and whins. The man told her to go to this hill and hide herself among the bushes near an open space on it, and she would hear something to help her. She did as she was told. She had not been long in her hiding-place till a lot of fairy women came with their spinning wheels and sat down on the open space not far from her. She saw her friend amongst them. As she span she went on saying, 'Little does the guidwife ken it my name's Marget Totts.' The woman withdrew without being seen by the fairies. The day fixed for bringing back the yarn came, and the woman appeared with it. 'Here's yir yarn, if ye can tell me what my name is.' 'Your name's Marget Totts,' said the guidwife. The spinner went up the lum in a blaze of fire, and left the yarn.

2. *Mochrum.*—The Brownie is believed to be, for the most part, of a kind, obliging disposition.

A Brownie that bore the name of Aikendrum went one day to the mill of Birhosh and offered his services to the guidwife on the sole condition of getting a 'cogful o' brose each evening atween the licht an the dark' as his wages. He took in hand for this wages to bring all the grain into the stackyard and to thresh it, and to gather the sheep into the 'rees.' The guidwife was quite keen for keeping him, but the daughters objected as no wooers would come to the house so long as Aikendrum was in it. The mother ordered silence, and took the Brownie into service. The harvest was late, and he began his work at once. Within a short time all the grain was safe in the stackyard. One evening he was ordered to gather in all the sheep. By morning, when the family was astir, the sheep were all in the 'rees.' 'It must have been a hard job for you,' said the guidwife, on seeing what had been done. 'I had mair trouble,' said the Brownie, 'wi a little broon ane wi' waggin' horns nor a' the laive thegither.' The little 'broon ane wi' waggin horns' was a hare. A married daughter came to live at the mill. One day she gave him a pair of her husband's breeks. He was so offended that he left at once. Before going away he took out the two millstones and threw them into the weal below the bridge over the Bladnach. He would have nothing more than his fixed wages—'the cogful of brose.'

3. *Mochrum.*—The following story was told to my informant when a boy by an old woman eighty years of age. It was on the Sacrament Sunday, 'the langest day in June.' She was a girl at the time, and was left to look after the house in the absence of the other members of the family at church. She went outside and sat down on a stone 't' read her beuk.' While sitting and reading she saw 'the bonniest wee man she ever saw in her life come oot amon' the thorn busses, go to the kiln knowe, and sit doon on the loupin-on-stane, and for twa oors he played on the bagpipes "The Birks o' Aberfoyle," the bonniest music she ever heard in her life.' The bonnie wee man was dressed in green, braided with yellow, and had a four-cornered hat.

4. *Mochrum.*—About forty-eight years ago, as some men were approaching the bridge over the Airlour Burn, a big black dog with fire flying out of his mouth was seen crossing the road into a wood on the opposite side of the road. Before any of them could come up to him, he had entered the wood and disappeared.

5. *Mochrum.*—It is considered to be unlucky to cart away 'standing stones,' *i.e.* the stones of the circles called Druidical.

6. *Mochrum.*—It is unlucky to cart away any of the soil from a graveyard, however long it has ceased to be used. There is a farm called Kirkland in the parish of Mochrum. On it is a spot said to have been used as a burial-ground long ago. It remained untouched till about sixty years ago. At that time the tenant set about carting away the soil. Hardly had he begun work when two of the horses fell dead.

7. *Mochrum.*—To forget the Sabbath-day and to begin to work as on week-days was very unlucky. The farmer of D—— once forgot that it was the Sabbath, and yoked the plough as usual. A man going to church saw him ploughing; he ran to him and told him what day it was. The farmer said he had forgotten. Within a year the farmer, his wife, and the farm had all gone to ruin.

8. *Mochrum.*—If one was leaving a house with a grudge and did not wish the incoming tenant to thrive, the following ceremony was gone through. After all the furniture was taken out, the house was swept clean and all the ashes were removed from the hearth, which was also swept quite clean. Stones were then placed upright on the hearth, in the same way as peats are placed to make a fire. Those that entered the house would be as bare as the house, and there would be no luck to the indwellers till that fire (of stone) would burn. My informant has seen such.

9. *Mochrum.*—On taking up one's abode in a house from which others had removed, in case 'ill had been left on the house,' a hen, a cat, a dog, or other living creature was thrown into it.

10. *Wigtownshire (General).*—When one is meeting a reputed witch,

the thumbs are stuck into the palms, with the fingers pressed tightly over them.

11. *Whithorn.*—A thorn-bush or tree would not be cut down. It is believed to be a protection against witches.

12. *Mochrum.*—A piece of 'will-grown' rowan tree about ten inches long used to be kept in the byre, on the 'wa'-head' over the door, with which each calf was rubbed when it fell from the cow. This act kept off the witches. My informant, a farmer, had such a piece in his byre not over six months ago.

13. *Inch.*—When a cow calved, a piece of rowan tree about two inches long was tied to her tail. My informant has seen this done.

14. *Minnigaff.*—Some goodwives keep a small rod of rowan tree in the milk-house wherewith to stir the cream in the 'crock.' This keeps the witches' power at a distance.

15. *Minnigaff.*—My informant has heard of those that carried a piece of rowan tree in their pocket to protect themselves from the power of the witch.

16. *Mochrum.*—A piece of the bark of the rowan tree was carried by some to ward off the power of witches.

17. *Minnigaff.*—To find out who was to be her husband, the young woman took an apple in one hand and a lighted candle in the other on Halloween, and placed herself in front of a mirror, and then ate the apple in the name of 'Uncle Geordie,' *i.e.* the devil. The face of the future husband appeared in the mirror when the last mouthful was eaten. My informant once went through this incantation, but when she came to the last bit she turned and fled in fright lest 'Uncle Geordie' should make his appearance.

18. *Mochrum.*—If an unmarried woman takes one of her shirts and goes to a stream, well, or loch where three lairds' lands meet, washes it in the water, returns home, hangs it in front of the fire, goes to bed, and lies awake, she will see her future husband come and turn the article of dress.

19. *Mochrum.*—When an unmarried woman sees the new moon for the first time, if she lifts her foot and examines the sole of her shoe she will find a hair of the colour of her future husband's hair.

20. *Galloway (General).*—Friday is the common day for celebrating marriage.

21. *Inch.*—A marriage party always carried bread and cheese, with whisky. The first person met, no matter of what rank, must eat and drink. A story is told of the Lord Stair (John Dalrymple), who died in 1821, that a marriage party at one time met him, and as a matter of course asked him to partake of bread and cheese with a glass of whisky. He refused, but wished the two all happiness, and in token of his good will made a present of a sovereign to the couple.

22. *Inch.*—When the bride was brought home a 'farle o' bread' was broken over her head.

23. *Mochrum.*—The bride was welcomed to her own house by the bridegroom's mother, if she was living.

24. *Mochrum.*—The 'best man' and the 'best woman' attended the newly married pair to church the Sunday after the marriage—the 'kirkan.'

25. *Mochrum.*—Tuesday was at one time (about thirty-five or forty years ago) the chief day for celebrating marriages. Few marriages took place on Friday. Now Friday is the chief day.

26. *Inch.*—The husband's breeks used to be laid on the bed when the wife was in travail.

27. *Inch.*—After the birth there is a feast called the 'blythe meat.' It consists of bread and cheese, buns, whisky, and other good things.

28. *Minnigaff.*—My informant (aged 85) has seen a live coal cast into the water in which a new-born babe was washed.

29. *Inch.*—When a sleeping infant was left alone a Bible was laid below the pillow to prevent the fairies from carrying it off. (Informant aged 85.)

30. *Mochrum.*—A Bible was put below the pillow of an infant; no Satanic power could then hurt it.

31. *Mochrum.*—A pair of the husband's breeks laid on the bed over the wife when lying in childbed kept the fairies at a distance.

32. *Wigtownshire* (*General*).—When a cradle was borrowed it was not sent empty. An apron, a shawl, or a pillow was put into it. What was put in might be returned.

33. *Minnigaff.*—A scone was at times laid into a cradle when borrowed.

34. *Mochrum.*—Something must always be laid into a new cradle before being taken into the house in which it was to be used. A carpenter, known to my informant, had made a cradle. When he was entering the house in which it was to be used, he was met just outside the door by the old grandmother, who took off her apron and cast it into the cradle. This took place about fifteen years ago.

35. *Minnigaff.*—A new cradle was never taken empty into the house in which it was to be used. A common thing placed in it was a pillow.

36. *Minnigaff.*—The cradle when in use is always placed in the back part of the apartment with the head towards the door.

37. *Minnigaff.*—The cradle, when there is no infant, is stowed away in some convenient place. It is not lucky to allow it to stand in the apartments occupied by the family.

38. *Minnigaff.*—Rocking the cradle when the child was not in it caused headache to the child.

39. *Minnigaff.*—It was accounted unlucky if the infant did not cry when the water of baptism was sprinkled on the face.

40. *Inch.*—Young women sometimes pin a piece of bread and cheese under the baby's dress when attired for baptism. After baptism the bread and cheese are divided and put below the pillow to call forth dreams as to the young women's future husbands. It is called 'dreaming cheese.'

41. *Minnigaff.*—Unbaptized children were buried in a corner by themselves apart from other graves.

42. *Mochrum.*—When a child's tooth falls out it is thrown over the left shoulder into the fire, and the words are repeated :—

Fire, fire, burn bane,
And bring me back my tooth again.

43. *Inch.*—When a child's tooth falls out it is thrown over the left shoulder in the belief that a sixpenny piece will be found. My informant has done this.

44. *Inch.*—Of the fingers :—

This is the man that broke the barn,
This is the man that stole the corn,
This is the man that sat and saw,
This is the man that ran awa',
And peerie weerie Winkie paid for them a'.

A variant of the last line :—

And wee Willie Winkie paid for a'.

45. *Inch.*—Of the face :—

This is the broo of knowledge,
This is the ee of life,
This is the bubbly ocean,
This is the pratie knife.

A variant of the third line is :—

This is the snokie college.

46. *Inch.*—Dandling the child :—

This is the way the ladies ride,
Mim, mim, mim ;
This is the way the gentlemen ride,
Gallop-a-trot, gallop-a-trot.

47. *Inch.*—

The way the ladies ride (*softly*),
The way the gentlemen trot (*more quickly*),
Cadgers, creels an a' (*roughly*).

48. *Mochrum.*—Bathing in the sea is done when the tide is ebbing. It is believed that, if there is any disease, the tide carries it in, and that one, bathing when the tide is flowing, may catch it.

49. *Inch.*—A cure for whooping cough was to put the patient under the belly and over the back of an ass.

50. *Minnigaff.*—A cure for the same disease is to take the patient down the shaft of a mine (lead).

51. *Mochrum.*—Patients labouring under whooping-cough are carried to Chapel Finnan Well, and given a draught of its waters.

52. *Wigtownshire* (*known over*).—The well of St. Medana (St. Maiden) in the parish of Glasserton is resorted to for the cure of whooping-cough. At times the water is carried away for the same purpose. Not long ago a lady of title had a quantity of it sent to be administered to some members of her household that were suffering from the disease.

52*a*. *Kirkmaiden.*—There is a well at St. Medan's cave, at which visitors were in the habit of leaving pins, buttons, and suchlike small articles. Some may still be seen around it.

53. *Mochrum.*—To get a 'piece'[1] from a married woman having the same name as her husband effected a cure of whooping-cough.

54. *Mochrum.*—A cure for the bite of an adder is to kill a chicken, split it up, and while still warm tie the whole bird over the wound.

55. *Minnigaff.*—A mode of curing warts is by 'selling' them. The one that has the warts takes as many stones as there are warts, ties them into a 'bundle,' and lays it on the public road. Whoever comes across it and opens it gets the warts.

56. *Mochrum.*—One mode of curing a cow or other domestic animal was to strike the teeth with a clew of blue yarn. My informant has seen this done.

57. *Minnigaff.*—When one was dying the window or windows of the apartment were opened.

[1] A little bit of anything given to a person, particularly a child, to eat.

58. *Minnigaff, Inch.*—When death looked near or when one was dying, all kinds of food were taken from the apartment.

59. *Minnigaff.*—When one was dying, if there was a cat in the room, it was driven out.

60. *Minnigaff, Inch.*—When one died the looking-glass was turned or covered with a cloth.

61. *Minnigaff.*—The clock was stopped when one died.

62. *Minnigaff.*—A plate with a little salt was placed on the breast of the dead body.

63. *Minnigaff.*—A penny was placed on the eye of the dead if it did not close.

64. *Inch.*—A few friends are always present at the 'kistin'—*i.e.*, when the body is put into the coffin.

65. *Inch.*—There used to be wakes. Those present commonly employed themselves in religious exercises,—'read and prayed time aboot.' Those of the 'wilder sort' smoked tobacco and kept themselves in good cheer by drinking whisky.

66. *Inch.*—Wine and short-bread are commonly served to those that are present at a funeral.

67. *Inch.*—The coffin, when the house of death is at a distance from the graveyard, is conveyed in a cart to the graveyard.

68. *Inch.*—The coffin of a suicide was carried to the graveyard on two rough beech branches, and not on the 'spokes' on which the coffins of those who died a natural death were carried. The coffin was hoisted over the wall and buried close under it. The two beech branches were cast on the side of the grave next the wall. In later times the coffin was carried through the gateway.

69. *Minnigaff.*—A suicide was not buried in the graveyard. The clothes of the unfortunate were either buried in the grave or burned.

70. *Mochrum.*—It is believed that if one is ill and about to die, the cat of its own accord leaves the apartment in which the patient is lying.

71. *Mochrum.*—A dog's howling at night forebodes death.

72. *Mochrum.*—If one was ill and confined to bed, a Bible was placed below the bolster. My informant has seen this done.

73. *Wigtownshire (General).*—One on setting out on a journey, or to transact any piece of business, must not turn back to fetch anything that may have been forgotten.

74. *Mochrum.*—It is accounted unlucky to meet a bare-footed woman.

75. *Mochrum.*—It is unlucky to meet a hare. (Gamekeeper, Alticry).

76. *Mochrum.*—It is unlucky to shoot a cuckoo. (Gamekeeper, Alticry).

77. *Mochrum.*—Crows flying high is an indication of coming wind and rain.

78. *Mochrum.*—Sea-gulls coming inland during the afternoon is a sign of rain. (Gamekeeper, Alticry).

79. *Mochrum.*—Geese 'flaupin' up the water with their wings when they are swimming is a sign of rain.

80. *Mochrum.*—Of the magpie it is said :—

Yane's sorrow,
Twa's mirth,
Three's a beerial,
Four's a birth,
Five's a ship in distress at sea,
Six is a love-letter comin' t' me. (Gamekeeper, Alticry).

81. *Mochrum.*—It is unlucky to meet a single magpie. To meet two brings luck.

82. *Mochrum.*—A few magpies flying and hopping about a house is an indication of a death in the house within no long time.

83. *Mochrum.*—If a hen crows she is killed at once. She is not cooked and used as food, but buried. Such a crowing is accounted most unlucky.

84. *Mochrum.*—It is looked on as unlucky if a hen lays a very small egg.

85. *Minnigaff.*—A little of the cow's droppings—'sharn'—was put into the calf's mouth when it fell from the cow.

86. *Mochrum.*—A little salt is sprinkled along the cow's back when the calf is dropped.

87. *Inch.*—A sixpenny piece and a little salt were put into the bottom of the milking pail into which the first milk of a cow just calved was drawn.

88. *General.*—'Beesnan' is the name given to the first drawn milk of a newly calved cow. It is sometimes given as a draught to the cow, and sometimes part of it is made in scones, which are called 'beesnan scones.'

89. *Mochrum.*—Some put a pinch of salt into the churn when the cream was to be churned.

90. *Minnigaff.*—One day the goodwife at the farm of Waterside parish of Minnigaff began to 'kirn the kirn.' She churned in vain. No butter would 'come.' A horseshoe was put below the churn, and the butter came at once.

91. *Inch.*—Each child carried every morning to school a peat to serve as fuel for the day. A scholar was appointed to see that each brought a peat, and of the proper size. If he considered any peat too small, or if any one neglected to bring one, the defaulter had to bring two next morning. This inspector bore the name of 'Peat-bailie.'

92. *Inch.*—The first reading book was called 'Reed-a-ma-daisy.'

93. *Minnigaff.*—It was a custom that the beadle got a fleece of wool from each farmer in the parish at 'clippin' time.' The sheep-shearing took place in June, and the beadle made his rounds commonly in July to collect his dues.

94. *Minnigaff.*—When a carpenter finishes his apprenticeship he treats some of his fellow-workmen and companions to strong drink. This treating is called the 'Lowsan.'

95. *Mochrum.*—The quantity of oats taken to the mill to be ground into meal at one time for household use was commonly four bolls. This quantity was called a 'kilncast,' and the meal made from it a 'melder.' When the 'melder' was brought home, a bannock of $1\frac{1}{2}$ or $1\frac{3}{4}$ inches was baked, and 'fired' in front of the fire. At the evening meal a dish of 'brose,' called the 'melder brose,' was served to the whole household, and then a piece of the bannock was given to each member of the family. A small quantity of the 'melder' was given to a poor neighbour, or to a working-man with a large family. This deed was thought to bring a blessing on the 'melder' and make it last well.

96. *Inch.*—A small cake with a hole in the centre, called the 'melder-bannock,' was baked from the 'melder' for each member of the family. The younger members not unfrequently put a piece of string through the hole and hung it round the neck.

97. *Mochrum.*—If a sower inadvertently omitted to sow a 'rig' when

he was sowing the seed, a member of the family would die before that time next year.

98. *Mochrum.*—The reapers, when 'shearing,' would not allow a woman to put off her bonnet and 'shear' with bare head. If a woman did so, one of the reapers would soon cut his (her) fingers.

99. *Minnigaff.*—When a young horse was taken to the smithy to receive the first shoes, whisky was carried by the one that took the animal to the smithy. When the first nail was driven into the first shoe, the smith and any others that might be present were treated with a glass each.

100. *Port William, Mochrum.*—An old blacksmith told me that it was the custom to give the smith a glass of whisky when he had finished putting on the first shoe of the first set of shoes of a young horse.

101. *Minnigaff.*—On the first day of April jokes used to be played. One would pretend to send a letter to a friend, and the one on whom the joke was to be played was asked to carry it. The victim, suspecting nothing, took the letter and carried it. All that the letter contained was, 'Send the gowck another mile,' and this might sometimes be done.

102. *Minnigaff.*—On Halloween a dish of mashed potatoes—'beetlt praties'—was prepared. Into it were put a ring, a sixpenny piece, and a button. The dish was stirred in the form of the figure 8. The household partook all together of the dish.

103. *Minnigaff.*—There existed at one time in the parish of Minnigaff a Hell-fire Club. The members used to meet at Creeton. On one occasion they celebrated the Sacrament of the Lord's Supper by giving the bread and wine to their dogs. The room in which this profanation took place was afterwards haunted. All the members died untimely deaths.

104. *Minnigaff.*—If a fire was kept constantly burning for a period of years, a beast grew at the back of it. Such was the case with the fire of a woman called Nelly Coull. that lived at Corbreknowe or Cordorkan.

105. *Minnigaff.*—Over the river Penkiln there is a bridge not far above the point where it joins the Cree. It is called Queen Mary's Bridge. It consists of two arches. The middle pier rests on a rock. On the top of this rock is a round hole like a small cauldron. It is a custom to take three stones, to form a 'silent wish,' and to lean over the parapet, and drop the stones, the one after the other, into the hole. If the stones fall into it, the wish will be fulfilled.

106. *Minnigaff.*—Children's Hogmanay rhyme :—

> Rise, guidwife, an shake your feathers ;
> Dinna think that we are beggars,
> Boys and girls come out to play,
> To seek our Hogmanay.
> Gin ye dinna gee's our Hogmanay,
> We dunner a yer doors the day.

107. *Inch.*—Everything was made ready for the New Year's welcome. Oaten cakes had been baked ; and a haggis had been cooked, and was served cold. The 'first fit' got a 'farle o' bread' and a slice of the cold haggis.

108. *Minnigaff.*—A cake of flour with dried fruit is made by each household. It is of a round shape. It is baked in a pot.

109. *Minnigaff.*—A day or two before Hogmanay a haggis has been cooked and set aside to cool. On Hogmanay it is laid out on a table with a knife beside it. When the 'first fit' has finished his congratulations he

helps himself to a slice of the haggis, and walks away. Each one that calls afterwards does the same. The custom still exists, but not to such an extent as in days of old. 'There's not one in fifty' compared with old times.

110. *Minnigaff.*—All dirty water and ashes—in short, all that is usually carried out of a house each morning—are carried out on the last evening of the year. This is done that nothing may have to be taken out on New Year's Day.

111. *Inch.*—The ashes, as well as all dirty water, were carried out of the house on the last evening of the year.

112. *Minnigaff.*—Nothing was given out of a house on New Year's Day.

113. *Inch, Minnigaff.*—It was deemed unlucky to give a burning peat to a neighbour to kindle a fire on the morning of New Year's Day, and no housewife would do so.

114. *Minnigaff.*—It was taken as an omen for good if one brought anything into the house on New Year's Day.

115. *Inch.*—It was accounted unlucky for a man with red hair to come into the house on New Year's morning as 'first fit.' If it was known that one with such hair intended coming as 'first fit,' means were taken to forestall him.

116. *Mochrum.*—One with fair hair is accounted an unlucky 'first fit' on the morning of the New Year. There are some that will not open the door to one having such hair.

117. *Mochrum.*—One with dark hair is counted a lucky 'first fit' on the morning of New Year's Day.

118. *Inch.*—One of good character was preferred as 'first fit' on the morning of New Year's Day.

119. *Creebank Farm, Minnigaff.*—At 12 o'clock on New Year's Eve the 'foreman' entered the master's bedroom as 'first fit.' He carried with him a sheaf of oats and a bottle of whisky. He cast the sheaf on the bed over the master and his wife. A glass of whisky was then poured out and health to the family and prosperity to the farming operations were drunk to.

120. *Mochrum.*—It was customary on the morning of the New Year to give a portion of unthreshed oats to each of the horses and the cattle of the farm.

121. *Mochrum.*—One must have on some piece of new dress on New Year's Day.

122. *Minnigaff.*—As the clock strikes twelve at night on Hogmanay a large bonfire is kindled on the Green of the village of Minnigaff. For some weeks before the boys are busy collecting brushwood and pieces of fallen trees from the neighbouring woods. The Earl of Galloway, to whom the woods belong, gives all facilities for this purpose. By the last day of the year a goodly quantity of material has been gathered. On that day everyone is busy in erecting the pile to be burned, and before the appointed hour everything is ready. There is no ceremony before or at the kindling, and there is no special person set apart to apply the fire. The pile burns through the night and commonly through part of next day. It is always erected on the same spot. About seventy years ago the bonfire was composed of different material. For months before the bones all round the district were collected and stored in a little hut built by the boys with rough stones in a corner of the village green. The bones of

any animal that had died and been buried for a considerable time were dug up and stored. For about a fortnight previous to Hogmanay the boys went the round of the village and laid all the peat-stacks under tribute. The peats were all carefully stowed away till required. On the last day of the year the peats were first piled up, and then the pile was covered with the bones. At twelve o'clock at night the whole was set on fire, and the younger part of those present ran round the blazing pile, but no words were repeated. My informant (eighty-three years of age) has engaged in all this. He also said that he as well as others used to get empty tar-barrels, put a little tar into them, place them on their heads, have the tar in them set on fire, and, with them blazing on their heads, parade the village. About thirty years ago those in authority set themselves to put down the custom. The bonfire was erected as usual, but the word went round that the kindling of it was to be prevented, and if anyone succeeded in kindling it every endeavour would be made to 'droon't oot,' and this could have been easily done, as the village pump is quite close to the site of the bonfire. Nothing daunted, the villagers assembled to wait the current of events. As the midnight hour approached, the policeman made his appearance carrying a pail. He came up to the pile, put down his pail, and began to walk round and round the green. The boys stood at a distance, peeping from every corner, and watching if an opportunity of throwing a piece of fire on the pile could be found. A few yards from where it stood is a house in which lived at that time a woman named Jess Clelland. Jess was on the side of the old custom, and she was on the watch to outdo the men of authority. The policeman took a rather wider turn than usual, and when his back was turned Jess seized a burning peat from her hearth, rushed out, and thrust it into the bonfire. When the policeman turned he saw the pile in a blaze. He ran, seized the pail, and made for the pump. The pump-handle was gone, and the policeman withdrew. Jess gained the victory. Let Mr. Lang indite an ode to her.

122*a*. At Newton-Stewart there is a fire procession which starts from 'The Angle' on Hogmanay exactly at twelve o'clock at night. A tar-barrel is fixed on two long poles by means of two cross-bars. The barrel is well filled with tar and paraffin. The whole is mounted on the shoulders of four (?) men, and the contents of the barrel are set on fire. The procession marches along the street past the bridge over the Cree that leads to Minnigaff village. When the end of the street is reached the processionists retrace their steps till they come to the bridge. This they cross and march through the village of Minnigaff to the green, where the bonfire is now in full blaze. Here they get their barrel replenished if need be. They then retrace their steps through the village and over the bridge to Newton-Stewart, and then along the street to 'The Angle,' the point from which they started. Here the poles and barrel are thrown down and the whole burned. During the procession the carriers of the blazing barrel are changed every now and again. Last year an attempt was made to put a stop to the procession, under the plea that it gave occasion to much drunkenness. Mr. J. Reid, the minister of Minnigaff, remonstrated with the authorities against such a step, and most luckily his remonstrance prevailed, and the procession took place with all order, Mr. Reid himself being witness.

[A bonfire is burned at Invergordon, Ross-shire, on the last day of the year. It is kindled at twelve o'clock at night.]

123. *Inch.*—When one saw the new moon for the first time, the hat or whatever was worn on the head was lifted.

124. *Inch.*—The money in the pocket must be turned the first time the new moon is seen.

125. *Mochrum.*—Human hair was never burned. Burning the hair made one cross. It was twisted up, and put commonly on the 'wa' head,' but at times into crevices of the walls of the dwelling-houses. My informant has seen tufts of human hair in holes of the walls of old uninhabited houses.

126. *Mochrum.*—If one puts an indignity on a good spring-well, he (she) will not do well in after-life.

The 'Hare.'

127. *Mochrum.* — Notwithstanding the introduction of reaping machines, the 'hare' is still cut in the old fashion. Here is the mode of cutting it. A small quantity is left to form the 'hare.' It is divided into three parts and plaited, and the ears are tied into a knot. The reapers then retire the distance of a few yards, and each throws his or her 'heuk,' *i.e.* hook, in turn, and tries to hit and cut down the 'hare.' It must be cut below the grain-knot, and the reapers continue to throw their hooks in regular succession till one is skilful enough to cut it below the knot. This one is said to be the 'best han',' and receives as reward double the quantity of whisky the others receive. The 'hare' is carried home and given to the female servant in the kitchen, who places it over the kitchen-door inside. The christian name of the first male that enters the kitchen is the christian name of her future husband. If there are several female servants, each in turn, as agreed, gets her chance. The 'hare' is allowed to hang for a considerable length of time in the place where it is first laid.

128. *Minnigaff.*—The 'hare' was often kept till the following harvest.

129. *Minnigaff.*—The one that cut the 'hare' carried it home and placed it over the kitchen door, and the kitchenmaid had to kiss the first man or boy that entered.

130. *Inch.*—When the 'hare' was cut, there was great cheering. It was carried home and placed over the kitchen door. The goodwife had to kiss the first male that entered.

131. *Minnigaff.*—When the 'hare' was cut the unmarried reapers ran with all speed home, and the one that reached it first was the first to be married.

132. *Mochrum.*—In reaping grain during the time of harvest a reaper, if a capable reaper, was set to reap 'a rigg.' The first 'rigg' was called the 'pint,' *i.e.* point, and the one that reaped was named the 'pintsman.' The last 'rigg' of those occupied by a set of reapers was called the 'heel,' and the reaper bore the same name. In cutting the 'hare' the 'pintsman' was the first to throw the 'heuk,' and then each reaper threw in succession till it came to the 'heel,' if it had not been cut before. If not cut the first round, the same mode was followed till it was cut.

133. *Mochrum.*—The 'Winter,' *i.e.* the one that took the last load of grain to the stackyard, was treated in a somewhat rough manner. Some one of his fellow-servants watched for him to dash over him a quantity of dirty water, and the dirtier so much the better. To avoid such a bath he

had to be on the outlook, but at times the opportunity occurred, and over him the dirty water went. My informant has been so served oftener than once.

134. *Mochrum.*—It may be stated that for each four capable reapers there was one to bind and 'stook,' *i.e.* set the sheaves on end opposite each other with the heads pressed together. There were commonly twelve sheaves in the 'stook,' *i.e.* six on each side.

My informants have all assisted in cutting the 'hare.'[1]

The Seventh Son.

135. *Mochrum.*—A seventh son born in succession has the power of healing running sores by rubbing them with his hand. My informant, a blacksmith, had an apprentice of the name of Wallace, who was a seventh son. One day a man having running sores in one of his legs arrived. The young apprentice and he retired together to go through the process, so that my informant did not see the mode of procedure. This took place about twenty-five years ago.

Sting of an Adder.

136. *Portlogan.*—'Gee a fat cat a bit knap,' *i.e.* give a fat cat a blow to stun it, rip it up and put it hot over the wound.

137. *Kirkmaiden.*—Tear a fowl 'sindrie,' *i.e.* asunder, and put it hot and bleeding over the wound. This was done, according to my informant, about thirty years ago in the case of a man named James Garva.

Measles.

138. *Kirkmaiden.*—Measles or any kind of infectious disease is cured in the following way. The operator stands in front of an ass with the patient in her (or his) hands, and passes him (or her) three times round the animal's neck from left to right, repeating each time on reaching the upper side of the neck the words, 'In the name of Jesus of Nazareth.'

Whooping Cough.

139. *Kirkmaiden.*—A sail is considered efficacious.

140. *Kirkmaiden.*—Take the patients out to sea in a boat and keep them at sea till the tide turns.

141. *Kirkmaiden.*—Place a slice of raw pork ham on the chest of the patient.

142. *Kirkmaiden, Kells.*—Let the patient get a 'piece' from a married woman whose maiden name is the same as that of her husband. My informants have seen this cure carried out.

143. *Kirkmaiden.*—The patient is taken to the house of a married man and woman whose maiden name was the same, but who are not relatives. The patient gets a 'piece' on arrival. After a time porridge is cooked and given, and after another interval tea is partaken of. Food has to be eaten three times. Afternoon is the time when the visit is paid.

144. *Kirkmaiden.*—There is a cave on the west coast of Kirkmaiden, about two miles west of Logan House. From the roof of the cave hang a good many stalactites, which go by the name of 'Peter's Paps.' Those

[1] See *The Golden Bough*, vol. ii. pp. 10, 11, and the *Folklore Journal*, vol. vii. pp. 47, 48.

labouring under the disease are taken to the cave, held up under one of the paps, so as to allow the water from it to fall into the mouth. Sometimes the pap is taken into the mouth and sucked.

145. *Dalry.*—The patient is put into the hopper of a mill. This was done to my informant's father.

Erysipelas, or 'Rose.'

146. *Tungland.*—Tow sprinkled with flour is laid over the affected part.

147. *Kirkmaiden.*—Dry flour is sprinkled over the spot affected, which is then covered with hemp.

148. *Kirkmaiden.*—Flour warmed and dusted over wormwood is laid over the diseased part.

Warts.

149. *Dalry.*—The juice of the dandelion rubbed on warts dispels them.

150. *Kirkmaiden.*—Rub the wart with the red-hot stalk of a new clay tobacco-pipe. My informant has seen this done.

151. *Kells.*—Rub the wart with a black snail. My informant has done this.

152. *Kirkmaiden.*—Rub the wart with a black snail (*Arion niger*), and then hang the snail on a thorn-bush. As the snail wastes, the wart wastes till it is gone.

153. *Kirkmaiden.*—Rub the wart with the hot blood as it flows from a pig when it is being killed. My informant has seen this done.

154. *Kells.*—My informant's foot was covered with warts. A pig was being killed. He took off his boot and stocking, and held the foot under the blood as it flowed from the animal. Without wiping off the blood, he put on the stocking and boot. The warts disappeared in a short time.

155. *Dalry.*—Rub the wart with rain-water from a natural hollow in a rock or big stone.

156. *Portlogan.*—Rub the wart with a halfpenny, tie the halfpenny in a piece of paper, and lay it on a public road. The one that picks it up gets the wart.

157. *Kirkmaiden.*—My informant saw lately a young woman whose hands were disfigured with warts rub them with a copper coin. It was cast away. The warts in due time vanished.

158. *Kirkmaiden.*—Cut a potato into nine pieces, rub each wart with each of the nine pieces, then tie up the pieces in a bit of paper and bury the parcel. As the pieces waste the warts waste. My informant has done this.

Colic.

159. *Kirkmaiden.*—A cure is to sit with 'bare bottom' over a pot of warm water.

160. *Kirkmaiden.*—In a child the cure was effected by turning it three times heels over head.

Cholera.

161. *Mochrum.*—When cholera visited the country in 1832, pieces of raw beef were fixed to long poles, and the poles were erected on Mill Hill, near Port William, to catch the disease.

The Styan.

162. *Dalry.*—Nine thorns are picked from a gooseberry-bush and put into the hand of the patient, who throws them over the left shoulder. This was done to my informant.

Sea-bathing.

163. *Mochrum.* — Bathing in the sea is done when the tide is ebbing.

164. *Mochrum.*—Once bathing in the sea is considered dangerous to the health. Several baths must be taken to turn off the evil effects of only one bath, and to produce good results. My informant knew a man that bathed only once. 'Blushes,' *i.e.* red spots, appeared all over his body.

Deafness.

165. *Kirkmaiden.*—Hare's urine is used as a cure. The bladder is taken from the animal, and the urine is squeezed out of it, and allowed to drop into the ear. Mr. MacDouall, of Logan, has given a hare for this purpose.

Nettle-sting.

166. *Dalry.*—The burnt part is rubbed with the leaf of a dock, and the following words are repeated :—

Nettle, nettle, gang awa',
Dockan, dockan, come again.

'Black Leg' (Anthrax).

167. *Portlogan.*—The animal was groped all over till the spot of the disease was found. The skin over the diseased part was cut open, and a quantity of chewed garlic was rubbed into the slashes.

APPENDIX IV.

On the Method of determining the Value of Folklore as Ethnological Data. By G. Laurence Gomme, *F.S.A.*

The survey of one distinctive area, such as Galloway, by so well trained an observer as Dr. Gregor, has brought into notice a number of customs and superstitions differing from each other in form, *motif*, and in almost all characteristics. The question is, Of what value is this material as data for ethnology, and how are we to find out the value? The Committee engaged upon this important inquiry will have collections from other parts of the British Isles, indeed, it is to be hoped, from all parts, before their work is finished; and it is important that at this early stage it should be understood upon what basis they are going to work. Dr. Gregor has rightly put his collections into the simple form of a catalogue. That is the only way in which they should appear fresh from the hands of the collector. But other branches of the survey—physical types and measurements, material monuments, implements, and other evidence of the history of the district from the earliest times—though presented in the same unattractive form of a catalogue, are practically all ready to be dealt with upon approved and generally recognised principles; and it is in respect of folklore only that no principle has been determined or even discussed, upon which to arrange the material placed before us.

In the following pages I shall attempt to determine such a principle. For this purpose I shall need to select some one custom or belief as an illustration of the method of dealing with all items of custom and belief. Fortunately there is ample material to select from, and I shall take the fire custom at Minnigaff (No. 122) for my purpose. I shall endeavour to show how this custom has to be treated if it is to be of value for ethnographical purposes; and I shall suggest that each single custom and belief must be treated in the same way and on the same lines.

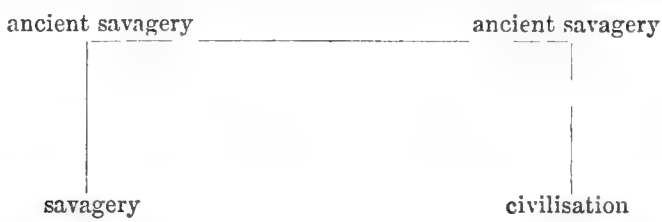
1. *The Principles of Analysis and Classification.*

It is generally admitted that much of the custom and belief which is known under the name of folklore is ancient. How ancient, or, being ancient, how much it contributes to the history of ancient times, has not been determined. It is even questionable whether the general admission of the antiquity of popular custom and belief is of any value, because, although specialists who deal with the myths and early religions of the ancestors of civilised people use the evidence of folklore, the general historian is always loth to admit such evidence even if he is aware that it exists.

The historian is not altogether to blame. He has nothing very definite to work upon. Even the great work of Grimm is open to the criticism that it does not *prove* the antiquity of popular custom and belief—it merely states the proposition, and then relies for proof upon the accumulation of an enormous number of examples and the almost entire impossibility of suggesting any other origin than that of antiquity for such a mass of non-Christian material. Then the great work of Grimm, ethnographical in its methods, has never been followed up by similar work for other countries. The philosophy of folklore has taken up almost all the time of our scholars and students, and its contribution to the anthropology of the civilised races has not been made out.

In all scientific investigation nothing is accepted as proved except upon the most careful and laborious investigation. Darwin's great work is the result of such an accumulation of experiments in all branches of natural history that no naturalist could, even if he would, afford to neglect such evidence. The mathematical element of proof formed so large a proportion of the entire case that it was impossible to upset it unless, by following exactly the same laborious methods, it had been found that there was a mathematical answer to the problem as stated by Darwin. And no such answer has been forthcoming.

The exact opposite of this process has obtained among investigators into the origin of custom and belief. The comparative method of inquiry has been used to an extreme extent. The unmeaning custom or belief of the peasantry of the western world of civilisation has been taken into the domains of savagery or barbarism for an explanation without any thought as to what this action really signifies to the history of the custom or belief in question. No doubt the explanation thus afforded is correct in most cases; but I question whether such an explanation will be admitted as an important element in the history of European peoples until it has been proved to be scientifically justified. For it must be obvious that the effective comparison of a traditional peasant custom or belief with a savage custom or belief is only a very short cut indeed to the true process that has been accomplished. This process includes the comparison of an isolated custom or belief belonging, perhaps secretly, to a particular place, a particular class of persons, or perhaps a particular family or person, with a custom or belief which is part of a whole system belonging to a savage race or tribe; of a custom or belief whose only sanction is tradition, the conservative instinct to do what has been done by one's ancestors, with a custom or belief whose sanction is the professed and established polity or religion of a people; of a custom or belief which is embedded in a civilisation, of which it is not a part and to which it is antagonistic, with a custom or belief which helps to make up the civilisation of which it is part. In carrying out such a comparison, therefore, a very long journey back into the past of the civilised race has been performed. For unless it be admitted that civilised people consciously borrow from savages and barbaric peoples, or constantly revert to a savage original type of mental and social condition, the effect of such a comparison as we have taken for an example is to take back the custom or belief of the modern peasant to a date when a people of savage or barbaric culture occupied the country now occupied by their descendants, the peasants in question, and to compare the custom or belief of this ancient savage or barbaric culture with the custom or belief of modern savage or barbaric culture. The line of comparison is not therefore simply drawn level from civilisation to savagery; but it consists, first, of two vertical lines from civilisation and savagery respectively, drawn to a height scaled to represent the antiquity of savage culture in modern Europe, and then the level horizontal line drawn to join the two vertical lines. Thus the line of comparison is



The custom and belief of savage and barbaric races have been generally accepted as identical with the custom and belief of early or primitive man. It has followed from this that wherever, as is so often the case, the custom and belief surviving among the peoples of civilised countries are found to be exactly or nearly parallel to savage or barbaric custom and belief, these survivals are put down as belonging to early or primitive peoples. This conclusion is in the main correct; but it is correct not because it has been proved by the best methods to be so, but because, of all possible explanations, this is the only one that meets the general position in a satisfactory manner.

If this be the short-cut process that has been accomplished by the comparative method of research, it must be drawn out in detail if we would scientifically prove its results, and if those results are to be recognised by the historian as new data for the prehistoric periods. The magnitude of such an enquiry as this suggests has to be considered. The labour and research might in point of volume be out of proportion to the results, and it may be questioned, as it has already been questioned by inference, whether it is worth the while. The first answer to this objection is that all historical investigation is justified, however much the labour, however extensive the research. Secondly, considering the very few results which the study of folklore has hitherto produced upon the investigations into Prehistoric Europe, it must be worth while for the student of custom and belief to conduct his experiments upon a recognised plan in order to get at the secret of man's place in the struggle for existence, which is determined more by psychological than by physical phenomena. Thirdly, if the psychical anthropology of prehistoric times is to be sought for in the customs and beliefs of modern savages, it is of vital importance to anthropological science that this should be established by methods exactly defined. Whatever of traditional custom and belief is capable of bearing the test and of being definitely labelled as belonging to prehistoric man becomes thereafter the data for the psychical anthropology of civilised man.

Now if the several items of custom and belief preserved by tradition are really ancient in their origin, they must be floating fragments, as it were, of an ancient *system* of custom and belief—the cultus of the people among whom they originated. This cultus has been destroyed. It has either struggled unsuccessfully against foreign and more vigorous systems of religion and society, or it has slowly developed from one stage to another. In the western world at all events we know that the former has been the process at work, and that it is matter of definite historical record that all non-Christian culture has had to succumb to Christianity. To be of service to the historian of our country and people, therefore, each floating fragment of ancient custom and belief must not only be labelled 'ancient,' but it must be placed back in the system from which it has been torn away. To do this is to a great extent to restore the ancient system; and to restore an ancient system of culture, even if the restoration be only a mosaic and a shattered mosaic, is to bring into evidence the prehistoric race of people to which it belongs.

This hypothesis of traditional custom and belief being relics of an ancient cultus helps to form the method and principles of enquiry. It would be impossible to suppose that all these relics have been preserved equally well, all at the same stage of arrested development, all equally untouched by later influences. Their existence has been attacked in different places, at different times, by different influences; and therefore the actual form of their survival must vary almost as frequently as an example occurs. The modern connection of a custom or belief is no sure guide, and is very often a misleading guide, to its ancient connection. It is only by correct analysis and classification, therefore, that the various examples can be put into a condition for examination and identification.

We have for our purpose nothing more than a series of notes of customs and beliefs obtaining among the lower and lowest classes of the people, and not being the direct teaching of any religious or academic body. These notes are very unequal in value owing to the manner in which they have been made. They are often accidental, they are seldom if ever the result of trained observation, and they are often mixed up with theories as to their origin and relationship to modern society and modern religious beliefs.

The method of using these notes for scientific purposes is therefore a very important matter. It is essential that each single item should be treated definitely and separately from all other items, and, further, that the exact wording of the original note upon each separate item should be kept intact. The original account of every custom and belief is an organism, not to be tampered with except for the purpose of scientific analysis, and then after that purpose has been effected all the parts must be put together again, and the original organism restored to its form.

The handling of each custom or belief and of its separate parts in this way enables us, in the first place, to disentangle it from the particular personal or social stratum in which it happens to have been preserved, and, secondly, to prepare it for the place to which it may ultimately be found to belong. The first step in this preparation is to get together all the examples which have been preserved, and to compare these examples with each other, first as to common features of likeness, secondly as to features of unlikeness. By this process we are able to restore whatever may be really deficient from insufficiency of any particular record—and such a restoration is above all things essential—and to present for examination not an isolated specimen but a series of specimens, each of which helps to bring back to observation some portion of the original.

The first important characteristic which distinguishes a custom or belief in survival from a custom or belief belonging to an established system is that not only do different examples present points of common likeness, but also points of unlikeness. The points of likeness are used to determine and classify all the examples of one custom or belief, the points of unlikeness to trace out the line of decay inherent in survivals.

This partial equation and partial divergence between different examples of the same custom or belief allows a very important point to be made in the study of survivals. We can estimate the value of the elements which equate in any number of examples, and the value of the elements which diverge; and by noting how these values differ in the various examples we may discover an overlapping of example with example which is of the utmost importance. A certain custom consists, say, of six elements, *a*, *b*, *c*, *d*, *e*, *f*. Another example of the same custom has four of these elements, *a*, *b*, *c*, *d*, and two divergences, *g*, *h*. A third example has elements *a*, *b*, and divergences *g*, *h*, *i*, *k*. A further example has none of the radical elements, but only divergences *g*, *h*, *i*, *l*, *m*. Then the statement of the case is reduced to the following:—

$$
\begin{aligned}
1 &= a, b, c, d, e, f. \\
2 &= \quad a, b, c, d + g, h. \\
3 &= \qquad a, b + g, h, i, k. \\
4 &= \qquad\quad + g, h, i, l, m.
\end{aligned}
$$

The conclusions to be drawn from this are, first, that the overlapping of the several examples (No. 1 overlapping No. 2 at *a*, *b*, *c*, *d*, No. 2 overlapping No. 3 at *a*, *b*, *g*, *h*, No. 3 overlapping No. 4 at *g*, *h*, *i*) is the essential factor in the comparison. Secondly, that example No. 4, though possessing none of the elements of example No. 1, is the same custom as example No. 1. Thirdly, that the divergences *g* to *m* mark the line of decay which this particular custom has undergone since it ceased to belong to the dominant culture of the people, and dropped back into the position of a survival from a former culture preserved only by a fragment of the people.

The first two of these conclusions are not affected by the order in which the examples are arranged; whether we begin with No. 4 or with No. 1, the relationship of each example to the others, thus proved to be in intimate association, is the same. The third conclusion is necessarily dependent upon what we take to be 'radical elements' and 'divergent elements;' and the question is, How can these be determined? As a rule it will be found that the radical elements are the most constant parts of the whole group of examples, appearing more frequently, possessing greater adherence to a common form, changing (when they do change) with slighter variations; while the divergent elements, on the other hand, assume many different varieties of form, are by no means of constant occurrence, and do not even amongst themselves tend to a common form. To these considerations, derived entirely from a study of the analysis, is to be added the fact that the radical elements are alone capable of being equated with customs or beliefs obtaining among savage or barbaric peoples.

When any given custom or belief, having undergone this double process of analysis of component elements and classification of the individual examples, reveals a distinct parallel between its radical elements and the elements of a custom or belief occupying a place in the cultus of a barbaric or savage people, we may then, and only then, discuss its right to a genealogy which can be traced back to a prehistoric cultus of the same stage of development as that of modern barbarism or savagery. This right will depend upon several important conditions. The custom in question must in the first place be not a single isolated example of such a possible genealogy, but must be found associated with several other customs, each of which, being treated in exactly the same manner, has been found to exhibit exactly the same relationship to the same barbaric or savage cultus or religion. In this way classification and analysis go hand in hand as the necessary methods of studying survivals. Without analysis we cannot properly arrive at a classification of examples; without classification we cannot work out the genealogy of survivals. The argument for detecting in modern survivals the last fragments of a once prevailing system based upon this extensive groundwork is of itself a very strong one, and can only be upset by one counter argument. This is nothing less than proof that no such system ever existed, or could have possibly existed, in the country or among the people, where and among which the survivals have been discovered. Clearly the burden of such a proof could hardly be supported; for the very fact of the existence of such survivals becomes in itself one of the strongest arguments for the existence of the original system from which they descended, and of the race or people among whom such original system obtained.

2. *Fire Rites and Ceremonies.*

The particular custom which I purpose examining on the principles laid down relates to the use of fire. I shall not attempt to draw any general conclusions until the work of analysis and classification is completed, but shall first of all simply put together the evidence as it appears from the notes of the collectors and chroniclers of this group of customs. Apart, however, from general conclusions, there are a few special characteristics which it will be well to specify during the progress of our work, partly because their significance would not appear so usefully if deferred until the work of analysis and classification is completed, and partly to avoid what must always be an obstacle to researches of this kind—namely, repetition of description.

The most important example is the well-known custom of burning the clavie at Burghead. The fire is made by the youths of the village, who must be the sons of the original inhabitants, and every stranger is rigidly excluded from the ceremony.[1] This is a clear recognition of the blood bond, because the early ties of relationship still hold their place against the later ties of locality, a mere resident not being recognised as a person fitted to take part in the ceremony. Secondly, the clavie must be lighted by a burning peat, the custom being that no form of modern lighting is allowed to approach the precincts.[2] The next point is that the smoking embers of the clavie were scattered among the assembled villagers, by whom they were eagerly caught at, and with them the fire on the cottage hearth was at once kindled.[3]

The date fixed upon for the ceremony, namely, New Year's Eve, is the next important element to note, it being obvious that a fire kindled on the last day of the old year, and allowed to burn into the first morning of the new year, has carried on its flame from one year to another, though actually only through one year's end into another year—a fiction which may very well stand for an original perpetual burning. And, finally, there are details of ritual in this custom which are as significant of archaic origin as they could well be. The object of the ceremony is the perambulation, with the sacred fire, of the bounds of the village and of the fishing boats. At certain houses and at certain street corners a halt was made, and a brand whipped out of the clavie and hurled among the crowd. He who seized the brand was the favourite of fortune during the months of the coming new year. Afterwards the fire was carried to a small artificial promontory, where a circular heap of stones, called the 'Durie,' was built up for the purpose, and the still burning clavie was placed in the hollow centre, from which it was distributed to the villagers.[3] The whole community joined in the ceremony as an act necessary to its welfare and prosperity during the year. If the bearer stumbled it was looked upon as a dire calamity foretelling disaster to the place, and certain death to the bearer in the course of the next year.[4] As the ceremony was therefore a sacred one, those who took part in it, especially those who acted as carriers of the fire, would be honoured above their fellows by the distinction. Accordingly, in the clavie custom, 'the first lift is an honour,' and was usually conferred upon some member of the community who had recently been married. As soon as one bearer gave signs of exhaustion, another took his place, and should any of them meet with an accident during the journey 'the misfortune excites no pity even among his near relatives.'[5]

Injury in the service of the fire is clearly not a misfortune, but a sign of recognition of dutiful service; and it is just possible that the prominence given to the recently married member of the community may represent some early recognition of the service thereby rendered in securing a future mother of the kindred. In entire keeping with these very significant facts are the details attending the construction of the fire-pile. 'Unwritten but unvarying laws' regulate every action, one of which laws is that every article is borrowed, nothing bought. And in this we have, I think, a clear indication of the time when personal property in the nature of tools was not the subject of barter—a time, that is, before the days of commercial economics, and consequently coincident with tribal society. This indication of a prehistoric date for the origin of the custom is confirmed by one other detail, namely, that although

[1] *Folklore Journal*, vii. 12.
[2] *Trans. Soc. Antiq. Scot.* x. 649.
[3] *Folklore Journal*, vii. 12.
[4] *Proc. Soc. Antiq. Scot.* x. 649.
[5] *Folklore Journal*, vii. 12, 13.

the long nail which fastens the staves of the clavie is iron, and is made specially for the purpose by the village smith, the hammer used for the purpose must be a round stone.[1]

The completeness of the Burghead example in so many details of significance enables us to fix upon it as the typical form of survival of the fire-custom. The justification for this conclusion will appear later on, when we have fully examined the other examples and compared them with the Burghead example; but in the meantime I can state that it has no parallel for completeness anywhere. I will now set out the elements it contains in the shape of a formula, so that reference back to these elements may be made in as simple manner as possible. The following is the formula required :—

(*a*) The fire is made by a group of men connected by a common descent, that is, a kindred.

(*b*) The original inhabitants of a village form the unit from which common descent is traced.

(*c*) The flame for the fire is obtained in a sacred manner.

(*d*) Continuous life of the fire (symbolised).

(*e*) The house-fire is derived from the village-fire.

(*f*) The possession of an ember is the means of good fortune.

(*g*) The bounds of the village have the fire carried round them.

(*h*) Welfare and prosperity of the community dependent upon the performance of the ceremony.

(*i*) The bearers of the fire are honoured.

(*k*) Early economic conditions are enforced in the performance of the ceremony.

(*l*) Stone-age implements are used.

A custom in Lanarkshire has preserved some essential elements of the Burghead example. Thus, at Biggar the villagers collect a large quantity of fuel, and about nine o'clock on the last day of the old year the pile is lighted, each member of the crowd 'thinking it a duty to cast into the flaming mass some additional portion of material.' It is necessary to maintain the fire until New Year's day is far advanced, and if the house fire has been allowed to become extinguished, recourse must be had to the village pile.[2] Here the collective action of the villagers, the connection between the village-fire and the house-fires, and the symbolical continuation of the fire from one year to the next year, are still closely preserved. But the sanction for the proceeding has changed. In the Burghead example the prosperity of the whole community depended upon the lighting of the village-fire; in the Biggar example it was to provide the flame for the house-fire on account of the unluck of giving out fire on New Year's day. The two sanctions, different in form, are practically identical in *motif*; the Burghead example in this, as in other features, is the more archaic; the Biggar example has assumed the usual condition of survivals and substituted the non-specific notion of unluck for the specific notion of prosperity of the community as the sanction for the ceremony of the village-fire. In this respect the Biggar example is an important link in the evidence we are

[1] *Folklore Journal*, vii. 13. The stone is thrown away after use; and it may be that in this act we have an indication of the sacred character of the stone, in that it was not to be used for any other purpose after being used in the clavie ceremony.

[2] *N. and Q.* 2nd Series, ix. 322.

now seeking. It is, on the one hand, definitely connected with the form preserved at Burghead; on the other hand it departs from that form in one important particular which, however, as we shall see, reappears in many other examples which do not equate so nearly in other respects with the Burghead example. Thus, we have a partial equation and a partial divergence in the Biggar example, as compared with the typical form of Burghead, and the formula would appear as follows :—

(*b*) Making the fire by group of co-villagers.
(*d*) Continuous life of the village-fire.
(*e*) Lighting of the family fires by the village-fire.
(*m*) Unlucky to give fire from the house.

So that the Biggar example equates with the typical form at Burghead in three elements, and introduces the first divergence in the belief of unluck attending the giving out of fire from the house. That this belief is an essential part of the custom is an important factor in the argument; it is because of this taboo against giving fire from the house that the village-fire is necessary, and the two conceptions are part and parcel of the same set of beliefs.

We can now go forward to examine other examples of the fire custom. In the country parts of Ireland (unfortunately no direct locality is fixed upon) the May-day fire was formed by the inhabitants of each village. When the fire had nearly expired each individual present provided himself with a *braune* or ember of the fire to carry home, and if it becomes extinguished before reaching the house it is an omen of impending misfortune; the new fire is kindled with this spark. They also throw lighted embers into the cornfields, or among the potato crops or the flax to preserve them from witchcraft and to ensure a good return.[1] Here there are three elements of the typical form, *b*, *e*, and *g*; and possibly a variation of *f*. The divergences, however, are extremely important. Many of the old people might be seen circumambulating the fire and repeating to themselves certain prayers. If a man was about to perform a long journey he leaped backwards and forwards three times through the fire to give him success in his undertaking; if about to wed he did it to purify himself for the marriage state; if going to undertake some hazardous enterprise he did it to render himself invulnerable; as the fire sank low the girls tripped across it to procure good husbands, women great with child to ensure a happy delivery; and children were carried across.[2] These details give us two additional divergences, namely :—

(*n*) Walking round the fire saying prayers.
(*o*) Passing through the fire for success and good luck.

The significance of these rites lies in the fact that they are performed for the express purpose of obtaining aid in time of need. They brought the devotee into direct and close contact with the fire, and hence obtained for him its protection. This is the meaning of the ceremony; and it allows no room for a trace of a malevolent deity demanding sacrifice, whether human or animal, all the evidence pointing to a

[1] Wilde's *Irish Popular Superstitions*, 49; Vallancey, *Collectanea*, ii. 67, records practically the same rite as obtaining in Waterford and Kilkenny; Brand's *Pop. Antiq.* (Ellis), i. 305; *Trans. Kilkenny Arch. Soc.* i. 373, 381, Kerry, Kilkenny, and Dublin being the places mentioned specifically.

[2] Wilde, *loc. cit.*

beneficent influence affording help to those who performed the necessary rites. Other examples only confirm this view, the significance of which will presently appear. The Manx custom was to light fires on the hill-tops on the eve of St. John the Baptist and on May-day. The household fires were put out on that day and rekindled with some of the sacred fire. This fire was also placed on the windward side of fields, so that the smoke might pass over the corn; and the cattle were driven between two fires as an antidote against murrain or any pestilential distemper.[1] This preserves four elements of the typical form—*b*, *d*, *e*, and *g*—and one important divergence, *o*. The contact with fire as the means of obtaining its support is here extended to animals. Beginning with the fields and boats in the Burghead type form, the action was extended to crops generally, and to human beings in the Irish example, and to the corn crops and animals in the Manx example. There can be no doubt that we are dealing with the same rite in all these cases; and as no idea of a sacrifice could occur in the case of the fields and crops, as no idea of a sacrifice is conveyed by the actual ceremony performed by animals and human beings, it is important to note that the evidence so far distinctly points to the conception of contact with some sacred power to ensure help and protection, and therefore negatives any supposition of a sacrifice. In the western islands of Scotland the ceremony was for "eighty-one married men (being thought the necessary number for effecting this design)" to take two great planks of wood, and nine of them were employed by turns to rub one of the planks against the other until the heat thereof produced fire. From this forced fire each family is supplied with new flame to light its household fire which had previously been put out.[2] Elsewhere it is mentioned that it was an ancient custom to make a fiery circle about the houses, corn, cattle, &c., belonging to each particular family; a man carried fire in his right hand and went round.[3] This example equates with elements *b*, *e*, and *g* of the type, and supplies a new and very important variant of the method of kindling the fire, *c*.

In the Burghead example it was noted that the sanction of married life was an element in the choice of the man who was to be the bearer of the fire; in this western isle example it is the same sanction which governs the choice of the men to create the fire, and the significant repetition of this feature cannot be wholly due to accident. But the Scottish historian, Hector Boece, tells a curious legend about the fire on the same island—Lewis—to which Martin refers. 'The fame is,' says Boece, 'als sone as the fire gangis furth (dies out) in this ile, the man that is haldin of maist clene and innocent life layis one wosp of stra on the alter, and when the pepill are gevin maist devotly to thair praers, the wosp kindelies in ane bleis.'[4] Here the resort is to the church, where miraculous fire is obtained for the same purpose as the sacred forced fire; and it may be that we have a late example of the method the Church adopted to occupy the place of the older religion. The point is of some importance, because we shall presently have to note the survival of these fire customs among the ritual observances of the early Church.

All these examples point to a periodical renewal of fire on some par-

[1] *Mona Miscellany*, p. 143.
[2] Martin's *Western Islands*, 113.
[3] *Ibid.* 116. Cf. *Proc. Soc. Antiq. Scot.* xii. 556, for the importance of fire as a symbol of possession in Lewis and St. Kilda.
[4] Brown's *Early Descriptions of Scotland*, p. 89.

ticular day, the last day of the old year, May eve, and so on; and the significance of these, in the indication they give of continuous life, has been noted. I now come to examples of sacred fires which are not created on a particular day, but for a particular purpose. The points of contact between the two groups of examples are, however, many. The alleged purpose of the fire in these new examples is the same as one of the ceremonies performed during the fire ritual in the examples just given; the actual mode of creating the fire is the same; the connection between the village-fire and the house-fires is the same. In short, the elements of each example are the same, but the assumed importance of each element in the popular mind is not the same.

In the isle of Mull, off the west coast of Scotland, the people carried to the top of Carnmoor a wheel and nine spindles of oak-wood. They extinguished every fire in every house within sight of the hill, and the wheel was then turned from east to west over the nine spindles long enough to produce fire by friction. They then sacrificed a heifer, cutting in pieces and burning while yet alive the diseased part. Finally, they lighted their own hearths from the pile, and ended by feasting on the remains of the heifer. The cause of the ceremony was to cure the disease among the black cattle.[1] Here we have three elements of the typical form *b*, *c*, and *e*, and the important divergence *o*. More important, however, are the facts of sacrifice and the sacred feast; and I suggest that these are not radical elements, but signs of the degradation of the ritual into other uses or channels. Clearly there is no connection between the sacrifice and the ceremony of lighting the house-fires from the village-fire; and as this element is the strongest link to the other examples which have been examined it must be regarded as the test of origins. Another form of this example confirms this view. In the Highlands and in Caithness new fires were made 'to defeat sorceries.' 'Certain persons who have the power to do so' were sent for to raise the new fire.[2] The qualification of the persons engaged in the ceremony is extremely important. It may point to a kind of priesthood, or to the descendants of persons originally qualified. Up to the present it is remarkable that no idea of a priesthood is hinted at in these customs; and on this I shall have something to say presently; while in the Burghead typical form common descent from originally qualified persons, who were not priests, appears. In the absence, then, of direct evidence on this important point, I am inclined to class the 'certain persons' of the Caithness custom with the common descendants of qualified persons of the Burghead custom.[3] The ceremonial of creating the fire is very curious. Upon any small island in a river or lake a circular booth of stone or turf was erected, on which a couple or rafter of a birch tree was placed, and the roof covered over. In the centre was set a perpendicular post fixed by a wooden pin to the couple, the lower end being placed in an oblong groove on the floor, and another pole was placed horizontally between the upright post and the legs of the couple, into both of which the ends, being tapered, were inserted. This horizontal

[1] Grimm, *Teutonic Mythology*, ii. 608.

[2] Logan, *Scottish Gael*, ii. 68.

[3] Jamieson, *Scottish Dictionary*, s.v. 'New fire,' quotes, from the *Agricultural Survey of Caithness*, the same ceremony as that described by Logan, which, however, says, instead of 'certain persons,' that 'charm doctors' superintended the lighting of the new fire. This, of course, may point to a priesthood, but I do not think it does, and the point needs further investigation.

timber was called the auger, being provided with four short arms or spokes by which it could be turned round. As many men as could be collected are then set to work, having first divested themselves of all kinds of metal. From this the new fire was instantly procured, and all other fires having been quenched with water[1] they were rekindled from the new fire and accounted sacred; and the cattle were successively made to smell them.[2] In many ways this is more important than the Mull example. It gives five elements, *a*, *b*, *c*, *e*, and *l*, and the important divergence *o*, which imposes the smelling of the fire by the cattle. In this latter incident lies the justification for asserting that cattle sacrifice is no part of this ritual. It is contact with the sacred element which is necessary, not sacrifice. So, too, in Moray, when a contagious disease occurred among the cattle, the people of the villages extinguished all their household fires and then produced a fire by means of friction. On this a vessel was placed in which juniper branches were boiled, and with this decoction all the cattle were sprinkled. On the conclusion of the ceremonies the household fires were relighted by a brand from the friction fire.[3] Shaw wrote this account in the last century, and it is somewhat difficult to localise the customs he records. He says that the midsummer solemnity was celebrated by making 'the deas-soil about their fields of corn with burning torches of wood in their hands to obtain a blessing on their corns.' On Midsummer eve 'they kindle fires near their corn fields and walk round them with burning torches,' and 'the like solemnity was kept on the eve of the first of November as a thanksgiving for the safe ingathering of the produce of the fields.'[4] This example yields five elements, *b*, *c*, *d*, *e*, and *g*; and it accentuates the conception of contact with, rather than sacrifice to, fire by the act of sprinkling water heated by fire instead of the natural action of the smoke as an indication of contact.

With these facts before us we pass on to the well-known example at Kildare sanctioned and upheld by the Christian Church. Giraldus Cambrensis is the authority for this. He says that 'the nuns and holy women tend and feed the fire, adding fuel with such watchful care that from the time of St. Bridget it has continued burning through a long course of years.' Twenty nuns were engaged. Each of them had the care of the fire for a single night in turn, and on the evening before the twentieth night, the last nun, having heaped wood upon the fire, said: 'Bridget, take charge of your own fire, for this night belongs to you.' The nuns then left the fire, and in the morning it was found alight as usual. The fire was surrounded by a hedge made of stakes and brushwood, and forming a circle within which no male could enter.[5] Giraldus wrote in the twelfth century, and St. Bridget was born, according to tradition, in 453. This would give a life of seven hundred years for this fire. Henry de Londres, Archbishop of Dublin, caused it to be extinguished in 1220, but it was afterwards again lighted and remained so until the suppression of the monasteries by Henry VIII.[6] This supplies remarkable evidence of the fact of perpetual fire, which has only been symbolised in the examples hitherto adduced, but on the other hand the adaptation to church and

[1] The mention of water is given by Jamieson's authority only, not by Logan.
[2] Logan, *op. cit.*; Jamieson, *op. cit.* s.v. 'Black spaul.'
[3] Shaw, *Hist. of Moray* (2nd edit.), iii. 154; 'all this I have seen done,' says Shaw.
[4] *Ibid.* iii. 146.
[5] Giraldus Cambrensis, *Topography of Ireland*, lib. ii. cap. xxxiv.-vi.
[6] Archdall's *Mon. Hib.* iii. 240.

monastic purposes has left the Kildare example shorn of other primitive characteristics, except perhaps the substitution of an artificial kindred, the monastic group, for the real kindred. There are also two divergent elements, *p*, *q*, in the virgin attendants and the circular form of the fire. It leads us, however, to the action of the Church elsewhere. In the island of Inismurray is the church of Teach-na-Teinedh, or the Church of Fire, and there was formerly a remarkable flagstone upon which, according to tradition, the monks kept a fire always burning for use by the islanders.[1] The flagstone is called Leac-na-Teinidh, the Stone of Fire. It consists of seven stones, four of which are placed on edge and set deeply in the ground in the manner of a cist. The sides face as nearly as possible the cardinal points, and are in position *not* coincident with the surrounding walls of the church. The natives aver that here of old burnt a perpetual fire, from which, all the hearths on the island which from any cause had become extinguished were rekindled.[2] Here we have elements *a*, *d*, and *e*, and the fact of perpetual fire. In England, churchwardens' accounts contain entries of payment for fuel 'for the holy fire;'[3] and the explanation of these entries is that hallowed or holy fire was kindled in the church porch on the morning of Easter Eve, and was obtained from the sun by means of a crystal or burning glass if the morning was bright, or a flint and steel if the weather was unpropitious. This fire was blessed by the priest, and from it the Paschal candle, the lamps of the church, and the candles on the altar were lighted for Easter Day. The people, too, took home with them a light from the sanctuary, and the hearth that had been allowed to become cold and brandless then became warm and bright once more, and the evening candle shone brightly again with a flame from the new hallowed fire.[4] This would seem almost to be a direct handing on of the pagan sacred fire to the Christian priesthood. At least four elements, *a*, *c*, *d*, and *e*, of the type are preserved, the continuation of the light from Easter eve to Easter morn being of the same characteristic as that from New Year's eve to New Year's morn already dealt with, as Easter was looked upon by the early Church as the beginning of the Christian year.[5]

Finally we turn from the church to the record evidence of the Irish tribal system. In an ancient tract which was written at the time of the break-up of the Irish tribal system, and shows the transition from blood-ties to economical ties, a chieftain, who is not noble, but who represents the tribesmen as their chief official, stands out as the outcome of this

[1] Wood-Martin, *Pagan Ireland*, 93.

[2] *Journ. Roy. Hist. and Arch. Assoc. of Ireland*, 4th Series, vii. 228–9.

[3] Bilson, *Leicestershire County Folklore*, 75. Municipal accounts also contain entries of payments for 'coals for the new fire on Easter Eve,' *Hist. MSS. Com.* iv. 432, vi. 495 (Hythe and Bridport).

[4] Rock, *Church of Our Fathers*, iv. 94. Dr. Rock quotes only one passage from an English authority for his facts about the Anglo-Saxon ritual, namely, Bede, *De Tabernaculo* (lib. iii. cap. 1); but he rightly points out that to understand this passage the ceremony above described is necessary, and he draws it up 'from the older ritual and the early liturgical writers in those parts of Germany which heard and took their Christian belief from Anglo-Saxon preachers.'

[5] There may be something of archaic significance, too, in Dr. Rock's observation that 'for church use at least this fire might truly be said to have lived the whole year through, for as lamp was lighted from lamp it thus kept on burning from one Holy Saturday to another' (*loc. cit.*).

transition period. He was known as the Bruighfer chief; and among his duties and privileges, enumerated with the usual precision of the Irish legal treatises, are certain objects which 'he shall have without borrowing—a grinding-stone, a mallet, an axe, a hatchet, a spear for killing cattle, ever-living fire, a candle upon a candelabra without fail, a perfect plough with all its requirements.'[1] I refer back to the Burghead custom to note the significant parallel in the taboo against borrowed articles,[2] to the specified articles themselves in connection with the construction of the clavie, and to the 'ever-living fire' of the Bruighfer chief.

Here the examination of the more perfect examples of the custom fire—that is, those which contain the element of the house-fires of the family units being derived from the village-fire—ends; and we must next ask as to the less perfect examples. These will be found to consist of many well-known, but little understood, customs, which equate with the examples just dealt with in one or more particulars, and which gradually shade off into examples which have reached the last stages of decadence. Perhaps with few other instances of traditional usage has the unfettered imagination of writers been more busy than with this. The lighting of fires at Easter, May-day, Midsummer, and Yule, has been so widespread in the Celtic parts of the islands that the subject has been peculiarly attractive to every school of Celtic scholarship. The result is unfortunate for the cause of science. It has served to make the subject peculiarly distasteful to sober inquirers who do not care to go on a roving expedition to Phœnicia and all sorts of ancient civilisations for the origin of a cult the remnants of which exist in modern Britain; and hence very little attention has been given to the evidence supplied by the customs themselves when studied with due regard to scientific conditions.

Leaving out of consideration all those general statements as to lighting of fires on particular festivals, which do not supply any of the details which have been the subject of particular observation, I will proceed to classify those definite examples of ceremonial fires which do not contain the essential feature of supplying the flame for the household fire, the object of the classification being to see how far their elements equate with the elements of the more perfect examples already examined.

In Cornwall the festival fires were kindled on the eve of St. John the Baptist. The people attended with lighted torches and made their perambulations round the fires and proceeded from village to village.[3] Later writers give further details, but do not state that the house-fires were lighted from the village-fire. At Penzance young men and women passed up and down the streets where fires were lighted, swinging round their heads heavy torches, the flames of which almost equalled those of tar-barrels. At the close of the proceedings a great number of persons of both sexes used to join hand in hand forming a long string, and running through the streets playing thread-the-needle, and leaping over the yet glowing embers.[4] Sir Arthur Mitchell has collected from the Kirk

[1] *Brehon Law Tracts*, iv. 311.

[2] It seems probable that the word bonfire is derived from boon-fire, *i.e.* from he fact that the materials were obtained by boons gathered from everyone in the neighbourhood. (See Ellis's Brand, i. 301.) Murray, however, decides that etymologically the derivation is from *bone* fire.

[3] Borlase, *Antiquities of Cornwall.*

[4] Edmond's *Land's End District*, 66; Hunt's *Pop. Rom. of West of England*, pp. 207, 208; Brand, *Pop. Antiq.* (Ellis), quotes an eighteenth-century writer that these fires were called 'Blessing Fires' in the west parts of England.

session records of Elgin, Kinneddar (now Drainie), Duffus, and Inveravon, many interesting particulars of the attempt to put down the burning of clavies round the boats and the fields of the fisherfolk and peasantry in the country round about Burghead, attempts which take back the custom to 1655, when it was considered an ancient 'idolatrous and heathenish practice,' and shows that the custom of 'burning the clavie is not a ceremony peculiar to Burghead, and has no special connection either with that spot or with a sea-going community.'[1] At Warkworth in Northumberland every year the farmers kindled a new fire with some ceremony at a certain farm agreed upon, and the cattle were then shut up in the straw barn, where the fire was kept up among them for some time, after which a lighted brand was carried on to the next farm where preparations had been made for a similar proceeding. If the brand went out, the virtue was gone; and that year would be looked forward to with dread of many deaths among the herd.[2] In Herefordshire and Somersetshire fires were made in the fields to bless the apples.[3] It will be readily detected that these examples contain four elements which belong also to the group of examples just examined, *b*, *c*, *g*, *h*, and only one divergent element, namely, the Penzance thread-the-needle ceremony (*r*). Perhaps the Warkworth custom of carrying fire from farm to farm is the divergent form (*s*) of the lighting of the house-fire at the village-fire.

One thing further has to be noticed, and this is of singular interest to the present line of enquiry, because it links on fire customs to an important social institution. The meeting-place of the tribe, sacred to it in many ways, is preserved in many places throughout the kingdom; and some years ago I collected the evidence together in my little book 'Primitive Folk Moots.' We have seen how the fire is connected with the tribal chieftains in Irish evidence, and we know that the care of the tribal fire was a part of the chief's duty as priest-king of the tribe. The relationship of the place of fire-kindling to the place of meeting is therefore an important feature of the cult. Is it to be found among the surviving fire customs of the class we have been examining?

A splendid example is to be found in Ayrshire. The Torbolton moot hill and the ancient so-called altar for kindling the fire adjoin each other. The moot hill was used as a meeting-place until recent times, while the fire-kindling is carried on to this day. The date is the nearest Tuesday to June 3; the fire is kept burning for three days, and the boys of the neighbourhood indulge in the ancient practice of 'leaping on the altar.'[4] I have not been able yet to give other examples of the close connection between the tribal meeting-place and the place for kindling the fire; but I suggest that the various toot hills throughout the country, and the many examples of a second and smaller hill, or a second and smaller stone, which occur near to the hill or stone of meeting, afford ample ground for believing that the necessary evidence will be forthcoming when my researches are completed.

These examples complete the evidence I am able to bring forward as to the village phase of the fire custom, and I will now tabulate the results up to this point. The following table gives the result of the analysis of

[1] *Trans. Antiq. Soc. Scot.* x. 652, 659.
[2] *Denham Tracts*, ii. 365, 366.
[3] Aubrey, *Remaines* [1685], p. 96.
[4] Smith's *Prehistoric Antiquities of Ayrshire*, p. 149.

each example into its constituent elements (*a* to *i*) and divergent elements (*m* to *t*):—

Burghead [1]	=	*a, b, c, d, e, f, g, h, i*
Lanarkshire	=	*b, d, e + m*
Waterford, Kilkenny, Kerry, Dublin	=	*b, c, f, g + n, o*
Isle of Man	=	*b, d, e, g + o*
Western Isles	=	*b, c, d, e, g*
Mull	=	*b, c, e + o*
Caithness [2]	=	*a, b, c, e + o*
Moray	=	*b, c, d, e, g*
Kildare	=	*b, d + p, q*
Inismurray	=	*a, d, e*
Church rite	=	*a, c, d, e*
Irish tribe	=	*d*
Cornwall	=	*+ r*
Elgin, Drainie, Duffus, Inveravon	=	*g*
Warkworth	=	*b, c, h + s*
Herefordshire	=	*g*
Somersetshire	=	*g*
Ayrshire	=	*d + o, t*

In all these cases some of the elements which belong to each are common to all; and therefore whatever has been the later history of each particular example, whether it has continued by traditional sanction kept up by a body of co-villagers, or whether it has been preserved as a part of church ritual kept up by the priesthood, the origin of all the examples must be referred to one custom, and one custom only. A number of different local customs have been shown to closely interlace with each other, to contain elements of a common origin, to converge in certain particulars upon a condition of things far removed from the epoch of modern civilisation, to point unmistakably to prehistoric times, even if they do not actually touch prehistoric culture, to belong to a given social organism which, if represented by the modern condition of co-villagers, also contains the conception of co-worshippers at a common altar, and of co-relationship in a common blood tie; and the very terms which we are enabled to use in describing the first results of classification and analysis suggest to a great extent the final conclusions to be drawn.

3. *The House-fire Cult: Origin of the House-fire.*

The most important element brought out by the analysis of these examples of the fire custom is the practice of lighting the house-fires once a year in a ceremonial fashion from the village-fire; and we have now to see what this evidence indicates in connection with the house-fire.

A custom so remarkable in itself, when judged by the modern ideas of the house-fire, points to a connection between house-fires and village-fire of a more or less sacred character; and, if so, the question is, What is the

[1] The *k* and *l* elements are general indications of the Burghead custom, and not special, and accordingly they need not be counted in the analysis at this stage.

[2] This example also contains the *l* element.

nature of the sanctity conveyed from the village fire to the house-fires? Perhaps we may not get this question answered from the evidence afforded by British usage; but at all events it leads up to another pertinent question, namely, whether the kindling of the house-fires from the village-fire on one particular day in the year signifies the sanctity of the house-fire on that particular day only, or a sanctity which can only be conveyed by contact with the village-fire. There can be little doubt that the latter is the true interpretation of the rite; and it carries with it the assumption that throughout the year, from one anniversary of the formal lighting of the village-fire to another, the house-fire must have retained the sanctity derived from the village-fire. The only method of doing this is by continuous life, a feature we are already familiar with in connection with the village-fire.

The examples to be taken first are those house-fires which have already been mentioned as actually derived from the village-fire. The house-fires of Burghead, having been kindled from the clavie as already described, were kept up throughout the year, 'it being considered lucky to keep the flame from the clavie all the rest of the year.'[1] The Lanarkshire example is not so perfect, the continuous life of the house-fire, lighted from the village pile, being represented only for the period of transition from old year to new year, and not for the actual year, it being considered 'unlucky to give out a light to anyone on the morning of the new year.'[2] The Irish example falls into line by the evidence of Sir William Wilde that 'portions of the extinguished [village] fire are generally retained in each family'[3]—a form which we may accept as an obvious divergence from the continuous house-fire. In the Manx evidence we once more get a perfect form. There is not one of the native families 'but keeps a small quantity of fire continually burning, no one daring to depend on his neighbour's vigilance in a thing which he imagines is of such consequence, everyone consequently believing that if it should happen that no fire were to be found throughout the island most terrible revolution and mischief would immediately ensue.'[4] The Western Islands example again is not so clear, Martin simply saying that 'the fires in the parish were extinguished,'[5] each family being then supplied with new flame from the village-fire; but there can be little doubt that the continuous life of the house-fire is here symbolised if not actually recorded. In one of the islands of St. Kilda the evidence is complete. Turf fires are always kept burning, and if one happens to go out a live turf is borrowed from a neighbour. The fires of St. Kilda have probably been burning for centuries.[6] The fact of continuous life and its symbolisation in a recognised form are therefore both represented in these examples.

In the next group of examples we have the house-fires kept alive perpetually without renewal from the village-fire. This divergence from the more primitive form need not surprise us. The more archaic elements in the fire-cult would be the first to die out before the march of new social and economical ideas, and these are undoubtedly those ele-

[1] *Folklore Journal*, vii. 12.
[2] *N. and Q.* 2nd Series, ix. 322.
[3] *Irish Popular Superstitions*, 49.
[4] Waldron, *Description of the Isle of Man*, p. 7.
[5] Martin, *Western Islands*, 113.
[6] *Proc. Soc. Antiq. Scot.* xii. 191. Lucifer matches are only used by the minister, and there is no flint and steel on the island

ments which belong to the village phase. The family element, left to struggle on by itself, would take upon itself some of the features thus lost, especially such an extremely important characteristic as that of perpetual life. This is the explanation of the following remarkable survival. In Lakeland of northern England the old hearth-fire was raked or put into a condition of smouldering at nights with superstitious reverence, and was thus 'kept up from day to day, from month to month, from year to year, and from generation to generation,' and more instances than one are known 'where the house-fire had been kept up for three generations, and during all that time had been so zealously guarded that it had not been once allowed to go out. There is a well-known instance where a man had what he called his "grandfather's fire," that is, a fire that was known to have been kept up without extinction for at least three generations, and when it once accidentally went out he went to some woodcutters who had lighted their fire from his and brought back from their fire a fire to his own hearth, that thus he might possess as it were the seeds of his ancestors' original fire.'[1] The elimination of the ceremony of annual renewal in this case has caused the accentuation of the idea of perpetual life, but the process for renewal where perpetual life has been broken by accident brings back the old conception of the house-fire being derived from a sacred source.

This example, significant as it is of itself, becomes all the more so when it is discovered that other examples of the house-fire which do not renew their life annually from the village-fire have adopted a form of annual renewal which cannot but be considered as due to an original renewal from the village-fire. We have seen above that this particular element would be the first to give way before advancing civilisation. Granting that this had taken place in cases where the perpetuation of the cult of the house-fire was inclined to go on much longer in survival, we should get a form of annual renewal minus the village-fire from which such renewal was obtained. A further advance in the line of degradation may lead us to a form of annual renewal where not only has the village-fire ceased to be a part of the ceremony, but some other element has been introduced into the gap caused by the village-fire having dropped out of the ceremony. Thus there are two groups of fire customs to allow for—one where annual renewal pure and simple takes place, or is symbolised as taking place; the second where annual renewal takes place in connection with some other element than that of fire.

The examples where the annual renewal is symbolised are numerous. They take the following forms: embers of a particular fire are preserved to light the next anniversary fire, old and new fires being thus connected; the fire of New Year's eve in the old year is kept alight until New Year's morn in the new year, old and new years being thus connected by an unextinguished fire; the prohibition against giving light out of the house at certain sacred periods, or on certain sacred days, the life of every house-fire being thus held to be sacred on that day and kept up by the house-family itself and not by kindling from without. Variations of these forms will of course occur, but these variations do not suggest new forms of the symbolisation of the annual renewal of the house-fire. They only show the direction which degradation of the survivals takes when once symbolisation is made to do duty for actual fact.

[1] *Trans. Cumberland and Westmoreland Antiq. and Arch. Soc.* xii. 289, 290.

In these cases annual renewal from an old fire, which was in turn derived from an old fire, and so on backwards, takes back the 'seed of the fire' to the original method of obtaining it, namely, from the village-fire; and in this way these imperfect examples are connected with the perfect examples. But the formula of annual renewal also contains the formula of continuous life, and it becomes a 'struggle for existence' between these two formulæ as to which should ultimately prevail in determining the form which each survival should finally take. In the first of the above-mentioned groups both formulæ appear; in the second and third only the symbolism of continuous life; and thus we obtain a very instructive lesson in the process of degradation in survivals.

Of the first form a Nottinghamshire example is the best. There must always be a portion of last year's yule log left in the house to be burnt upon the next Christmas eve. The method is to first put a bit of last year's log into the fireplace and burn it, then the fresh log must be put on the fire and be allowed to burn for a little while. It must then be taken off and burnt a little every night until New Year's eve, when it is put on the fire and burnt, all except the small portion which is kept in the house until next Christmas Day. It is believed that the observance of this custom will 'keep the witch away.'[1] I do not think the significance of this piece of ritual will be lost upon any student; and the sanction for its due observance is the safety of the household, the same sanction, that is, which was noted among the survivals of the tribal fire rites at Burghead, in the Isle of Man, and elsewhere. In Lincolnshire the yule log was placed with ceremony on the fire on Christmas eve, the unconsumed part of the old log having been carefully preserved to burn with the new one.[2] In Northamptonshire it is taken from the fire when only half burnt and carefully preserved in a cellar or some other safe place, its possession being looked upon as bringing good luck to the house and preventing fire throughout the coming year.[3] This last divergence in the form of protection obtained from the fire is clearly a modern addition due to association of ideas; and we next come upon an example of this form of protection when it is unaccompanied, as in the present case, with the more archaic conception of safety to the family being bound up with the preservation of the sacred fire. In Northumberland a fragment of the Christmas log was saved for next Christmas,[4] during which time it secures the house from fire, and a small piece of it thrown into a fire occurring at the house of a neighbour will quell the raging element. A tall mould candle is also procured for the evening, and it would be unlucky to light either the log or the candle till the proper period. A piece of the candle is also kept to ensure good luck.[5] Here yule log and yule candle are evidently struggling for mastery as the emblem of the house-fire annually renewed, while the foreign element of protection from fire receives its most advanced form. The same evidence is derived from the district of Nidderdale. There the fag-end of last year's yule log is used to light the new one, which in its turn is saved for a like purpose in the following year. Each house is provided with twelve or more candles, which are all lighted

[1] Addy, *Household Tales and other Traditional Remains*, p. 104.
[2] Brogden, *Provincial Words*, s.v. 'Yule log.'
[3] Sternberg, *Folklore of Northamptonshire*, p. 186.
[4] My authority does not actually say 'to light' the next Christmas log, but there is no doubt, I think, that this is implied.
[5] *Denham Tracts*, ii. 25–26.

together on Christmas eve, and the members of the household hold them in their fingers alight for about ten minutes, when all but one are extinguished, and the one is left to cut the cheese by. After dark no person must take a light out of doors, as it is considered unlucky to do so.[1] In the North Riding of Yorkshire a large fire, known as *yule clog*, is made on Christmas eve, a piece of the clog being carefully preserved by the housewife, and on New Year's eve no one will suffer a light to be taken from his fire.[2] We now turn to the simplest form of this group. In Cornwall, the Christmas log was lighted by a portion saved from the last year's fire.[3]

Of the second group the most remarkable example is the South Yorkshire practice at Penistone. When the yule log was burnt on Christmas eve the fire was not allowed to go out during the night, and in the morning whatever burning ashes were left in the grate were carefully collected and taken down into the cellar and put under the 'milk benk' [stone bench where the milk vessels stood]. These ashes were supposed to 'keep the witch away' during the following year and bring good luck to the house; they were kept for years, forming a great pile in the cellar, and were not allowed to be taken away.[4] Although in this example we for the first time lose the element of annual renewal which has hitherto been present in all the examples, it is remarkable that other important elements remain. Not only do we get here the symbolism of continued life in the burning from Christmas eve to Christmas morn, but in the sacred character of the ashes preserved from year to year; and once again the connection of the house-fire with the prosperity of the family is contained in the survival. In Derbyshire exactly the same custom obtains, but it has reached its last stage of decline, as it is not in an absolute form, but only permissive. *If* the yule log is not burnt away on Christmas eve, the ashes or embers must on no account be taken out of the house.[5]

Next we note some customs where the Christmas log is kept alight during the whole season of Christmas and New Year, and the continuity of life in the fire is expressly made a solemn act of ritual, while the element of annual renewal has almost, if not entirely, disappeared. In Shropshire, half a century ago, the scene of lighting the hearth-fire on Christmas eve to continue burning throughout the Christmas season might have been witnessed in the hill country, from Clunbury and Worthen to Pulverbatch and Pontesbury. A great trunk of seasoned oak, holly, yew, or crabtree was drawn by horses to the house door, and thence by the aid of rollers and levers placed at the back of the wide open hearth. The embers were raked up to it every night, and it was carefully tended that it might not go out during the whole season, during which time no light might either be struck, given, or borrowed.[6] On all fours with the other

[1] Lucas, *Studies in Nidderdale*, pp. 43, 44. Mr. Lucas distinguishes between the *yule* log and the *Christmas* candle, and it is possible that we have here the meeting of two influences, northern and southern, upon the waning archaism of the Christmas festival.

[2] *Gent. Mag.* 1811, part i. p. 424.

[3] Whitcombe, *Bygone Days in Devonshire and Cornwall*, p. 194.

[4] Addy, *Household Tales*, p. 103.

[5] *Ibid.* p. 104.

[6] Burne's *Shropshire Folklore*, pp. 397–401. Miss Burne's evidence should be carefully read throughout, for although it adds no more details than those I have quoted above, it emphasises the country conception of the sacred fire during the Christmas season.

examples, as to the sacred character of the house-fire during the Christmas or New Year season, this example emphasises one important particular, namely, that the unluck of giving out a light includes the prohibition against receiving a light or making a light. Clearly, therefore, we have here symbolised in very direct form the continuous life of the New Year's house-fire during the season which carries it on from the old year into the new. In Warwickshire the Christmas block was not to be entirely reduced to ashes until the end of the twelve days of Christmas.[1]

The limitation of continuous burning through New Year's eve and morn has now to be considered as the last of this group, symbolising that the house-fire was carried on from one year to another. In Lancashire if any householder's fire does not burn through the night of New Year's eve it betokens bad luck through the ensuing year; and if any one allow another to take a live coal, or to light a candle, on that eve, the bad luck extends to the grantor.[2] In the border counties it is deemed highly unlucky to let the fire out on New Year's eve, All-Halloween, Midsummer eve, and Christmas eve, and no one will on the following morning give out a light lest he should give away his luck for the season.[3]

In the Northumberland example, quoted above, it was seen how the more modern yule candle was apparently displacing the archaic yule log. This provides the necessary connecting link to a group of customs where the burning of a candle or lamp all night on Christmas or New Year's eve appears as the sole remaining form of the survival. That this custom is a direct and genuine descendant from the house-fire can be proved by the fortunate preservation of the 'missing link' evidence between it and the Northumberland type. This comes from Lyme Regis, where the wood ashes of the family were formerly sold throughout the year as they were made, the person who purchased them being obliged to send as a present on Candlemas day a large candle. This candle was lighted in the evening, and only upon its self-extinction did the family retire to rest.[4] I think this explains the significance of the burning candle in connection with the survival of the house-fire cult; for the transference from Christmas or New Year's eve to Candlemas Day is not a serious flaw in the argument. I pass, then, to the more general form of keeping a burning candle all night on certain sacred anniversaries. In Yorkshire it was believed that unless this was done on Christmas eve there would be a death in the house.[5] In Scotland candles of a particular kind were made for Christmas Day, and each candle must be so large as to burn from the time of its being lighted till the day be done; if it did not, the circumstance would be an omen of ill-luck to the family for the ensuing year. In some parts the candle is not allowed to burn out, but is extinguished and carefully locked up in a chest, in order to be burnt out at the owner's date-wake.[6]

The third form of this particular phase of the cult of the house-

[1] *Folk-lore Journal*, i. 352.

[2] Harland and Wilkinson, *Lancashire Folklore*, pp. 155, 214.

[3] Henderson, *Folklore*, p. 72.

[4] Dyer's *Popular Customs*, p. 56. There is also the case of Dublin where, because the May-day fires were prohibited, the people fix a bush in the middle of the street and stick it full of lighted candles (*Gent. Mag.* 1791, p. 428).

[5] Addy, *Household Tales*, p. 105.

[6] Jamieson, *Dictionary*, s.v. 'Yule.'

fire does not assume many variations. It will be remembered that the prohibition against giving out fire included, in the Shropshire example, the prohibition against receiving it or creating it; and this significant inclusion of three definite forms for lighting the house-fire from within the house appears to suggest that continuation of the house-fire was symbolised. Further down, however, this symbolisation is reduced to very simple limits; but simple as they are they are connected directly with the whole system of the house-fire cult. 'No fire must on any account be taken out of the house between Christmas eve and New Year's eve,' is the Derbyshire survival;[1] and perhaps, as it carries the practice over a period longer than a particular day, it may be taken as the most archaic. In Scotland people would not allow a coal to be carried out of their house to that of a neighbour on Christmas Day, New Year's Day, Handsel Monday, and Rood Day, the reason being that it might be employed for the purpose of witchcraft.[2] Here again we have not a continuous period but certain selected sacred days. In Northumberland, however, although the ceremonial of the Christmas log obtains, as we have already noted, in a somewhat degraded form, it is only on New Year's Day that the prohibition against giving out fire obtains.[3] In the Forest of Dean, Gloucestershire, the people will not allow any fire to be taken out of their houses on Old Christmas Day.[4]

In Herefordshire we meet with the extreme divergent form of this custom, showing the direction of its decline into mere superstition. On Old Christmas Day and during the twelve days no person must borrow fire, but they may purchase it with some trifle or other, for instance a pin.[5]

4. *The House-fire Cult continued: Customs associated with the Household Fire.*

In the most perfect examples of the village-fire ceremonial certain elements were noted to be associated with the formal attribute of the fire —perpetual life—which, whether in their primary forms or in divergence from the primary form, were ascertained to contain fragments of ritual or primitive associations. Such associations cannot be claimed for the survivals of the house-fire in its formal attribute of continuous life, because the observers of examples of continuous life in the house-fire have not extended their work to gather together what the peasantry thought about, or how they treated the fire thus guarded from extinction. There are, however, one or two associated customs which have been noted, and these are of some importance. On the other hand there is another body of customs, drawn altogether from another set of examples, generally from another part of the country, which can only be explained by referring their origin to the same system of fire customs as those which stamp the village-fire and the house-fires lighted therefrom.

We will note, first, the few actually associated customs. In Lewis after the house-fire has been newly kindled from the village-fire, 'a pot full of water is quickly set on it and afterwards sprinkled upon the people infected with the plague or upon the cattle that have the murrain.'

[1] Addy, *Household Tales*, p. 104.
[2] Jamieson, *Dictionary*, s.v. 'Yule.'
[3] *Denham Tracts*, ii. 340.
[4] *Gent. Mag.* 1822, part ii. p. 603.
[5] *Gent. Mag.* 1822, part i. p. 13.

Fire is also carried 'round about women before they are churched after child-bearing, and it is used likewise about children until they be christened, both which are performed in the morning and at night . . . as an effectual means to preserve both the mother and the infant from the power of evil spirits who are ready at such times to do mischief and sometimes carry away the infant.'[1] In the Western Isles of Scotland, as Candlemas Day comes round, the mistress and servants of each family, taking a sheaf of oats, dress it up in woman's apparel, and after putting it in a large basket, beside which a wooden club is placed, they cry three times, 'Brüd is come, Brüd is welcome.' This they do just before going to bed, and as soon as they rise in the morning they look among the ashes, expecting to see the impression of Brüd's club there, which if they do, they reckon it a true presage of a good crop and prosperous year.[2] The same conception is more generally expressed in the Manx custom. In many of the upland cottages it is customary for the housewife, after raking the fire for the night, and just before stepping into bed, to spread the ashes smooth over the floor with the tongs, in the hope of finding in them, next morning, the trace of a foot. Should the toes of this ominous print point towards the door, then it is believed a member of the family will die in the course of the year; but should the heel of the fairy foot point in that direction, then it is firmly believed that the family will be augmented within the same period.[3]

I will next proceed to formulate the various elements which distinguish the ceremonies of the house-fire in those examples which are unconnected with any of the evidence previously dealt with.

That the hearth is the residence of a house-spirit is to be illustrated by many scraps of our fairy mythology. In a seventeenth-century work quoted by Brand, we read 'Doth not the warm zeal of an Englishman's devotion (who was ever observed to contend most stifly *pro aris et focis*) make him maintain and defend the sacred hearth, as the sanctuary and chief place of residence of the tutelary lares and household gods, and the only court where the lady fairies convene to dance and revel?' (ii. 504). Maids are punished by the fairies (fairies being the generic folklore title for any form of spirit) for untidy household habits, and particularly for not attending properly to the hearth. Thus in the old ballad of 'Robin Goodfellow' it is said:

> 'Where fires thou find'st unraked and hearths unswept,
> There pinch the maids as blue as bilbery.'

In Ireland the fairies are believed to visit the farmhouses in their district on particular nights, and the embers are collected, the hearth swept, and a vessel of water placed for their use before the family retire to rest;[4] Spenser observes that at the kindling of the fire and lighting of candles the people say certain prayers, and use some other superstitious rites, which show that they honour the fire and the light;[5] and in an old diary, printed by the Kilkenny Archæological Society (vol. i. [n. s.] p. 183), we read that 'servants when they scour andirons, fire-shovell, or tongues,

[1] Martin, *Western Islands*, pp. 113, 117.
[2] *Ibid.*, p. 119.
[3] Train's *History of the Isle of Man*, ii. p. 115; also Hampson's *Medii Ævi Kal.* i. p. 221.
[4] Croker's *Researches in the South of Ireland*, p. 84.
[5] Spenser's *View of the State of Ireland*, p. 98.

setting them down make a courtesie to each.' Drayton, in the 'Nymphidia,' records a piece of genuine traditional folklore in the following lines :—

'Hence shadows, seeming idle shapes
Of little frisking Elves and Apes,
To earth do make their wanton scapes,
As hope of pastime hastes them;
Which maids think on the hearth they see
When fires well near consumed be,
These dancing hayes by two and three,
Just as their fancy casts them.'

The same idea is given by Reginald Scott. 'Indeed, your grandam's maids were wont to set a bowl of milk before him (Incubus) and his cousin Robin Goodfellow, for grinding of malt or mustard, and sweeping the house at midnight.' [1] Not above forty or fifty years ago, says Brand, in his 'Description of Orkney, Zetland, &c.,' almost every family had a 'Brownie, or evil spirit, so called, who served them, to whom they gave a sacrifice for its service; as when they churned their milk they took a part thereof, and sprinkled every corner of the house with it for Brownie's use; likewise when they brewed they had a stone, which they called Brownie's stone, wherein there was a little hole into which they poured some wort for a sacrifice to Brownie.' [2] We get a glimpse of the same living belief in the hearth-spirit in Ireland. Among the Irish the expression 'the breaking of cinders' means to charge and confirm guilt on a man at his own hearth, so that his fire, which represents his honour, is broken up into cinders. The trampling of a man's cinders was one of the greatest insults which could be offered to him, as it conveyed the idea of guilt, and not only on the individual himself, but also on his family and household.[3]

At Fermanagh, a peculiar manner of cursing, rapidly dying out, is usually fulminated by tenants who suppose themselves to be in danger of wrongful eviction. The 'plaintiff' collects from the surrounding fields as many small boulders as will fill the principal hearth of the holding he is being compelled to surrender. These he piles in the manner of turf sods arranged for firing, and then, kneeling down, prays that until that heap burns may every kind of bad luck and misfortune attend the landlord and his family to untold generations. Rising, he takes the stones in armfuls and hurls them here and there in loch, pool, boghole or stream, so that by no possibility could the collection be recovered.[4]

From Cornwall I have obtained a note of a custom which is, to all intents and purposes, a hearth sacrifice. The practice of resorting to the hearth, and touching the cravel (the mantle-stone across the head of an open chimney) with the forehead, and casting into the fire a handful of dry grass, or anything picked up that will burn, is regarded as the most effectual means of averting any impending evils of a mysterious nature.[5]

These are the general superstitions which indicate a peculiar set of beliefs attaching to the domestic hearth in places where it is no longer lighted from the village-fire once a year. We now turn to the more

[1] Reginald Scott's *Dæmonology*, p. 980. See Keightley's *Fairy Mythology*, ii. p. 108.
[2] Keightley's *Fairy Mythology*, ii. pp. 273, 274.
[3] Sullivan's Introduction to O'Curry's *Lectures*, i. p. 278.
[4] *Journ. Roy. Hist. and Arch. Assoc. Ireland*, 4th series, iii. p. 460. [Cf. Dr. Gregor's No. 8.]
[5] Bottrell's *Stories and Folklore of West Cornwall*, 3rd series, p. 17. For another curious chimney custom, see *Folklore Record*, v. p. 160.

specific ceremonials of marriage and birth. In north-east Scotland the bride was led straight to the hearth, and into her hands were put the tongs, with which she made up the fire. The besom was at times substituted for the tongs, when she swept the hearth. The *crook* was then swung three times round her head, in the name of the Father, Son, and Holy Ghost, and with the prayer, 'May the Almichty mack this umman a gueedwife.' The last act of her installation as 'gueedwife' was leading her to the *girnal* or *mehl-bowie*, and pressing her hand into the meal as far as possible. This last action, it was believed, secured in all time coming abundance of the staff of life in the household.[1] Again, when the bride is entering her future home, two of her female friends meet her at the door, the one bearing a towel or napkin, and the other a dish filled with various kinds of bread. The towel or napkin is spread over her head, and the bread is then poured over her. It is gathered up by the children who have collected round the door. In former times the bride was then led up to the hearth, and, after the fire had been scattered, the tongs were put into her hand, and she made it up.[2]

In Scotland, according to Mr. Gregor's account, on the birth of the child the mother and offspring were *sained*, a ceremony which was done in the following manner: A fir-candle was lighted and carried three times round the bed, if it was in a position to allow of this being done, and if this could not be done, it was whirled three times round their heads; a Bible and bread and cheese, or a Bible and a biscuit, were placed under the pillow, and the words were repeated, 'May the Almichty debar a' ill frae this umman, an be aboot ir, an bliss ir an ir bairn.' When the biscuit or the bread and cheese had served their purpose, they were distributed among the unmarried friends and acquaintances, to be placed under their pillows to evoke dreams. Among some of the fishing population a fir-candle or a basket containing bread and cheese was placed on the bed to keep the fairies at a distance.[3] Dalyell records the following curious custom: 'The child put on a cloth spread over a basket containing provisions was conveyed thrice round the crook of the chimney'[4]—thus preserving the proximity of fire. Pennant describes a christening feast in the Highlands, wherein the father placed a basket of food across the fire, and handed the infant three times over the food and flame.[5]

In West Galway we meet with the curious notion that no fire must be removed out of a house in which a child is born until the mother is up and well.[6]

The mothers of Scotland are much afraid of the household fairy who changes the new-born babe; and the question is put to the test by an appeal to the house-fire. Mr. Gregor says the hearth was piled with peat, and when the fire was at its strength, the suspected changeling was placed in front of it and as near as possible not to be scorched, or it was suspended in a basket over the fire. If it was a 'changeling child' it made its escape by the *lum*, throwing back words of scorn as it disappeared.[7]

[1] Gregor's *Folklore of the North-east of Scotland*, p. 93. See also Henderson, *Folklore of Northern Counties*, p. 36.

[2] Gregor, *op. cit.* p. 99.

[3] *Ibid.* p. 5.

[4] Dalyell's *Darker Superstitions of Scotland*, p. 176.

[5] Pennant's *Tour in Highlands*, iii. p. 46. *Cf.* Miss Gordon Cumming's *In the Hebrides*, p. 101.

[6] *Folklore Record*, iv. p. 108.

[7] *Folklore of the North-east of Scotland*, pp. 8–9.

And so to discover whether it was a fairy-child, the hearth was again the place of operation. A new *skull* was taken and hung over the fire from a piece of a branch of a hazel tree, and into this basket the suspected changeling was laid. Careful watch was kept till it screamed. If it screamed it was a changeling, and it was held fast to prevent its escape.[1]

In Scotland we meet with the significant extinction of fire, on the occasion of a death, Pennant stating, in his 'Tour in Scotland:' 'All fire is extinguished where a corpse is kept.' How clearly fire is represented at death is shown, I think, by the widespread custom of the use of torches and lights while the body is lying in the house, a custom that is lengthily described by Brand.[2]

There is one other instance of the special use of the hearth-fire which I must mention before passing on. Mr. Hunt relates a story in his 'Popular Romances of the West of England'[3] which well introduces the subject. 'The child of a miner who had been suffering from a disease, and had been sent on several occasions to the doctor without any good resulting, was one day discovered by the father to be "overlooked." The gossips of the parish had for some time insisted upon the fact that the child had been ill-wished, and that she would never be better until "the spell was taken off her." It was then formally announced that the girl could never recover unless three burning sticks were taken from the hearth of the "overlooker," and the child was made to walk three times over them when they were laid across on the ground, and then quench the fire with water.'

5. *Comparison with Primitive Custom.*

This survey, by analysis and classification, of the fire customs surviving in Britain has been kept clear of any terminology which is not actually justified by the circumstances of each individual example or group of examples. But it cannot have escaped notice that the facts which have been quoted all tend in one direction, namely to the connection of the fire customs with the family, and through the family to some unit larger than the family, represented by the modern village in a geographical sense and by a group of common descendants in a personal sense.

But if we are justified in using such significant terminology as this, we have already made the first step towards the identification of these survivals as the remnants of a system of fire-worship belonging to some one or other of the early tribes who conquered Britain before they had conformed to the Christian religion; for I shall assert that the connection between the modern village-fire and the house-fire is due to the survival in traditional custom of the ancient connection between the tribal fire and the family or clan fire. When, therefore, in addition to this essential feature of the connection between the village-fire and the house-fire, an examination of the details of both village-fire customs and house-fire customs has revealed certain significant indications of the once sacred character of these fires, of ceremonies which recall almost the

[1] Gregor, *op. cit.* p. 9.
[2] Brand's *Popular Antiquities*, ii. p. 276 *et seq.*
[3] *Popular Romances of the West of England*, p. 212.

formula of a lost religious rite, and of usages which go back to prehistoric civilisation for their only possible explanation—when it has been found that these conceptions cluster round the burning embers of the modern fire, the case for deciding that the whole group of evidence belongs to the ancient tribal fire cult is provisionally at all events amply made out, and there only remains the work of comparison with the tribal fire cult of a primitive people to complete the proof.

Let us, however, first note whither this conclusion almost insensibly leads us. Nearly every writer on this subject has, it seems to me, begun at the wrong end. He has commenced with the few references to the god Bel, and has built up a theory of sacrifice and worship which has little or no evidence in its favour in the examples which have been examined in the previous pages. And in thus accentuating the religious element of these rites he has left wholly untouched the one clue to their origin, namely, the social organisation of the people who performed them. It is always useless to discuss early religions without taking count of the social organism of which the religion is only a portion. Early peoples did not differentiate, as modern peoples do, between the various elements of their culture; all the parts were closely interwoven, and cannot be divorced from each other even for the purpose of a separate analysis. To have established that these fire customs are intimately connected with a social unit is to connect them with a tribal religion and tribal society, and to limit their interpretation and meaning by what is conveyed by the term *tribal.* That term is applicable to the conditions of both the Celtic and Teutonic settlers of this country; and it is to these peoples, therefore, branches of the Aryan-speaking peoples, that we must provisionally at all events allot that portion of the tribal system which has been revealed by the customs already examined. They reveal the solemn rekindling of the tribal fire at least once a year, and the carrying of the sacred flame therefrom to the fire of the household, as the two essential details of the cult; and the several very significant rites which accompany these details are all illustrative of the tribal conditions to which the whole ceremonial belongs.

Having ascertained all there is to be deduced from the several elements preserved in the customs, there is one very important matter finally to be considered from an element which does not appear in the customs—I mean the entire absence of anything like a priestly caste as the necessary performers of the sacred rites; and the question is: Is this absence due to the degradation of the modern forms in survival, or is it due to the original conditions from which the survivals have descended? This is one of the questions not to be answered from the study of survivals, but which can only be deferred until the conclusions to be drawn from comparison with primitive rites are before us.

We will now turn, for confirmation of these views, to the comparison of the survivals of the British tribal fire cult with the system belonging to the early Aryan tribes elsewhere than in Britain.

The points of analogy are numerous and important enough to establish the intimate connection between the British and non-British evidence. But in one very important particular, just where it might be expected perhaps that the analogy of the modern survival to the early Aryan survival would not obtain, the conclusions drawn are very considerably strengthened. If the house-fire was in itself continuously kept up as a sacred duty, how is it that the time arrives for it to be put out and relighted from the tribal fire? Is this indeed a primitive characteristic, or is it a form of decay into which the survival has fallen? This is an important question, because if it has to be answered in the latter direction the answer would tell against the general evidence of which it is a part; but if it can be answered in the first sense, namely, that it is a primitive characteristic, it strengthens the position immeasurably.

The reasons for renewing the house-fire once a year at a solemn tribal festival are indeed not far to seek. Its employment in daily life, more particularly by its application to industrial purposes, made fire unhallowed according to the notions of the ancient Iranians; and hence it had to be purified from time to time, and to be brought back to the 'lawful place,' the holy fire altar of the community, from whence a fresh brand was obtained wherewith to revive the fire of the home hearth.[1] This explanation is, in fact, drawn from the early Avesta religion, and it not only accounts for the fire cult belonging to that religion, but also for customs among Greeks and Germans. There can be no harm, therefore, in using it to explain some of the peasant customs in Britain. It suggests that the annual or periodical extinction and renewal of the house-fire and the continuity of it from the time of its renewal to the time of its extinction are primary forms of survivals of the sacred hearth-fire in modern peasant custom. One other detail I must mention. It will be remembered that I laid special emphasis upon the fact that animals and human beings being made to 'pass through fire' did not tell for evidence of sacrifice, but for evidence of contact with some sacred element in the fire. This, too, is confirmed by the tribal fire cult of the Iranians: 'From the smoke and the flame of fire it was believed that the will of the deity could be recognised. His crackling flame was the means whereby he spoke to men.'[2]

I shall not elaborate further on this occasion the parallels between the fire customs of Britain, which I have here classified and analysed, and the fire customs of the primitive Aryan tribes. But I will refer to Mr. J. G. Frazer's admirable paper on 'The Prytaneum, the Temple of Vesta, the Vestals, Perpetual Fires,' in the 'Journal of Philology,' vol. xiv. pp. 145–172, as the parallel evidence in Greek belief—evidence so marshalled and arranged as to make it nearly unnecessary to attempt an exhaustive comparison, especially on an occasion like the present, when detail is not so needed as general principles. Suffice it to say, then, that the scattered remnants of fire customs which appear in our folklore can be restored by the comparative method, only possible when we have duly classified and analysed the customs, as a part of the early tribal system of organisation—a system, be it remembered, which governed every detail of early life, political, religious, and social, and which has left its marks on the map of Britain and on the early constitutional history of our people. The importance of this conclusion to folklore is that it enables us to proceed from the identification of tribal custom and belief to the identification of tribes: from the identification of tribes to the identification of races; and the importance of it to history is that it gives to historical data a large body of evidence not otherwise obtainable.

[1] Geiger, *Civilisation of the Eastern Iranians*, i. 78.
[2] *Ibid.* i. 75.

6. *The Tribal System from the Evidence of Early Records.*

The importance of studying the details of the tribal organisation in the early development of Aryan-speaking peoples has only been tardily recognised by historians. The material for it is not in fact to be found in the records, and it is only the recent comparative study of institutions which has revealed the tribal organisation as the basis of the early economic and social condition, and has enabled the student of records to understand passages that once passed for corrupted or obsolete texts not to be understood easily by modern commentators. From early records the tribe is seen very dimly; from the comparative study of legal institutions it is seen more clearly in so far as its own construction and position are concerned, less clearly when attempted to be identified in any particular country of Europe whose history has flowed on into the existing civilisation. Probably in Britain these two conditions are exemplified more sharply than elsewhere, the one in the Celtic divisions of the country, the other in the Teutonic.

The Celtic tribe can be studied from the early MSS. of Scotland, Wales, and Ireland; and the fascination of Celtic studies generally has caused a considerable amount of very valuable research. The Teutonic tribe is less observable from the laws, the poems, and the charters which have come down from early English times; and research into this branch of our history has concerned itself more with the origins of existing institutions than with the relics of lost institutions. It is taken for granted that some sort of tribal system existed; but what has become of it, and how it has stamped itself upon the history of the people, have never been shown.

The records have been studied through a long line of eminent scholars, of which the names of Stubbs, Freeman, Kemble, Elton, Skene, Maine, and Seebohm, stand out conspicuously. Bishop Stubbs contents himself with a masterly sketch in brief of the arrival of the first tribes of Englishmen, stating it as the starting-point of his investigations that 'the invaders come in families and kindreds and in the full organisation of their tribes . . . the tribe was as complete when it had removed to Kent as when it stayed in Jutland: the magistrate was the ruler of the tribe, not of the soil; the divisions were those of the folk and the host, not of the land; the laws were the usages of the nation, not of the territory.'[1] Clearly as this is put, it does not entirely shake off the influence of Kemble and of Freeman, neither of whom quite got clear of the terminology of a territorial constitution. Mr. Elton breaks new ground and deals with some of the anthropological evidence which was ignored by his predecessors; but the evidence of the tribe is lost in his accumulations of the fragments of primitive custom and belief. Mr. Skene deals rather with the tribes themselves than with the tribal organisation under which they lived. And thus it is only from Sir Henry Maine and Mr. Seebohm that the tribal life of the British peoples receives any light; the former deals with it from the juridical side, and the latter from the economical. It is therefore obvious that the history of the tribal constitution is not exhausted by these authorities; and Mr. Seebohm very grudgingly allows that folklore may be the means of restoring some of the lost evidence of the tribal system which is not supplied from the records.[2]

[1] Stubbs's *Constitutional History*, i. 64.
[2] Seebohm, *Tribal System of Wales*, p. 86.

The tribe as known by the records is :—

1. A group of kindred.
2. The kindred is formed by blood-tie primarily, with powers of assuming a blood-tie by ceremonial forms.
3. The blood-tie is reckoned by fatherhood, with power to reckon by motherhood by ceremonial forms.
4. The tribal group is divided into clan-groups by the break-up of kinship ties at the seventh generation.
5. The centre of the tribal group as of the clan-group is the sacred hearth-fire.
6. The sacredness of the tribal blood is the ruling force which governs the relationship of tribesmen to each other.
7. Tribal economics provide for the maintenance of every tribesman as an inalienable right.
8. Sonship is the essential factor of the tribal marriage system.

The tribe as known to traditional custom and belief contains the germs of all this and something more, namely, the cement which bound tribesmen together and formed them into an inseparable group—the cement of a tribal religion which had its seat in the fire of the tribe and the clan.

7. *Conclusion.*

I have stated above that, after the work of classification and comparison is completed for any one custom, there are further conditions before the first results of comparison can be properly and finally accepted. One of these conditions imposes the necessity for proving that the fire customs which have by the application of the comparative method been identified with the fire customs of the early tribal system of Aryan peoples shall, upon examination, be found to be associated with other customs which, upon classification and comparison, can be identified with the Aryan inhabitants of these islands. This work is, of course, a matter of time and further research ; and we can only accept the conclusion I have drawn in this report as preliminary to the final results whenever they be obtained. In the meantime, justification for this conclusion is derived from the evidence of the records upon the tribal system—evidence which is complementary to that derived from traditional custom. I have, however, also prepared a diagram to show how this part of the investigation may be most readily proved. I first of all mark on a map of Britain the places where the fire customs obtain. I then join these places together by a straight line, and, withdrawing from this result all reference to the map which formed the basis of it, a geometrical figure of a certain shape in outline and a certain shape in internal detail is obtained. This figure is of great importance. We may call it, for practical use, 'the ethnological test-figure.' Upon working out other groups of customs the process would be to see how far the same figure is reproduced, and how far one figure of a series differs from other figures, whether in simply being incomplete or whether in radical form. I have not been able, in the time at my disposal, to bring forward a test case, that is, another custom of Aryan origin to equate with the fire custom, but from some provisional studies I am satisfied that the test-figure produced by the fire customs will be produced by other customs similarly dealt with. In the meantime there is the important question to ask—Are there customs which will not produce the test-figure? For the purpose of answering this I have compared roughly the important group of customs relating to water-worship.

Now I have stated in my 'Ethnology in Folklore' reasons for considering water-worship customs to be non-Aryan in origin, to belong, therefore, to the pre-Celtic people of these islands; and it is remarkable that the 'ethnological test-figure' produced from the water customs differs radically from that produced by the fire customs. I suggest, therefore, that in this interesting fact we have provisionally a proof of the value of this method of studying the ethnological basis of folklore.

The Lake Village at Glastonbury.—Third Report of the Committee, consisting of Dr. R. MUNRO (*Chairman*), Professor W. BOYD DAWKINS, Sir JOHN EVANS, General PITT-RIVERS, Mr. A. J. EVANS, *and* Mr. A. BULLEID (*Secretary*). (*Drawn up by the Secretary.*)

THE fifth season of the Exploration of the Lake or Marsh Village near Glastonbury began in May last, and the investigations have already yielded results of more than ordinary interest and importance. The recent dry weather has been most favourable for deep digging, the ground being examined in many places to the depth of nine or ten feet; a depth not admissible in former seasons owing to flooding by rain, or the rapid percolation of water from the surrounding peat. Since presenting this report at Ipswich the following work has been carried out. The remaining 500 feet of the palisading bordering the village has been traced, and the peat examined immediately contiguous and outside it for the width of from 10 to 40 feet. The circumference of the village has now been completely explored, and an accurate and detailed plan of it made. Besides this eight more dwelling mounds have been examined, together with the spaces of ground between and around them. The portions of the border palisading remaining over from last year and exposed this season were situate at the north and south sides of the settlement, and at both places it was found to be stronger and in a better state of preservation than elsewhere. In many places, but more especially at the south part of the border, the horizontal pieces of timber and trunks of trees, although much displaced and decayed, still formed a platform 3 feet thick; and the vertical palisading posts bordering this frequently formed a line three or four abreast.

Near the north edge of the village some large mortised oak beams were found *in situ*, and fixed by their original piles. Other beams of the same kind were discovered among the timber forming the substructure of an adjacent dwelling mound, evidently not in their original position. As a rule, where the palisading was strongest, the peat outside contained a larger amount of débris, and the signs of occupation were dug up at a greater depth than elsewhere.

With regard to the construction of the dwellings, an important discovery of wattle work was made early in the season. Among the wood and débris underlying the clay of a dwelling mound three hurdles were uncovered; the more complete one measured 6 feet 3 inches high by 10 feet 6 inches wide, with an average space between the upright posts of 5 inches. In close proximity to the hurdles was a beam of oak, having small mortise holes arranged along one side parallel to the edge; the distance between the holes exactly tallied with the spaces between the hurdle posts. From the way the under surface of the beam was cut and notched, it was evident that it had been placed at right angles to a similar piece of timber. We have here distinct proof that some of the dwellings were not angular, and that the walls were about 6 feet in height.

With reference to the eight dwelling mounds examined, one especially needs mentioning, although all have yielded their various points of interest. The mound in question was one of the largest in the field, and was found to be composed of nine layers of clay or floors, with a total thickness of 6 feet, the substructure being 3 feet in depth. At or near the centre seven superimposed hearths were unearthed; the two uppermost were constructed of stone, the rest being composed either of gravel or baked clay. The fifth hearth made of clay was the most remarkable one of the series, its shape was, roughly speaking, a square of 5 feet 3 inches with the corners rounded; it was raised 4 inches above the surrounding floor level, and its edges bevelled off; the surface was smooth and flat and covered with an impressed decoration of circles measuring 5½ inches in diameter, arranged in rows parallel to the edges. In the clay floor apparently corresponding to hearth No. 4, a basin shaped hollow was found measuring 2 feet in diameter and 9 inches deep, with the sides and base baked hard; with the exception of a little fire ash, it contained nothing of importance. Near the edge of No. 3 hearth a circular hole was discovered 6 inches in diameter and about 9 inches deep, filled with charcoal and fire ash. There was also a somewhat similar hole near hearth No. 5, but of larger size. The dwelling corresponding to the lowest floor had evidently been destroyed with fire, as shown by the quantity of baked clay bearing wattle, timber, and crevice marks, and also by the pieces of charred timber. Passing now to the smaller objects, the following may be mentioned.

Wood.—The handle of a quern.

Two blocks, probably the sockets for the pivots of a door.

Several lathe-turned wheel spokes and part of an axle box similar in shape to the piece discovered and described last year.

A large ladle quite complete, and parts of two smaller ones.

Portions of two small tubs cut from the solid, one being decorated with two bands of incised herring-bone pattern.

Part of a large basin-shaped bowl cut from the solid, with a grooved rim intended for holding the projecting moulding of a cover; the outer surface of the fragment is ornamented with an incised circular design.

Amongst other things made of wood may be noticed fragments of several stave-made tubs or cups, pieces of awl and spade handles, a mallet, part of a basket, and fragments of a thin piece of wood fifteen inches long by three inches wide, perforated with small holes at the ends and along one ridge, and ornamented on one side with a triangular design.

Pottery.—As in former seasons quantities of both wheel- and hand-made pottery have been met with, and include six vessels quite perfect; many others, although found in fragments, will be complete when reconstructed. Several new designs of ornamented pottery have been met with this season.

Flint.—Some well-made scrapers and a few cores and flakes.

Stone.—Spindle whorls, whetstones, and three circular and saddle-shaped querns.

Bronze.—Six spiral finger and other rings, the upper flattened surface of one being ornamented with three groups of concentric circles. An awl-shaped implement five inches long

Portions of several fibulæ, a few inches of a cup or tub hoop, several rivet-heads, and other fragments.

Iron.—Amongst the implements of iron are :

Two reaping-hooks.

Two adzes.

A saw.

A gouge.

And a billhook, all of which were found intact with wooden handles.

Part of a second billhook.

A stay or loop.

A roughly semicircular-shaped implement fifteen inches long, pointed out and bent at one end for fixing in a handle.

A bar of iron eighteen inches long.

A small ring, and many nondescript fragments.

Lead.—A spindle whorl, a fishing-net weight or plummet.

Kimeridge Shale.—Fragments of several armlets and rings.

Glass.—Three complete blue beads.

Horn.—More than thirty pieces of cut horn, including ferrules haftings, handles, cheek pieces, and eight long-handled weaving combs.

Worked Bone.—A number of implements, among them being needles, gouges, polishing bones, and twenty or more perforated metacarpal sheep bones.

Baked Clay other than Pottery.—Portions of several large triangular blocks or loom weights, spindle whorls, sling pellets, and part of a small three-cornered crucible.

Human Bones.—The following list of human remains have been found at various parts of the excavation this season :

1. A complete adult skull, badly cut in the occipital region.
2. Three more or less complete skeletons of very young children ; one was found on the floor of a dwelling two feet from the hearth.
3. An adult skull in fragments, and portions of the lower extremities belonging to the same body.
4. Several fragments from other bodies—one of these, a clavicle, bears distinct traces of having been gnawed by a dog.

Bones of animals have been as abundant as formerly. Geological and botanical specimens have been collected and carefully preserved for examination ; among the latter is a sack full of sloe, wild plum stones, and other seeds, found together within the space of a few feet among the débris outside the palisading.

Shallow test borings have been made through the peat at various parts of the village, and in the surrounding fields. The greatest depth of peat met with has been sixteen feet ; underlying it is a layer of soft blue clay more than six feet thick. The borings are being extended at intervals of 100 yards in a line north and south of the village between the raised lands of Glastonbury and Godney. Of the original sixty-five dwelling mounds there still remain twenty-six unopened ; these, together with the spaces of ground around them and near the centre of the village, representing more than one-third of the total area of the settlement, await future examination. Some of the more recent discoveries are being exhibited during the meeting of the Association.

Linguistic and Anthropological Characteristics of the North Dravidian and Kolarian Races.—the Urânws.—Report of the Committee, consisting of Mr. E. Sidney Hartland (*Chairman*), Mr. Hugh Raynbird, jun. (*Secretary*), Professor A. C. Haddon, *and* Mr. J. L. Myres.

This Committee was appointed to report upon the materials accumulated by Mr. Hugh Raynbird, jun., during several years' residence among the Urâ*nws* and other non-Aryan races of Chu*t*ia Nāgpūr. The languages of these races are almost unknown to philology. Dr. Oscar Flex has published an elementary introduction to Urâ*nw*, and there are grammars and vocabularies of an elementary character in some of the Kolârian dialects, but these languages have not yet been treated scientifically or fully. Mr. Raynbird has collected, including variants, more than 800 folk-tales, 4,000 folk-songs, many riddles, proverbs, and phrases; has compiled vocabularies, and begun a systematic Urâ*nw* grammar. His materials are already partially, and will, it is hoped, be eventually wholly, deposited with the Royal Asiatic Society, where they will be accessible to specialists. Mr. Raynbird is now in England, but is prevented by his circumstances from devoting his time to the elaboration of his materials. He hopes eventually to be enabled to return to India to resume his investigations.

The Committee have conferred with Mr. Raynbird, have examined some part of his materials, and have assisted him to prepare some part of them for publication; a representative selection from them is appended, consisting of three tales which illustrate points in the cosmology, historical traditions and customs of the Urâ*nws*, with Mr. Raynbird's explanatory notes.

As the work of translation, transcription, and indexing so large a mass of quite new and unfamiliar data is necessarily slow and laborious, the Committee ask to be re-appointed, and hope at the end of the coming year to be in a position to recommend the Association to take effective action in the matter.

APPENDIX.

I. *The Sun and the Moon.*

This tale was first of all told to me in English by a Christian Uraon named Elias Bochcho whilst we were out for a walk together. As soon as we got home he wrote it down for me in English. I then asked him if he could write it down in the Uraon language, and he did so.

He was at that time a schoolmaster in the S.P.G. Mission school at Ranchi. He could speak and write High Hindi and the dialect of Eastern Hindi spoken in Chutia Nagpur. He was well acquainted with both the Roman and Devanagri characters. I taught him Church history, Euclid, and Algebra, and he was the most intelligent specimen of his race I have met with.

He said that the tale was told him by his mother. She belonged to a small village named Chipra, which lies six miles to the west of Ranchi, the chief town in the wild and hilly district of Chutia Nāgpur. This is the most western part of Bengal, and borders on the Central Provinces of India. This old woman was entirely uneducated. She only understood the Uraon language and perhaps a little rustic Hindi. She had very little idea of civilisation.

There are internal evidences of matter, idioms, and words in the tale itself which seem to me to stamp it as a genuine Uraon folk tale and not made up by the Christian narrator or borrowed from literary or Aryan sources.

1. Once upon a time the Moon covered up her children with a large leaf basket, and, having boiled sweet potatoes, sat down to eat them.

2. At that time the Sun came to her and said: 'Sister, what are you eating? Give me also a little.'

3. The Moon gave.

4. The Sun tasted it, and asked her: 'Sister, what is this?'

5. The Moon said: 'I have boiled my children from hunger, and I am eating them.'

6. The Sun slunk away to his home, and boiled his children in a very large pot and ate them.

7. Then the Moon uncovered her children.

8. The Sun saw this, and he seized a bow to kill the Moon with, and chased her.

9. The Moon went and hid in a banyan tree.

10. The Sun came up and hit the Moon, and took out a small piece.

11. The Ku*nr*'qars (that is, the Urâ*nw*s) say that the same banyan tree is seen in the Moon to this day.

12. Again, they say that the Sun cut the Moon in two; therefore the Moon is sometimes small and sometimes large.

13. They say there were also many children of the Sun, but if they had remained all men would have died from the heat.

III. *The Tale of Dadgo Village.*

This tale was first of all written down for me as an exercise in English by one of my pupils, the Rev. Markas Manjan, a native Uraon pastor in the S.P.G. Mission in Chutia Nāgpur. He came originally from the village of Dādgo. It is a remote village about twenty miles south-west of Ranchi. A few miles south of it we begin to meet with the Uriyas, the Aryan people who inhabit Orissa, and who speak a language closely allied to Bengali. Markas Manjan wrote the tale first in English, but long afterwards I got the Uraon version from him. The two versions agree in all important particulars.

Though Markas Manjan could write in the Roman and Deva Nagri characters, and was a fair High Hindu and English scholar, I very much doubt if he had ever read any tales, as his education had been for the most part in Biblical and theological literature.

This tale is important, as containing much *undesigned* evidence about the habits and customs of the Uraons. *E.g.* :—

1. Division of lands.
2. Husking of rice. (Manner and locality.)
3 Two kinds of rice fields. (Upland and lowland.)

4. Human sacrifice. (Compare the Meriah of the Khands of Central India.)

5. Drinking of rice beer; &c.

1. Dadgo is a small village eighteen miles south-west of Ranchi.[1]

2. Formerly it was a large village, but now it has been divided into three villages, viz. Dadgo, Balandu, and Nawa*t*olî.

3. At first it was divided in two villages, viz. Dadgo and Nawa*t*olî, and the latter was quite separate from Dadgo, but the other two were reckoned as one.

4. The following tale is told about the separation of Dadgo and Balandu.

5. Dadgo itself was a big village, and contained many rich people.

6. In such villages there are many young women, and they make their Kâ*nr*î (*i.e.* the place where the rice is husked) outside the village.

7. According to this custom the young women here also had made their Kâ*nr*î outside the village, just where two tamarind trees now stand south of Markas Manjan's (the narrator's) house.

8. Now it happened that a man called by the U*rânw*s On*d*ok, and by the Sadâns (low caste Hindus) Ota*n*ga (*i.e.* a man who offers human sacrifice to his god), came by with a boy in his bag, whom he was carrying to sacrifice.

9. Hearing the noise made by the people he thought they were tipsy.

10. He hung the bag on a tamarind tree, and going into a house he asked for rice-beer.

11. When he had taken rice-beer, then he became tipsy.

12. Meanwhile the young women of the village came to the tamarind tree to separate the husks from the rice.

13. They saw the bag and heard the child cry inside the bag.

14. They took away the child, and in place of it they put some thorny bushes and lumps of earth.

15. Next morning the man came to the tree and took the bag on his back and went away on his journey.

16. And it is said that when the thorns pricked him, he said, 'Be quiet, little child, now we are near your mother;' for the man did not know what the young women of the village had done.

17. That little child was brought up by the chief men of the village, and when he became a young man his marriage took place.

18. After this the chief men of the village consulted together among themselves about him, and settled that some portion of the land, apart from their children, should be given to him, because he was their adopted child.

19. It is said that in those days there was more rain in Chu*t*ia Nāgpūr than nowadays, and therefore the land which is called 'chaurâ,' *i.e.* the high land, was more fertile than the 'kudar,' *i.e.* the lowland.

20. Now when the chief men of the village met to fix what part of the village they should give to him, they chose that part where the soil was least fertile, and thus they gave their adopted son the spot on which the village of Balandu now stands.

21. They gave half of the lands to him.

22. This is now more fertile than the other part.

[1] Ranchi is the chief town of the province of Chu*t*ia Nāgpūr.

23. So Balandu is now a bigger village than Dadgo, because it has more fertile land than Dadgo.

24. And thus the inhabitants of Dadgo are very poor.

25. It is now a very small village, and contains only twenty or thirty houses.

26. It now belongs to Jagnâth Khutiya, who is one of the heathen priests of Purî.

27. He got it from the king of Chutia Nagpur.

28. The king presented it to him when he was on pilgrimage to Purî.

XII. *Tale of a Mouse.*

This tale was told by our ayah or nurse, Elisabā, wife of Budhu. She came originally from the village of Kachābārī, on the south-west side of Ranchi. She could neither read nor write, and understood very little High Hindi, but could talk fluently in Eastern Hindi.

This tale was written down for me by my wife, Āsā Lakṛā ('Hope Tiger'), a Christian Urâon, who could at that time read and write in the Devā-nāgri character only. She has since come to England and learnt to read and write English. She assists me in these studies.

My wife was told this tale also by Susannah, the wife of Philip the carpenter. Susannah is also from the village of Kachābārī.

1. A mouse had a field.

2. He ploughed it and sowed hemp in it.

3. In course of time the hemp grew up and blossomed.

4. The mouse was always watching it.

5. One day, what happened? Some young women, who were picking herbs,[1] went into that hemp field, and were engaged picking the hemp flowers.

6. At once the mouse cried out, 'Who is picking my flowers?'

7. The young women heard him crying out and ran away.

8. Whilst they were running away, the comb of one of them dropped in the field.

9. As the mouse was going along he found the comb and took it home.

10. When the young women had gone a little distance, they saw that one of them had lost her comb.

11. Then she, whose comb was lost, said to the others, 'Come along, we will go and look for my comb.'

12. Then they all went to look for the comb, and wandered about in the hemp-field looking for it, but could not find it.

13. The mouse soon came forward from somewhere or other, and said, 'What do you want in my field?'

14. They said, 'We are looking for a comb; give it to us if you have found it.'

15. He said, 'Whose comb is lost? If she will live with me then I will give it, otherwise I will not.'

16. She said, 'I will go and live with you. Give me my comb.'

17. Then he gave up the comb, and took her away to his home.

18. When they arrived she would not enter his house.

19. Then the mouse said:

[1] By 'herbs' would be meant any kind of greens or leaves boiled to eat as a relish with rice.

(Song) 'Will you enter my house or not?
Will you remain crying?
Give me my hemp flower.
Go to your parent's home.'

20. Then she entered the house, but did not want to cook the food.
21. Then he said:

(Song) 'Will you cook or not?
Will you remain standing?
Give me my hemp flower.
Go to your parent's home.'

22. Then she cooked the food.
23. After eating and drinking, he told her to spread a mat.

(Song) 'Will you spread the mat or not?
Will you remain standing?
Give me my hemp flower.
Go to your parent's home.'

24. Afterwards she spread the mat, and they lay down to sleep.
25. Early the next morning they both went to her parent's home.
26. The mouse was darting about saluting every one.
27. Whilst he was engaged saluting he fell into some hot rice-broth, and after struggling a time he died.

The possible Infectivity of the Oyster, and upon the Green Disease in Oysters. By Professor RUBERT W. BOYCE, *M.B., M.R.C.S., and* Professor W. A. HERDMAN, *D.Sc., F.R.S., University College, Liverpool; being the First Report of the Committee, consisting of* Professor W. A. HERDMAN (*Chairman*), Professor R. BOYCE (*Secretary*), Mr. G. C. BOURNE, *and* Professor C. S. SHERRINGTON, *appointed to report on the Elucidation of the Life Conditions of the Oyster under Normal and Abnormal Environment, including in the latter the effect of sewage matter and pathogenic organisms.*

AT the last meeting of the British Association, Ipswich, 1895, we brought forward, as a paper 'On Oysters and Typhoid' laid before Section D, some results based upon the artificial feeding and cultivation of oysters in sewage-contaminated sea-water. We concluded that the laying down of oysters in localities where there was a constant change of water, by tidal current or otherwise, was beneficial to the health of the oyster, and we surmised that by methods similar to those employed in the *bassins de dégorgement* of the French ostreiculturist, where the oysters are carefully subjected to a natural process of cleaning, oysters previously contaminated with sewage could be freed of pathogenic organisms or their products without spoiling the oyster.

Nature of Present Report.—The present report, which is still incomplete, deals almost exclusively with the bacteriology of the oyster and the behaviour of the *Bacillus typhosus* in sea-water and in the oyster. The subject of the green coloration in oysters will be treated more fully in a subsequent report. The questions investigated are the following:—

I. The identification and differentiation of the *Bacillus typhosus* and *B. coli communis*.

II. The action of sea-water upon the growth of the *B. typhosus.*

III. The bacteria present in the alimentary canal of the oyster.

IV. The infection of the oyster with the *B. typhosus* and its removal by washing.

V. The green coloration and green disease in oysters.

I.—*The Identification and Differentiation of the* Bacillus typhosus *and* B. coli communis.

We have systematically tested the majority of the chief differential reactions upon samples of *Bacillus typhosus* and *B. coli* obtained from numerous sources, and have in all cases found unmistakable differences between the two bacilli.

Table showing Differences of Reaction.

Source	Fermentation. Glucose Gelatine	Indol Reaction	Coagulation	Potassium Iodide Potato Gelatine
	A. *B. typhosus.*			
1. Institut Pasteur .	none	none	none	very small growth
2. From spleen of typhoid patient .	,,	,,	,,	,,
3. Prof. Delépine . .	,,	,,	,,	,,
4. Prof. Wright (Netley).	,,	slight trace	clot slowly formed	,,
5. Dr. Sims Woodhead	,,	none	none	,,
6. Dr. Sims Woodhead	,,	,,	,,	,,
7. Dr. Sims Woodhead	,,	,,	,,	,,
8. Dr. Kanthack	,,	,,	,,	,,
9. Dr. Kanthack	,,	,,	,,	,,
10. Institute of Preventive Medicine .	,,	,,	,,	,,
	B. *B. coli.*			
1. Institut Pasteur .	well marked	marked pink	marked	growth abundant
2. Prof. Delépine . .	,,	slight pink	,,	,,
3. Prof. Wright . .	,,	pink	,,	,,
4. Dr. Sims Woodhead	,,	slight pink	,,	,,
5. Dr. Sims Woodhead	,,	marked pink	,,	,,
6. Dr. Sims Woodhead	,,	pink	,,	,,
7. Dr. Sims Woodhead	,,	,,	,,	,,
8. Dr. Sims Woodhead	,,	,,	,,	,,
9. Dr. Sims Woodhead	,,	,,	,,	,,
10. Dr. Sims Woodhead	,,	,,	,,	,,
11. Dr. Sims Woodhead	,,	,,	,,	,,
12. Dr. Kanthack	,,	slight pink	,,	,,
13. Dr. Kanthack	,,	absent	,,	,,
14. Institute of Preventive Medicine .	,,	,,	,,	,,

Summary of Constancy or Variability of Reactions.

A. For *B. typhosus* :—1. *Fermentation test.* Constant (Burri and Stutzer have shown gas formation). 2. *Indol reaction.* Slight indication in one case. 3. *Milk coagulation.* Slight clot in one case. 4. *Potassic iodide potato gelatine.* Characteristic invariably ; very little use as a separating medium. 5. *Potatoes.* Constant with usual precautions. 6. *Reaction in gelatine.* Marked differences of rate of diffusion.

B. For *B. coli*:—1. *Fermentation.* Rate of gas formation variable, otherwise constant. 2. *Indol reaction.* Reaction not constant. 3. *Milk coagulation.* Rate variable. Constant with us, with others not constant. 4. *Potassic iodide potato gelatine.* Abundant growth. 5. *Behaviour in gelatine.* Diffusion very variable; in many cases less rapid than *B. typhosus.* 6. *Motility.* Very variable.

II.—*The Action of Sea-water upon the Growth of the* B. typhosus.

EXPERIMENT I.

	No. of Bacilli
At time of mixing	29,250
After 21 hours	20,475
„ 45 „	9,945
„ 71 „	9,360
„ 95 „	5,850
„ 271 „	260
„ 340 „	11

EXPERIMENT II.

	No. of Bacilli
At time of mixing	1,300
After 21 hours	1,105
„ 45 „	780
„ 71 „	650
„ 95 „	325
„ 271 „	2
„ 340 „	0

EXPERIMENT III.

	No. of Bacilli
At time of mixing	22,750
After 5 hours	17,550
„ 23 „	11,700
„ 48 „	3,250
„ 72 „	3,260
„ 247 „	455
„ 316 „	325

EXPERIMENT IV.

	No. of Bacilli
At time of mixing	130
After 6 hours	41
„ 23 „	31
„ 48 „	38
„ 72 „	negative
„ 247 „	1
„ 316 „	0

EXPERIMENT V.

	No. of Bacilli
At time of mixing	31,200
After 172 hours	9,360
„ 244 „	325

EXPERIMENT VI.

	No. of Bacilli
At time of mixing	325
After 172 hours	2

EXPERIMENT VII.

	No. of Bacilli
At time of mixing	325
After 504 hours (water kept at 8° C. to 10° C.)	79

EXPERIMENT VIII.

	No. of Bacilli
At time of mixing	325
After 504 hours	0

These results are fairly uniform. When a large number of bacilli are added to the water their presence may be demonstrated longer than in cases where smaller quantities are used. Fourteen days would appear to be the average duration in sea-water incubated at 35° C., whilst kept in the cold their presence was demonstrated on the twenty-first day. There appears to be no initial or subsequent multiplication of the bacilli. Between forty and seventy hours after infection there is less decrease than at other periods; but there is no evidence of increase in numbers of the bacilli when grown in sea-water either when incubated or at ordinary temperatures. We do not think, however, that these experiments can be taken without reserve as an indication of what might take place in nature.

III.—*The Bacteria present in the Alimentary Canal of the Oyster.*

This research has proved of very considerable utility in guarding us against errors in our subsequent infection experiments, and are of further interest in demonstrating the large number of cases in which the colon bacillus was normally present.

Oysters	No. of Colonies		Bacillus isolated giving following Reactions:					
	Agar	Salt-water Gelatine	Fermentation	Indol	Coagulation	KI Gelatine	Motility	—
A	0	not made						
B	5							
C	0							*B. coli* not looked for
D	0							
E	1							
F	6							
Shop 2	108							
	1,040		active	marked	marked	marked	—	decolorised
	390							
„ 4	455							
„ 5	2							
	2		active	marked	marked	marked	very motile	decolorised
	102							
	350							
	12							
	1,170							
	21							
	195							
„ 6	5							
	20							
„ 7	3							
	2							
„ 8	3							
	70		active	none	marked	marked	motile	decolorised
„ 9	9		active	none	marked	marked	—	decolorised
	5							
	65							
	260							
„ 10	195							
	520							
„ 11	65		active	marked	marked	marked	motile	decolorised
	70							
„ 12	650							
	260		active	none	marked	marked	motile	decolorised
„ 13	150		active	marked	marked	marked	motile	decolorised
	195							
„ 14	6		none	none	marked	marked	motile	decolorised
	2							
„ 15	100		active	marked	marked	marked	motile	decolorised
	5							
„ 16	20		active	marked	marked	marked	motile	decolorised
	70							
„ 18	25	3,025	active	marked	marked	marked	motile	decolorised
„ 19	1	2,330						
„ 20	265	13,000						
„ 21	100	1,755	active	marked	marked	marked	motile	decolorised
„ 22	35	2,330	active	marked	marked	marked	motile	decolorised
„ 23	15	3,025	active	marked	marked	marked	motile	decolorised
„ 24	40	6,500						
„ 25	5	13,000						
„ 26	2	8,775						
„ 29	325	17,550	active	marked	marked	marked	motile	decolorised
„ 30	50	20,475						
„ 31	65	2,925	active	marked	marked	marked	motile	decolorised

Methods.—In analysing the contents of the stomach we have in all cases cauterised the mantle over the region of the stomach, and have inserted a sterilised fine glass pipette and withdrawn a quantity of fluid varying from $\frac{1}{20}$ to $\frac{1}{40}$ of a cubic centimetre. The contents of the tube have then been mixed with liquefied agar, ordinary gelatine, or sea-water gelatine, and Petri dishes made. The agar dishes have been incubated at

37° C., the gelatine at 21° C. to 24° C. As the figures will subsequently demonstrate, there is an enormous difference between the number of organisms appearing upon the agar incubated at the high temperature and the simple or sea-water gelatine incubated at the low temperature. This heat method of separation proved quite equal to, if not better than, the carbolic acid or potassic iodide methods.

Experiments.—In the first six cases examined precautions were taken to ensure that the oysters were especially fresh ; in the other cases they were obtained haphazard from the various shops (see table opposite).

The number of organisms taken from the stomach of the oyster which could survive a temperature of 37° C. were comparatively small. In a very large proportion of cases ($\frac{1}{3}$ to $\frac{1}{2}$) the organism present was *B. coli* in overwhelming numbers, and next in frequency were species of *Proteus.* It will be seen that in one instance at least the organism approached in its reactions the typhoid type. We believe that on account of the presence of this coli group the identification of the *B. typhosus* would be difficult in nature. We cannot at present state whether the coli group found in these experiments indicates sewage contamination, or whether we are dealing with a group common in the intestine of the oyster and in salt-water. The matter is being investigated by us. But as bearing upon the next question we have found that the perfectly fresh oyster contains far fewer bacteria, and that the percentage of *B. coli* is much less.

IV.—*The Infection of the Oyster with the* B. typhosus *and its Removal by Washing.*

The following table shows that the typhoid bacillus does not increase in the body or in the tissues of the oyster. The figures would rather indicate, comparing the large number of bacilli present in the water with those found in the alimentary tract, that the bacilli perish in the intestine.

Table showing Number of Organisms present in Stomach after infecting Water.

Oyster	Inoculated	Examined	No. of Colonies	Organisms present in Oyster	Number present in the Sea-water
			Agar		
1	Aug. 25	Aug. 26	1,700	almost entirely typhoid	water in the same case 585,000 per c.c.
2	"	"	"	"	
3	"	Aug. 27	7,020	"	water in the same case 468,000 per c.c.
4	"	Aug. 28	7,000	"	water in the same case 40,950 on agar, 5,200 gelatine
5	Aug. 26	Aug. 29	455	"	
6	Aug. 28	Aug. 30	195	"	water in the same case 2,047,500 per c.c.
7	"	Sept. 4	390	"	
8	Aug. 31	"	325	"	
9	"	Sept. 10	455	"	

In the following series of experiments infected oysters were taken, the duplicates of which, as seen in the preceding table, contained comparatively large numbers of the *B. typhosus*, and were subjected to a running stream of pure clean sea-water. The result is definite and uniform; there is a great diminution or total disappearance of the *B. typhosus* in from one to seven days.

Oyster	Inoculated	Washed	Examined	No. of Colonies Agar	Kind of Organisms present
1	Aug. 25	Aug. 26	Aug. 30	80	2 colonies *B. typhosus*
2	"	Aug. 28	"	23	*B. typhosus* present
3	Aug. 26	"	"	44	" "
4	"	Aug. 29	"	40	" "
5	Aug. 27	"	"	5	" "
6	"	"	Aug. 31	700	abundant *B. typhosus*
7	Aug. 28	Aug. 30	"	55	*B. typhosus* present
8	Aug. 26	Aug. 28	Sept. 3	4	? *B. typhosus*
9	Aug. 27	Aug. 29	"	10	no *B. typhosus* found
10	"	"	"	8	3 colonies of *B. typhosus*
11	Aug. 28	Aug. 30	Sept. 4	4	1 colony of *B. typhosus*
12	"	Sept. 3	"	200	majority *B. typhosus*
13	Aug. 31	?	"	4	
14	Aug. 28	Sept. 3	Sept. 6	65	no *B. typhosus*, but *Proteus*
15	Aug. 31	"	"	5	? *B. typhosus*
16	"	Sept. 5	"	70	one half colonies *B. typhosus*
17	"	Sept. 3	Sept. 10	1	no *B. typhosus*
18	"	Sept. 5	Sept. 11	2	? *B. typhosus*

V.—*The Green Coloration and 'Green Disease' in Oysters.*

We have been investigating the well-known green coloration of certain healthy oysters grown at Marennes and other places on the west and north coasts of France, and in the river Roach in Essex. It has long been known that copper has nothing to do with this green colour, but an attempt has lately been made to show that it is due to the presence of iron in the mud which is taken up by cells in the gills, &c. At our request Dr. Kohn has made a chemical analysis of oysters from a number of localities for us, and his results (given in detail as a separate paper) show conclusively that, while there are minute quantities of both iron and copper in all oysters, the amount present bears no proportion to the degree of green coloration. There is not more iron in the gills and labial palps than in the rest of the body, and there is, on the whole, more iron in ordinary white or yellow American and Dutch oysters than in the green 'huitres de Marennes.'

We have made experiments in the feeding of oysters with various strengths of a number of saline solutions of iron and of copper salts, with the result that, although in some of the experiments the oysters lived healthily for weeks, and the shells and other exposed parts became strongly coloured—green, blue, brown, and yellow, according to the salt deposited—in no case did the soft tissues take in any staining until after death. There was no evidence that any iron had been taken up by the animal. The cause and meaning of the green coloration of the French cultivated oyster are still under investigation, and we hope to give a fuller account of it in our next report. We do not doubt that these oysters are in a thoroughly healthy condition, and their colour is not due to copper or iron.

There is, however, a pale greenness (quite different in appearance from the blue-green of the 'huitres de Marennes') which we have met with in some American oysters laid down in this country, and which we regard as a disease. It is characterised by a leucocytosis in which enormous numbers of leucocytes come out on the surface of the body, and especially on the mantle. The green patches visible to the eye correspond to accumulations of the leucocytes, which in mass have a green tint. These cells are granular and amœboid. The granules do not give any definite reaction with the aniline stains, and so far we have not made out their precise nature. Associated with the green disease we have found numerous exceedingly small flagellate organisms both in the blood and in the green patches, and observations so far lead us to believe that there is some relationship between the two. We have tried growing oysters under various unusual conditions, including the addition to the sea-water of fluids from alkali works, such as may enter our estuaries, in the hope of getting some clue to the cause of this green disease, but have so far failed to reproduce exactly in the laboratory the changes which apparently take place in nature. Our present opinion, however, is that oysters exhibiting this pale-green leucocytosis are in an unhealthy state, and we may add that we find the liver in these specimens is histologically in an abnormal, shrunken, and degenerate condition. Whether actually 'unfit for food' or not, they are at any rate in very 'poor' condition, and have lost the aroma and flavour of the normal healthy oyster.

For much assistance in connection with this research the authors acknowledge their indebtedness to Mr. Andrew Scott, Drs. Abram, Evans, and Balfour Stewart.

Physiological Applications of the Phonograph.—Report by the Committee, consisting of Professor JOHN G. MCKENDRICK (*Chairman*), Professor G. G. MURRAY, Mr. DAVID S. WINGATE, *and* Mr. JOHN S. MCKENDRICK, *on the Physiological Applications of the Phonograph, and on the Form of the Voice-curves made by the Instrument.*[1]

1. THE work of the Committee has, during the past year, been directed to improving the method by which the curves of the phonograph may be transcribed. The arrangement described in the 'Journal of Anatomy and Physiology' for July 1895 has been much improved in two respects: (1) by driving the phonograph at a slow rate by a small electric motor; and (2) by adapting the recording lever, now made of aluminium, to a new form of siphon recorder.[2] In this way beautiful curves may be obtained, amplified from 500 to 800 times, and on strips of telegraph

[1] See *Brit. Assoc. Report* for 1895, p. 454.

[2] The Committee are much indebted to Lord Kelvin for encouragement during the research. They also desire to express their obligations to Mr. Reid and to Mr. Keen, of James White and Co., for executing the mechanical devices employed.

paper moving at such a speed that the vibrations occurring in 0·5 second are spread over a distance of about 12 feet. The curves are thus greatly amplified, and the following facts may be demonstrated graphically:—(1) That many instruments have a curve-form so characteristic as to enable one by inspecting the curve to recognise the instrument. (2) That the curve-forms of sounds produced by instruments giving a pure tone are comparatively simple, while the curve-forms of instruments giving a mixed tone (with numerous partials) are more complicated. (3) That the curve forms of sounds produced by a band of music, or such a noise clang as that of a boiler-maker's shop, are very complicated. (4) That if the tone of an instrument predominates in the sound of a band, the characteristic curve-form may be seen, modified to some extent by the other instruments. (5) That the curve-forms indicating a gradation from a tone of one pitch to a tone of another pitch may be observed. (6) That when numerous sounds, varying in pitch, follow each other in rapid succession (as when a piece of music is quickly played), from ten to fifteen vibrations appear to be sufficient to enable the ear to appreciate the relative pitch of any one of the tones, or, in other words, pitch may be appreciated by vibrations lasting only a fraction of a second. This time cannot yet be definitely stated, as it has been found to vary from $\frac{1}{10}$th to $\frac{1}{50}$th of a second.[1]

2. The Committee has carefully studied *the mechanism of the recording point in the English form of the phonograph*, and they have constructed a model which makes the matter easily understood. The original tinfoil phonograph was so constructed that when the diaphragm was pressed inwards by the condensation of the air wave, the marker made a corresponding depression on the tinfoil, and when the diminution of pressure came on, corresponding to the rarefaction of the air wave, the marker passed away from the tinfoil. There were thus a series of marks the depth of each of which corresponded to the degree of pressure on the diaphragm. A hasty inspection of the more complicated apparatus in the English model might lead one to suppose that the action in it was of the same nature, but a careful scrutiny will show that this is not the case. By a large model made for the Committee it can be seen that, when pressure is made on the diaphragm, the effect is to cause the cutting edge of the recording gouge to be directed downwards. As the cutting edge of the gouge is directed against the wax cylinder, and is opposed to the rotation of the latter, it is evident that this change of the angle of the gouge to a downward direction will cause the gouge to cut a deeper groove into the wax cylinder. The depth of the groove, as determined by the angular movement, is therefore a measure of the pressure on the glass disk. It must be borne in mind that when no pressure is exerted on the glass disk the marker cuts a groove. When there is greater pressure, by the cutting edge being placed at a larger angle with the tangent of the curved surface of the cylinder, a deeper groove will be cut. On the other hand, when the cutting edge is placed at a smaller angle with the tangent of the curved surface of the cylinder a shallower groove will be ploughed on the surface of the wax cylinder. It follows that, if the sound acting on the wax cylinder of the phonograph be very intense, during the increase of pressure, the groove will be deep, and during the diminution

[1] A detailed account of the investigation will appear in the *Trans. of the Royal Soc. of Edin.*, 1896.

of pressure the groove will be shallow ; and so great may be the difference between the plus pressure of condensation and the minus pressure of rarefaction that during the latter the recording point may only skim the surface of the wax cylinder, without making any groove. This explains an anomaly in several of the photographs taken of portions of the surface of the wax cylinder. For example, a photograph of a portion of a record taken of sound emitted by a full organ shows deep furrows, continued for a considerable distance, corresponding to the long chord-like sounds of the instrument, and these are succeeded by portions in which there is no groove. In this case, so great has been the rebound from the state of great pressure that the cutting edge has only slid along the surface of the wax cylinder without cutting a groove.

It is possible that here we have the explanation of one of the imperfections of the phonograph, or, perhaps, rather an illustration of the wrong way of using the instrument. All who have tried the instrument must have observed that the best effects are obtained by tones of moderate intensity. If too weak, the tones given out by reproduction are only imperfectly heard on account of their weak intensity, and by no system of reinforcement or electrical relays can these be made fairly audible. On the other hand, if too strong, there are two risks :—(1st) The intensity of the tone may cause a jarring between the end of the wire in the loop connecting the wire of the lever with the wire from the glass disk, and, as this is communicated to the glass disk, a noise is produced ; and (2nd) the intensity of the tone may be so great as to cause, during the rarefaction of the air corresponding to the diminution of pressure, the recording marker to come to the surface of the wax cylinder, or even to leave it altogether. Suppose the marker just skims the surface, it will produce a friction sound which must affect quality, and suppose the marker leaves the surface altogether for a fraction of a second, there will be a rebound from the glass disk (owing to the removal of pressure coming from the marker) which is not exactly the same as the diminution of pressure due to the rarefaction of the aërial wave in the immediately preceding vibration These changes must affect quality of tone.

3. The Committee has also been engaged on *a method of recording variations in the intensity of the sounds of the phonograph.* Suppose a series of sound waves of gradually increasing intensity to act on the disk of the phonograph, the pressure on the disk will gradually increase, and the normal groove will be cut deeper. In this process each vibration wil. be a little deeper than the one immediately before it, but the difference in depth will be very small. If the increase of pressure of the note or chord lasted more than half a second, the extent of surface covered by the recording point during that time would be nearly 7 inches, and there might be from 500 to 1,000 depressions in that distance. Suppose, now, that we recorded all these little depressions, it will be evident that the gradually increasing differences in height of the little curves would scarcely be appreciable. The slow method of recording vibrations, therefore, whilst it is the method by which data can be obtained that have to do with pitch and quality, will fail in giving us a record of variations in intensity. This aspect of the matter came under notice at an early period of the investigation. So far as the Committee are aware, no one has attacked this side of the problem. Nothing is more striking in listening to the phonograph when it is reproducing either human speech or musical

sounds than the way in which it catches every inflection of the voice or the slightest emphasis, diminuendo, and crescendo of the sound. This must be due to variations of pressure. How may these variations be recorded?

The most evident method is to attempt to record mechanically the variations in an electro-magnet produced by pressures on a variable resistance apparatus in the same circuit. The first attempt of the Committee was to place Graham's transmitter over the glass disk of the phonograph and to place in the same circuit an electro-magnetic marker such as is used for physiological purposes. This gave poor results, but still they were encouraging. On placing a Breguet's chronograph in circuit the results were much better, and it was evident that there was a movement of the vibrator of the chronograph for each note or chord emitted by the phonograph. The Committee then heard of an ingenious apparatus devised by Heurtley of Breslau, by which he has succeeded in recording by electrical and mechanical arrangements the sounds of the heart. His apparatus consists essentially of a large stethoscope on which a peculiar resonator is fixed. The resonator carries a small wooden tuning-fork, between the prongs of which is fixed a simple microphonic contact of two carbon buttons. This is one half of the apparatus. The other half consists of an electro-magnet, over the poles of which is fixed, face downwards, a shallow tambour, of the Marey pattern, having on its under surface a broad ferrotype plate. This tambour is then connected with an extremely delicate recording tambour. It is evident that the second half of this apparatus is exactly what is wanted for the phonograph work, and, by the kindness of Professor Heurtley, the apparatus was made in Tübingen without delay. When placed in the circuit along with the carbon transmitter the pen of the recording tambour moves at right angles to the line of revolution of the cylinder with each tone and chord played by the phonograph. When the ear perceives tones of considerable intensity the lever point is seen moving through a greater distance than when the tones are weaker; consequently we have a graphic record of the variations in intensity. If the recording cylinder is timed to travel at the same rate as the cylinder of the phonograph, then the curves on the former exactly correspond to the ensemble of the minute marks on the latter corresponding to a particular variation in intensity. When the recording cylinder is caused to travel as fast as the phonograph cylinder, the variation in the heights of the curves recorded on the revolving cylinder is not so apparent as when the recording cylinder travels more slowly. It is easy, however, to time the rate of revolution of both cylinders by a chronograph. Thus we have found that when the recording cylinder is travelling at such a rate that an extent of surface of one-fourth of an inch corresponds to one-fourth of a second, an easily read tracing is obtained. In such a distance we may have one little wave representing the pressure of a chord lasting for one-fourth of a second, or we may have from two to as many as fifteen little waves, often varying much in general character. Suppose we find as many as fifteen; then each must have lasted not more than $\frac{1}{60}$th of a second. Even then the ear is able to follow the individual notes when the phonograph is listened to simultaneously. This may be readily done either by listening directly to the phonograph or by connecting a telephone with the secondary of an induction coil, while the current in which the variable resistance apparatus is interposed passed through the primary. If, then, we hold the telephone to the ear while we look at the little pen writing on the recording drum, it is easy to see that the sensations are simultaneous. Now if a note of a pitch, say, of 300 vibrations per second lasts only $\frac{1}{60}$th of a second, it is evident that only five vibrations must have occurred in that time. This shows that we may appreciate a tone and decide as to its pitch if only five vibrations fall on the ear. This conclusion coincides with the opinion previously arrived at from a careful inspection of the photographs and of the mechanically recorded curves. Of course we assume that the music is being played by the phonograph in its proper *tempo*. If the phonograph is made to travel faster, possibly it may be found that pitch may be appreciated for even shorter periods. Examination of the curves shows that as a rule no 'chord' lasts longer than half a second. This method of recording seems well suited to the study of the time relations if a series of complex sounds pour in upon the ear. By causing the lever of the tambour to act on the siphon recorder, large curves are readily obtained, and a complete tracing of a piece of music from the phonograph cylinder may be transcribed on a band of paper about four feet in length.

If one doubts whether the movements of the recording lever are expressions of the tones of the phonograph, three ways are open by which the statement may be put to the test :—(1) Listen attentively with the telephone, and at the same time watch the recording point. The sensations of hearing and of vision for any particular note are simultaneous. (2) Remove the elastic tube from the recording tambour and place it in the ear, and the music will be heard. (3) Lead the elastic tube from the electric tambour to a recording phonograph, and a feeble record will be obtained of the music, showing that all the vibrations are present. In the last two experiments, as might be expected, quality suffers, but the rhythm, the *tempo*, and the general character of the tune are reproduced.

The apparatus may also be used for recording phonetic sounds, such as syllabic sounds, words, sentences, &c.

4. The Committee desire reappointment and an additional grant of 15*l*. It is proposed to carry out the following work during the year 1896–97 :—

(1) To continue the investigation, with the improved recorder, of the phonographic curves of one or two selected instruments.

(2) To investigate the curves of speech, taking simple syllabic sounds, such as man, can, pat, rat, &c.

(3) To begin a series of phonographic records of dialects with the view of ascertaining how far such records can be made available for philological purposes. This investigation was suggested in the report of the Committee made to the meeting at Ipswich in 1895, but it had to be delayed from pressure of other work.

On the Ascent of Water in Trees. *By* FRANCIS DARWIN, *F.R.S.*

[Ordered by the General Committee to be printed *in extenso.*]

WITHIN the last few years the problem of the ascent of water has entered on a new stage of existence. The researches which have led to this new development are of such weight and extent that they might alone occupy our time. It will be necessary, therefore, to avoid, as far as possible, going into ancient history. But it will conduce to clearness to recall some of the main stepping-stones in the progress of the subject.

The two questions to be considered are—(1) What is the path of the ascending water? (2) What are the forces which produce the rise?

(1) The first question has gone through curious vicissitudes. The majority of earlier writers assumed that the water travelled in the vessels. This was not, however, a uniform view. Cæsalpinus, 1583, seems [1] to have thought that water moved by imbibition in the 'nerves.' Malpighi and Ray held that the vessels serve for air, and the wood fibres for the ascent of water. Hales,[2] who believed in the 'sap-vessels' as conduits, speculated on the passage upwards of water between the wood and the bark. Also,[3] that water may travel as vapour not in the liquid state. In the present century Treviranus,[4] 1835, held that water travelled in vessels; De Candolle, 1832, that the intercellular spaces were the conduits. In Balfour's 'Manual of Botany,' 1863, vessels, cells, and intercellular spaces are spoken of as transmitting the ascending water.

The change in botanical opinion was introduced by the great authority of Sachs,[5] who took up Unger's view [6] that the transpiration current travels in the thickness of the walls as water of imbibition.

Then followed the reaction against the imbibitionists—a reaction which has maintained its position up to the present time. Boehm, who had never adopted the imbibition theory, must have the credit of initiating this change: his style was confused and his argument marred by many faults, but the reaction should in fairness be considered as a conversion to his views, as far as the path of the travelling water is concerned. Nevertheless, it was the work of others who principally forced the change on botanists—*e.g.*, von Höhnel,[7] Elfving,[8] Russow,[9] R. Hartig,[10] Vesque,[11] Godlewski,[12] and others.

(2) The second question has a curious history, and one that is not particularly creditable to botanists generally. It has been characterised

[1] Sachs, *Hist. of Bot.* (English Trans.), p. 451.

[2] *Vegetable Staticks*, p. 130.

[3] *Loc. cit.* p. 19.

[4] Sachs, *History.*

[5] *Physiol. Végétale* (French Trans.), 1868, p. 235, and more fully in the *Lehrbuch.* Sachs also partially entertained Quincke's well-known suggestion of movement of a film of water on the surface of vessels.

[6] *Sitz. k.k. Akad. Wien*, 1868. Dixon and Joly's paper in the *Annals of Botany*, September 1895, gives evidence in favour of a certain amount of movement of the imbibed water.

[7] *Pringsheims Jahrb.* xii. 1879.

[8] *Bot. Zeitung*, 1882.

[9] *Bot. Centr.* xiii. 1883.

[10] 'Ueber die Vertheilung,' &c., *Untersuchungen aus dem Forst. Bot. Inst. zu München*, ii. and iii.

[11] *Ann. Sc. Nat.* xv. 1883, p. 5.

[12] *Pringsheims Jahrb.* xv. 1884.

by loose reasoning, vagueness as to physical laws, and a general tendency to avoid the problem, and to scramble round it in a mist of *vis à tergo*, *capillarity*, *Jamin chains*, *osmosis*, and *barometric pressure*.

An exception to this accusation (to which I personally plead guilty) is to be found in Sachs' imbibition theory, in which, at any rate, the barometric errors were avoided, though it has difficulties of its own, as Elfving has pointed out.

But the most hopeful change in botanical speculation began with those naturalists who, concluding that no purely physical causes could account for the facts, invoked the help of the living elements in the wood. To Westermaier [1] and Godlewski [2] is due the credit of this notable advance; for, whether future research uphold or destroy their conclusions, it claims our sympathy as a serious facing of the problem by an ingenious and rational hypothesis.[3]

We may pass over the cloud which arose to witness for and against these theories, and proceed at once to Strasburger's great work,[4] in which, with wonderful courage and with the industry of genius, he set himself to work out the problem *de novo*, both anatomically and physiologically. In my opinion it is difficult to praise too highly this great effort of Strasburger's.

Strasburger's general conclusion is now well known. He convinced himself that liquid can be raised to heights greater than that of the barometric column in cut stems, in which the living elements have been killed. Therefore, the cause of the rise could not be (1) barometric pressure, (2) nor root pressure, (3) nor could it be due to the action of the living elements of the wood. His conclusions may be stated as follows:—

(*a*) The ascent of water is not dependent on living elements, but is a purely physical phenomenon.

(*b*) None of the physical explanations hitherto made are sufficient to account for the facts.

Strasburger has been most unjustly depreciated, because his book ends in this confession of ignorance. I do not share such a view. I think to establish such distinct, though negative, conclusions would be, in this most nebulous of subjects, an advance of great value. Whether he has established these conclusions must of course be a matter of opinion. To discuss them both would be to go over 500 pages of Strasburger's book, and will not here be attempted. Conclusion (*a*) that the ascent is not dependent on living elements must, however briefly, be discussed, because it is here that the roads divide. If we agree with Strasburger, we know that we must seek along the physical line; if we differ from him, we are bound to seek for the missing evidence of the action of the living elements.

Schwendener's Criticism.—Perhaps the best plan will be to consider the most serious criticism that has been published of Strasburger's work, namely, Schwendener's paper 'Zur Kritik,' &c.[5]

[1] *Deutsch Bot. Ges.*, Bd. i. 1883, p. 371.

[2] *Pringsheims Jahrb.*, xv. 1884.

[3] It is of interest to note that Hales, in speaking of the pressure which he found to exist in bleeding trees, says: 'This force is not from the root only, but must also proceed from some power in the stem and branches' (*Veg. Staticks*, 1727, p. 110).

[4] *Leitungsbahnen*, 1891.

[5] *K. Preuss. Akad.* 1892, p. 911.

Schwendener objects that although a continuous column of water cannot be raised by air pressure to a greater height than that of the barometric column, yet when broken into a number of columns, as in the case of a Jamin chain, that a column considerably over 10 m., even as much as 13 or 14 m., of water can be suspended. This, though not fatal to Strasburger's conclusions, is no doubt a serious criticism. For if 13 m. can be supported, some of Strasburger's experiments are inconclusive. He finds that a branch can suck up a poisonous fluid to over 10 m., and, as above explained, argues that all ascent above that height, not being due to barometric pressure or to the living elements (since the wood is poisoned), is for the present inexplicable. But, if Schwendener is right, the effect above 10 m. may have been due to atmospheric pressure. Askenasy (*loc. cit. infra*, 1895, p. 6) objects to Schwendener that the supposed action cannot be continuous. By repeating the diminution of air pressure at the upper end the movement of water becomes less and less, and sinks to almost nothing. Askenasy adds, moreover, that the amount of water which could be raised according to Schwendener's theory would be very small.

One difficulty about Schwendener's theory is that the result depends on the length of the elements of which the chain is made up (such element being a water column *plus* an air bubble). In his paper 'Ueber das Saftsteigen'[1] he finds that the elements of the chain in *Fagus* equal in round numbers 0·5 mm. In his paper[2] 'Wasserbewegung in der Jamin'schen Kette' he finds the element in *Acer pseudo-platanus*=0·9 mm., in *Acer platanoides* and *Ulmus effusa*=0·2. But the calculation (1892, p. 934) is based on the existence of a chain in which the water columns are each 10 mm. in length; a condition of things which he allows does not occur in living trees.

But even if we allow Schwendener to prove theoretically the possibility of a Jamin chain being raised to a height much greater than that of a barometric column, I do not think he invalidates Strasburger's position. Schwendener's idea necessitates the travelling of a Jamin chain as a whole, *i.e.*, the translation, not only of water, but of air bubbles. But this cannot (as Strasburger points out) apply to his experiments on conifers, in which the movement of air to such an extent is impossible.[3] And for the case of dicotyledonous woods, Strasburger has shown that the movement of air is excluded by the fact that transverse walls occur in the vessels at comparatively short distances. In Aristolochia the sections may be as long as 3 m., but in ordinary woods, according to Adler,[4] we get: Alnus, 6 cm.; Corylus, 11 cm.; Betula, 12 cm.; Quercus, 57 cm.; Robinia, 69 cm. These facts seem impossible to reconcile with Schwendener's views.

Action of the Poisonous Fluids in Strasburger's Experiments.—The question whether the living elements are killed in Strasburger's experiments is of primary importance in the problem.

Schwendener does not criticise it at length; he seems to assume [5]—as far as I can understand—that since the death of the tissues extends gradually from the cut end upwards, there are living cells in the upper

[1] *K. Preuss. Akad.* 1886, p. 561.
[2] *K. Preuss. Akad. Sitz.*, 1893, p. 842.
[3] 'Ueber das Saftsteigen,' *Hist. Beiträge*, v. 1893, p. 50.
[4] As quoted by Strasburger.
[5] *Zur Kritik, loc. cit.*, 1892, p. 935

part which may still be effective. He also doubts 'whether the cells were always killed at once.' The first objection of Schwendener's may or may not be sound, but in any case it does not (as Strasburger points out) account for the experiment[1] in which an oak stem was poisoned by picric acid, and three days afterwards was placed in fuchsin-picric. The second reagent had to travel in tissues already killed with picric acid, yet a height of 22 m. was reached.

The question whether the reagents kill the cells in Strasburger's experiments does not lend itself to discussion. It is difficult to see how they should escape, and we have Strasburger's direct statement that the living tissues were visibly killed. It must not be forgotten that in some of his experiments the death of the tissues was produced by prolonged boiling, not by poisons.[2] Thus the lower 12 m. of a Wistaria stem were killed in this way, yet liquid was sucked up to a height of 108 cm. In the *Histolog. Beitr.*, v. p. 64, he has repeated his air-pump experiment, using a boiled yew branch, and found that eosin was sucked up from a vessel in which almost complete vacuum was established, so the action of living elements and of atmospheric pressure was excluded.

On the whole, the balance of evidence is, in my judgment, against the belief that the living elements are necessary for the rise of water. In other words, I think we should be justified, from Strasburger's work, in seeking the cause of ascent in the action of purely physical laws.

Strasburger's general argument from the structure of wood.—It seems sometimes to be forgotten that, apart from the physiological or experimental evidence, there is another line of argument founded on the structure of wood. Strasburger's unrivalled knowledge allows him to use this argument with authority, and he seems to me to use it with effect. Thus[3] he points out that though in coniferous wood the action of the living elements in pumping water is conceivable, yet this is far from being universally the case. He points out that in the monocotyledons such theories meet with almost unconquerable difficulties. This is, he says, especially the case in Dracæna. He goes on to point to difficulties in the case of such dicotyledons as Albizzia. The case may perhaps best be put in the generalised manner that Strasburger himself employs.[4] If the living elements are of such importance as Godlewski, Westermaier, and Schwendener hold, we ought not to find these difficulties; we ought rather to find structural peculiarities pointing distinctly to the existence of such functions. For instance, we ought to find the tracheal water-path actually interrupted by living elements, which might act like a series of pumping stations one above the other. It should, however, be remembered that if we deny the importance of the medullary rays and other living elements in raising water, we ought to be able to point more clearly than we can at present to the function of the medullary rays and to structural adaptations to these functions.

The work of Dixon and Joly and of Askenasy.—I now pass on to the recent work in which Strasburger's indications to search along a purely physical line have been followed; namely, the paper of Dixon and Joly,[5]

[1] *Hist. Beitr.* v. p. 12.
[2] *Leitungsbahnen,* p. 646.
[3] *Hist. Beitr.* v. p. 17.
[4] *Loc. cit.* p. 20.
[5] *Proc. Roy. Soc.*, vol. lvii. No. 340. Also *Annals of Bot.*, vol. viii.; *Phil. Trans.*, vol. 186, 1895 (B).

which was followed by that of Askenasy.[1] The leading idea common to these works is now well known, namely, that the raising of water to the tops of trees depends on the quality which water possesses of resisting tensile stress. To most botanists the existence of this quality is a new idea. To believe that columns of water should hang in the tracheals like solid bodies, and should, like them, transmit downwards the pull exerted on them at their upper ends by the transpiring leaves, is to some of us equivalent to believing in ropes of sand.

Askenasy has earned the gratitude of his botanical readers by giving some of the evidence which demonstrates the existence of this property of water.[2] A tube a meter in length was filled by Donny with water, and the remaining space was as far as possible freed from air. When the tube was placed vertically the water-column at the upper end hung there, and could not be made to break or free itself from the glass by violent shaking. Berthelot filled a thick-wall capillary tube completely with water at 28°–30 C.°; it was allowed to cool to 18°, so that the space left by the shrinking of water was filled with air. It was then sealed up and again warmed to 28°–30°, so that the air was dissolved in the water. When it was allowed to cool again it retained its volume, filling the tube completely. A slight shake, however, allowed the water to break and return to its proper volume at 18° with the appearance of a bubble of air. In this experiment the water contained air, yet it seems to have been until recently assumed by some physicists that, to show cohesion, water must be air-free. If this were the case the application of the principle to plants would be impossible. Dixon and Joly have, however, proved that this is not so, and this forms an important part of their contribution to the subject.

They also[3] investigated the amount of tension which water under these circumstances will bear, and found it about equal to seven atmospheres. If, therefore, the leaves at the top of a tall tree can exert the requisite upward pull on the water in the trunk, it seems certain (if no other conditions in the problem interfere) that the pull can be transmitted to the level of the ground. This opens up the question whether the leaves can exert this traction on the water in the tracheals, and what is equally important, Are there any factors in the problem incompatible with the theory?

1. *The sucking force of the leaves.*—In Dixon and Joly's first paper[4] they assume that tractional force is given by the meniscuses 'formed in the membranous *réseau* of the evaporating cell walls,' as well as possibly by the osmotic action of the cells of the mesophyll. We shall take these theories in order. Our knowledge of the cell wall does not allow us to believe in the existence of pores visible with even the highest powers of the microscope. Dixon's more general expression,[5] 'surface tension forces developed in the substance of the walls of the evaporating cells,' is there-

[1] *Verhand. d. naturhist. med. Vereins Heidelberg*, N.F., Bd. v. 1895; and N.F., Bd. v. 1896.

[2] He gives references to Donny, *Poggendorff's Annalen*, 67. Bd. (143. Bd. d. g. R.), 1846, p. 562; Berthelot, *Annales de Chimie et de Physique*, S. 3, t. 30, 1850, p. 232; Worthington, *Proc. Roy. Soc.* vol. l. 1892, p. 423.

[3] *Phil. Trans.* vol. 186, p. 570. With ethyl alcohol Worthington records a tension of 17 atmospheres. See *Proc. R. Soc.*, vol. l.

[4] *Phil. Trans.* pp. 563, 567.

[5] *Proc. Roy. Irish Acad.* Jan. 13, 1896, p. 767.

fore preferable. But Askenasy seems to me to state the matter much more conveniently by using the term 'imbibition.'[1] The force with which vegetable membranes, *e.g.*, the thallus of Laminaria, absorb water has been demonstrated by Reinke and others, and the existence of such a force is familiar to botanists.

Both Askenasy (*loc. cit.*) and Dixon and Joly[2] have pointed out that the force of imbibition, or the surface tension forces, as the case may be, can exert a tractional effect on the water in the tracheals, when the turgescence of the mesophyll has been destroyed. But Askenasy in his original paper (1895), Dixon in the January 1896 paper, and again Askenasy in his second paper (March, 1896) have also considered the imbibitional or surface tension forces in connection with the turgescent cell. In his 1896 paper Dixon in fact gives up the view published in the *Phil. Trans.* and adopts the view given by Askenasy in his original paper, that the tractional force is supplied by the osmotic suck of the leaves. It must clearly be understood that this does not remove imbibition from the problem. It is one of the chief merits of Askenasy's work that he clearly sees and states the important relation between these forces.[3] The sun's heat causes the evaporation of the water with which the walls of the mesophyll cells are imbibed : this water is replaced by imbibition from the cell-sap. The concentration of the cell-sap so produced maintains the osmotic force of the cell, which again exerts suction on the water on the tracheals.[4]

I have now given, in its simplest form, the modern theory of the rise of water. Apart from the main idea, it combines the points of several familiar views. Imbibition becomes a factor of paramount importance, though not in the way that Sachs employs it. The suspended threads of water remind us of Elfving's capillary theory, while the living-element factor is represented by the turgescent mesophyll cells.

Resistance.—It is not possible to discuss the question whether the tractional forces in the leaf are sufficient for the work imposed on them until we know what is the resistance to the passage of water through wood. For it is clear that the work done by the leaf includes, not only the lifting of a given column, but the overcoming of the resistance to its flow.

The resistance to the flow of the transpiration current is in want of further investigation. Janse[5] has discussed the question, and points out (*loc. cit.*, p. 36) that two kinds of resistance must be reckoned with. The first (which he calls statical) is illustrated by means of a cylinder of Pinus wood fixed to the short arm of a J tube filled with water, when it was found that in five days the level of water in the long arm was only 1 mm. above that in the short arm.[6] That is to say, when time enough is given, the resistance is practically nothing. Janse has also investigated the resistance to the passage of water flowing through wood at the rate of an ordinary transpiration current. His method seems to me open to criticism, but this is not the place to give my reasons. His experiments give a wide range of results. With *Pinus strobus* a pressure of water equal to ten times the length of the wood was required to force water through at

[1] *Loc. cit.* 1895, p. 10.
[2] *Annals of Bot.* Sept. 1895.
[3] Askenasy, 1895, p. 11.
[4] Sachs, *Text Book*, edit. iv. Eng. Tr., p. 679, describes evaporation taking place in the cell wall, which makes good the loss by imbibition.
[5] *Pringsheims Jahrb.* xviii. 1887, p. 1.
[6] Strasburger (*Leitungsbahnen*, p. 777) observed equilibrium established a good deal quicker.

a pace equal to the transpiration current. In Ginkgo the pressure was twenty-one times the length of the wood. Strasburger[1] has repeated Janse's experiment, and finds a column 'several times the length of the object' necessary. Nägeli[2] found that 760 mm. of mercury were needed to force water through fresh coniferous wood at the rate of $\frac{1}{21}$ mm. per second, *i.e.*, at 180 mm. per hour. If we allow one metre per hour as a fair transpiration rate,[3] we get a pressure of 5 atmospheres required to produce such a flow. To return to Janse's experiments: even if we assume that the resistance (expressed in water) = 5 times the length, it is clear that with a tree 40 m. in height, the resistance of 20 atmospheres has to be overcome. This would not be a pressure greater than that which osmotic forces are able to exert; but when we come to a tree of 80 m. in height, and a resistance of 40 atmospheres, the thing becomes serious.[4] A great difficulty in the question of resistance is that the results hitherto obtained are (though here I speak doubtfully) much greater than those obtained by physicists for the resistance of water flowing in glass capillaries. Until this discrepancy is explained, it is rash to argue from our present basis of knowledge.[5]

Is the osmotic suck sufficient?—The osmotic force of a turgescent cell is usually measured by its power of producing hydrostatic pressure within the cell. Thus, De Vries[6] investigated the force necessary to extend a plasmolysed shoot to its original length; Westermaier[7] the weight necessary to crush a tissue of given area; Pfeffer[8] the pressure exerted by growing roots; Krabbe[9] the pressure under which cambium is capable of maintaining its growth.

The figures obtained by these naturalists have a wide range; it may be said that the hydrostatic pressure varies between 3 and 20 atmospheres.

Another method is to ascertain the osmotic strength of the cell-sap in terms of a KNO_3 solution, and calculate the pressure which such a solution can produce. According to Pfeffer,[10] 1 per cent. KNO_3 with artificial membrane gives a pressure of 176 cm. = 2·3 atmospheres. De Vries[11] calculates that in a cell a 0·1 equivalent solution (practically=1 per cent.) gives a pressure of 3 atmospheres. We may therefore take it as between 2·5 and 3 atmospheres. Now, De Vries found that beetroot requires 6–7 per cent. KNO_3 to plasmolyse it; this would mean 15 – 21 atmospheres. I do not know what is the greatest pressure which has been estimated in this way. Probably Wieler's[12] estimate of the pressure in the developing medullary ray cells of *Pinus sylvestris* at 21 atmospheres is the highest. It is clear that investigation of the osmotic capacity of

[1] *Leitungsbahnen*, p. 779.

[2] *Das Mikroskop*, 2nd edit. p. 385.

[3] Sachs, *Arbeiten*, ii. p. 182.

[4] *Schwendener's* experiments, *K. Preuss. Akad.*, 1886, p. 579, do not particularly bear on this question.

[5] It is possible that the rate of the ascending water is much less than is usually assumed. Thus Schwendener (*K. Preuss. Akad.*, 1886, p. 584) calculates from an observation of v. Höhnel that the transpiration current in the stem of a tall beech was only 2 metres per day.

[6] *Untersuchungen über d. mechanischen Ursachen der Zellstrecken*, 1877, p. 118.

[7] *Deutsch. Bot. Ges.* 1883, p. 382.

[8] *Abh. k. Sächs. Ges.* 1893.

[9] *K. Akad. Berlin* (*Abhandlungen*), 1884, pp. 57, 69.

[10] Pfeffer, *Phys.*, i. p. 53.

[11] *Pringsh. Jahrb.*, xiv. p. 527.

[12] *Ibid.*, xviii. p. 82.

leaves for high trees is wanted; also investigations of the variation in osmotic power produced by varying resistances in the flow of the current. The experiments of Pfeffer and others [1] show that the osmotic strength of cell-sap is capable of great adaptation to circumstances—cells respond by increased turgescence to various stimuli. Whether they can respond sufficiently to account for the ascent of water is another question.

My own opinion is that the question of resistance to the flow of water is a difficulty which the authors of the modern theory have not sufficiently met. Unless it can be shown that the resistance to the flow of water in wood is less than that indicated by existing researches, we must face the fact that we do not at present know of osmotic forces which we can suppose capable of raising water to a greater height than 40 metres.

Continuity of the water in the tracheals.—The theory we are considering apparently requires that there shall be continuous columns of water from leaf to root, because a break in the column means a collapse of the machinery. This seems at first sight a fair assumption, though I doubt its complete correctness. It is in any case worthy of discussion. It has been constantly insisted on by Sachs and others that at the time of most active transpiration the vessels contain air, and not water. It is therefore a violent disturbance of our current views to believe in continuous columns of water.

For evidence on this point we are chiefly indebted to Strasburger. It is a remarkable fact that he should, without any theory to encourage such a view, have come to the conclusion that approximate continuity of water columns is a condition of primary importance, and that he should have made out the cognate fact that the whole of the *alburnum* need not be simultaneously occupied by a transpiration current; parts of it may be so occupied, while parts of it are filled with air, and do not function as water ways. This is a valuable contribution to knowledge, and to the adherents of the new theory it is priceless; the very existence of their hypothesis may depend on it.

Strasburger's statements and reasoning are by no means accepted by everyone; for instance, Schwendener refuses to take them seriously.[2]

Strasburger has microscopically examined the condition of the tracheals as regards air.[3] He found in the spruce fir in July 'almost no air bubbles' in the wood of the current year, but air in considerable quantity in four-year-old wood. In the same month *Pinus Salzmanni* (*Laricio*) showed scattered bubbles in the spring wood of last year, and more in the autumn wood. In a larch there were only very occasional bubbles in the two last years' wood. In the silver fir the current year's wood was practically free from air: the air increased in the inner rings. *Tsuga canadensis* had no air in this year's wood, only a little in last year's, and an increasing quantity in the older rings, the fifth being very rich in air. In February *Pinus strobus* had hardly any air in this year's wood, and the silver fir was all but free from it in the youngest ring. Robinia in July had the youngest wood almost air-free. *Ficus elastica* and *spuria*, various *Acacias*, and willows gave vessels not entirely free from air, but nearly so.

[1] Pfeffer, *Abhand. der k. Sächs. Ges.* xx. p. 300; Eschenbagen, *Untersuchungen aus d. Bot. Inst. z. Tübingen*, 1889; Stange, *Bot. Zeit.*, 1892.

[2] *K. Preuss. Akad.*, 1892, p. 931.

[3] *Leitungsbahnen*, p. 683 *et seq.*; Russow in 1882 (*Bot. Centr.*, Bd. xiii. 1883) observed similar facts in the distribution of water and air.

He concludes[1] that the path of the transpiration current is not absolutely free from air. The younger wood, which especially functions as the water-carrier, is the most free.

Dixon and Joly quote Strasburger's results, which they consider sufficiently favourable to their views. They rely, in addition, on the impermeability of wet cell-walls to air isolating the conduits in which air has appeared; and on the possibility that the air may be redissolved under root pressure,[2] an idea well worth testing.

I think Strasburger's facts are not so favourable to their theory as these authors believe; in the same way it seems to me that Askenasy is rash in saying[3] that the tracheals in many cases contain continuous columns of water. It is true that this statement does not affect the validity of his general argument, since he faces the undoubted occurrence of air bubbles in many cases. This is undoubtedly necessary, and fortunately we can once more turn to the *Leitungsbahnen*. Strasburger states that he has seen water creep past the air bubbles[4] in coniferous tracheids. The best evidence for this seems to be the fact mentioned[5] that the part of a single tracheid in front of an air bubble gets red with absorbed eosin, though the neighbouring tracheids are colourless. This clearly suggests the creeping round the bubble which Strasburger believes in. Schwendener[6] has been unable to confirm Strasburger's microscopic observations, and, moreover, denies the physical possibility of the phenomena. I am unable to judge of the validity of Schwendener's theoretic objections, and must leave this point. It is a question of great importance whether it is possible that on the breaking of a column of water a film of water remains surrounding the air bubble, and capable of holding the two columns together. If this is impossible we must suspend our judgment until we know more of the contents of the tracheals.

To sum up this part of the subject, we may believe that the tracheals in their youngest condition may contain water in continuous columns, since the cambium cells from which they arise certainly contain fluid. But we know also that this condition is not absolutely maintained, since Strasburger has shown that the young wood contains air, though in small quantity. We must therefore believe either (1) that the transpiration current is able to travel past the air-bubbles, or (2) that tracheals partly filled with air may again become continuous waterways by solution of the air. If we adopt the first alternative we must believe that the film of water between the bubble and the wall of the vessel is able to bear such a tensile stress that it can serve to link the column above with the column below the bubble. But this is analogous to trusting a rope so nearly cut through that only a few threads remain intact. With regard to the second alternative, we have at least indications from Strasburger's work that a tracheal, partly filled with air, does not necessarily remain permanently functionless (see *Leitungsbahnen*, p. 692).

The isolation of the tracheals.—There are a number of points connected with the structure and properties of wood which ought to be considered

[1] *Loc. cit.* p. 688.
[2] *Phil. Trans.* p. 572.
[3] *Verhand. naturhist. med. Vereins Heidelberg*, 1895, p. 15.
[4] *Leitungsbahnen*, pp. 704, 709. See also *Hist. Beitr.* v. p. 76.
[5] *Ibid.* p. 79.
[6] *Zur Kritik*, &c., p. 921.

in relation to the modern theories. Want of space forbids my doing more than referring to two of them.

The resistance which the wetted cell-wall offers to the passage of undissolved air is a point on which many writers have laid stress. It is clear that on any theory of the movement of water in the tracheals it is essential that air should not filter into the waterway. This necessity is not, however, stronger in the case of the modern theories we are considering. The pressure tending to fill the tracheals with air from outside cannot be greater than atmospheric pressure, and since the wetted cell walls of gymnospermous wood can resist the passage of air under a pressure of about an atmosphere,[1] we need not fear criticism of the theory on this ground. The above remarks seem, however, to be needed in face of the frequently recurring statement that wet wood membranes are impermeable to free air. Schwendener has some good remarks on this head.[2]

Strasburger has called attention to the important subject of the localisation or isolation of vessels or of certain lines of tracheids. When this is possible we may have one set of tracheals containing continuous water columns, while neighbouring ones contain air at negative pressure.[3] This is especially important in connection with the Dixon-Joly-Askenasy theory, since, if there were no such isolation, a functioning tracheal containing a continuous column of water would give up its water to one which was not functioning. In other words, the inactive tracheals would, by negative pressure, suck water from the active ones. In the coniferous trees the young wood is cut off by the absence of pits in the tangential walls [4] from free communication with the older wood, where air is more frequent.

In the same way the valve-like closure of the pits by the aspiration of the pit membrane comes to be a subject of much importance.

At present I merely wish to show by a couple of examples the necessity of a complete study of the minute structure of wood in relation to the modern theories. It is at least a hopeful fact for Messrs. Dixon, Joly, and Askenasy that we cannot point to anything in the anatomy of wood which is absolutely inconsistent with their views. Finally, with regard to the question at large, whether we are friends or opponents of Messrs. Dixon, Joly, and Askenasy's theory, the broad facts remain, that water has the power of resisting tensile stress, and that this fact must henceforth be a factor in the problem. There are difficulties in the way of our authors' theory, but it is especially deserving of notice that many of these difficulties are equally serious in the case of any theory which excludes the help of the living elements of the wood, and assumes a flow of water in the tracheals. The authors have not only suggested a *vera causa*, but have done so without multiplying difficulties. There is therefore a distinct balance in their favour.

Huxley, quoting from Goethe, makes use of the expression *thätige Skepsis.* It is a frame of mind highly appropriate to us in the present juncture if we interpret it to mean a state of doubt whose fruit is activity, and if we translate activity by experiment.

[1] *Leitungsbahnen*, p. 722. Nägeli and Schwendener, *Das Mikroskop*, 2nd edit., p. 367, give 225 cm. of mercury.

[2] *Zur Kritik*, p. 943.

[3] See *Histolog. Beiträge*, v. p. 87.

[4] Strasburger discusses in this connection the existence of tangential pits in the autumnal wood (see *Leitungsbahnen*, p. 713).

Preservation of Plants for Exhibition.—Interim Report of the Committee, consisting of Dr. D. H. SCOTT (*Chairman*), Professor I. BAYLEY BALFOUR, Professor L. ERRERA, Mr. W. GARDINER, Professor J. R. GREEN, Professor J. W. H. TRAIL, Professor F. E. WEISS, *and* Professor J. B. FARMER (*Secretary*), *appointed to Report on the best Methods of Preserving Vegetable Specimens for Exhibition in Museums.*

THE Committee are not yet in a position to present a definitive report; in the meantime they desire to place on record the results obtained by individual members of the Committee and others, as their experience may be of immediate service to those interested in this subject.

Mr. W. Gardiner points out that in his opinion the processes of (1) killing, and (2) fixing and mounting, have not been kept sufficiently distinct. The killing of the protoplasm should be as rapid as possible, so as to avoid active plasmolysis. He suggests (1) hot glacial acetic acid, owing to its power of rapid penetration; (2) superheated steam; (3) strong alcohol. If a rapidly acting substance cannot be used, a poisonous solution, possessing as nearly as possible the same osmotic equivalent as the cell-sap, should be employed. After the tissues have been killed they may be preserved in any suitable liquids, *e.g.* 70 per cent. spirit, or solution of formic aldehyde.

Professor Farmer has made a number of experiments with formic aldehyde. He agrees with Mr. Gardiner as to the advisability of a preliminary and rapid killing, and finds that green parts of plants immersed in strong alcohol for a short time, then transferred to strong solutions of copper acetate, and finally preserved in formic aldehyde, gave better results than when the preliminary killing in spirit was omitted. For most plants experimented on, he finds that strong solutions (15–30 per cent. of the commercial 'formaline') in weak (15–20 per cent.) spirit give better results than weaker solutions. In all cases the specimens were greatly improved by the treatment with copper acetate or sulphate (see Professor Trail's report, Appendix II.). Without this, the green colour had, with but few exceptions, failed after immersion in the formic aldehyde for four months, although they had in some cases shown no change until three months had elapsed.

Mr. J. R. Jackson, of the Royal Gardens, Kew, finds that a saturated solution of salt, boiled to expel air, and carefully stoppered, is useful for many fleshy fruits, some of which, *e.g.* apples, retain their colour very well under this treatment. He finds Goadby's solution, formerly so much employed, unsatisfactory, and considers methylated spirit, on the whole, the best of the liquids in common use. Formic aldehyde has been tried on a number of plants, with good results in some cases, especially with those fruits with red or reddish tints and firm flesh.

In drying large specimens of succulent plants or fruits, it is important that the process should not be hurried, or cracking and warping may ensue.

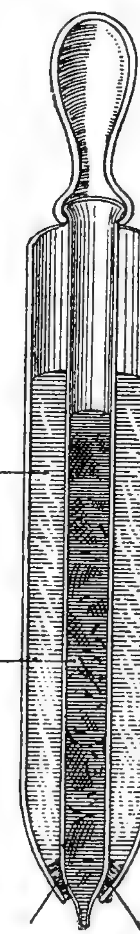
The following methods, devised by Mr. Tagg, assistant in the museum at the Royal Botanic Garden, Edinburgh, are in use there :—

1. *For cementing Specimens to Glass, Mica, &c.*—Gelatine is necessary for large specimens, and though becoming opaque in alcohol may be used when the specimen is sufficiently large to hide the cement.

Delicate specimens that dry when exposed to air for a very short time can be fixed to the glass with gelatine while still in alcohol. To do this a pipette with hot water jacket is required (see figure).

Pipette.—An ordinary pipette is surrounded by an outer tube forming a jacket, in which water is put.

Method of using Pipette with Hot-water Jacket.—Gelatine is taken into the pipette, the outer tube filled with water, and the whole placed in a beaker of boiling water till the water in the jacket surrounding the pipette is also boiling. The specimen is laid in a flat dish in alcohol; at the bottom is also the glass to which specimen is to be cemented. Having decided where specimen shall be fastened, the pipette with hot water is put quickly into the spirit, its orifice is made to touch the glass, and some of the hot gelatine is forced out. With the other hand the specimen is now gently pressed into the still soft gelatine and held in position for a second or two. The gelatine soon hardens, and the specimen is permanently fixed.



2. *For making flat-sided Vessels to hold Specimens.*—Pieces of glass are cut to required sizes for the sides of the vessel, and are then fastened together in the following manner :—1 oz. Nelson's amber gelatine is soaked in water for twelve hours. Water not absorbed is poured off, and the softened gelatine is melted over hot water. To this are added 0·5 grm. of bichromate of potash and 10 drops of glycerine. The cement is put on warm.

Professor Errera sent an account of experiments conducted in his museum in Brussels, and his statements are in agreement with those already set forth. He finally decides against all liquid preservative media in cases in which it is desired to retain the original colour, and substitutes a method of rapid desiccation in sand. By this means he has been able to prepare specimens which have remained unaltered as to colour for a considerable number of years. The method was described by E. Cornélis in 'La Belgique horticole,' August 1880. Professor Errera states that the drying *in vacuo*, as recommended by E. Cornélis, is, however, unnecessary. The dried specimens are preserved in airtight bottles, which contain in their hollowed stoppers some calcium oxide, in order to absorb any moisture from the air within the bottles.

The reports of Professors Errera and Trail appear of special importance, and are printed in full, forming Appendices I. and II.

APPENDIX I.

The Preservation of Plants for Exhibition: Report on Experiments made at the Institut Botanique de l'Université de Bruxelles. By Professor ERRERA.

Les quelques notes qui vont suivre n'ont en aucune manière la prétention de répondre aux nombreuses et intéressantes questions soulevées par le Comité de la *British Association.* Elles sont simplement destinées à résumer, suivant le désir de mon ami, le Dr. Scott, le peu d'expérience que nous avons pu acquérir à l'*Institut Botanique de l'Université de Bruxelles.*

J'ai préféré les rédiger en français plutôt qu'en anglais, afin d'être plus sûr de formuler exactement ma pensée.

I.—LIQUIDES CONSERVATEURS.

Alcool.—L'emploi de l'alcool fort est bien connu. Il durcit les tissus végétaux, ce qui, suivant les cas, peut être un avantage ou un inconvénient Dans les Musées, c'est généralement un avantage, puisque les objets conservent ainsi, une fois pour toutes, une *attitude* donnée.

On peut surtout reprocher à l'alcool de modifier la couleur des spécimens et—notamment en Belgique—de coûter fort cher. En revanche, il a le mérite, précieux dans nos climats, d'être pratiquement incongelable.

Divers objets brunissent dans l'alcool, par suite de l'oxydation d'un chromogène incolore. Hugo de Vries a indiqué, on le sait, un procédé fondé sur l'emploi de l'alcool acidulé d'acide chlorhydrique [1] qui empêche, dans la grande majorité des cas, ce brunissement.

Liquides aqueux.—Les liquides conservateurs aqueux que nous avons jusqu'ici employés à l'Institut Botanique sont : le 'liquide au sublimé,' la solution saturée de sel marin, et les solutions de formol (=aldéhyde formique).

Notre liquide au sublimé a la composition suivante :

Eau de pluie	1,000 c.c.
$HgCl^2$	2.5 grammes
NaCl	2.5 „
HCl concentré	5 c.c.

L'addition de sel et d'acide chlorhydrique a pour but de faciliter la dissolution du sublimé corrosif et d'empêcher qu'il ne se réduise sous l'influence de la lumière, ce qui troublerait la solution.

Ces liquides ne coûtent presque rien—détail important si les collections sont considérables et les budgets modiques. Mais ils ont le grand défaut d'être congelables. Afin d'avoir à cet égard des données précises, j'ai engagé, il y a un an environ, mon assistant, M. Clautriau, à déterminer le point de congélation de notre liquide au sublimé, pur et mélangé d'alcool ou de glycérine. Voici ses chiffres :

Liquide au sublimé	$-0^\circ.3$ Centigr.
Liquide au sublimé + 10 pour cent de glycérine	$-3^\circ.5$
Liquide au sublimé + 20 pour cent de glycérine	-7°
Liquide au sublimé + 10 pour cent d'alcool à 92° Gay-Lussac	-5°
Liquide au sublimé + 20 pour cent d'alcool à 92° Gay-Lussac	-9°

[1] H. de Vries, *Maandblad voor Natuurwetenschappen*, 1886, No. 1. Id., *Berichte der bot. Gesellsch.*, 1889, No. 7.

On voit donc qu'il faut ajouter à ce liquide des quantités assez grandes de glycérine ou d'alcool si l'on veut abaisser son point de congélation de quelques degrés seulement. Il doit en être de même pour les solutions de formol. Quant à la solution saturée de sel marin, elle ne se congèle, il est vrai, qu'à $-21°$, suivant Rüdorff;[1] mais déjà à une température beaucoup moindre ($-5°$ d'après Noelle; $-10°$ suivant d'autres)[2] elle dépose des cristaux de chlorure de sodium hydraté.

Dans tous ces liquides aqueux, les spécimens deviennent *flasques:* c'est là un défaut, lorsqu'il s'agit de les exposer d'une manière définitive.

Essais antérieurs avec les Liquides Aqueux.

Liquide au sublimé.—Nos essais avec ce liquide datent de 1893.

En voici le résultat: Les feuilles vertes sont soit décolorées (*Lathyrus, Dioscorea*), soit plus ou moins brunies (*Quercus, Humulus*). Les racines sont bien conservées (*Lathyrus*). Les feuilles rouges (*Quercus*) et les fleurs rouges (*Freycinetia*) sont brunies.

La coloration jaune du plasmode et la coloration brune des spores d'*Æthalium septicum* se sont bien conservées.

Les Champignons (*Amanita, Clavaria, Saprolegnia*) ont pris une teinte grise, mais sont bien conservés, surtout le dernier.

Solutions de formol (=aldéhyde formique).—Nos essais avec ce liquide datent de 1894. Il n'est pas invraisemblable que l'aldéhyde formique puisse se décomposer en présence des matières organiques, de sorte que la concentration des solutions baisse sans doute progressivement.

Dans le formol à 1 pour mille, les parties végétales charnues dépassant le niveau du liquide ont généralement moisi, et le liquide lui-même s'est couvert d'une couche épaisse de mycélium. Un mycélium analogue se développe parfois à la surface du formol à 1 pour mille, même lorsque aucun tissu végétal ne vient émerger.

Pour les objets qui sont depuis le printemps de 1894 dans le formol à 1 pour mille, on remarque que:

Les feuilles sont devenues vert-sale (*Lamium, Arum*) ou sont complètement décolorées (*Sinapis*).

Les tissus incolores le sont restés (racines de *Sinapis*, racines d'*Evonymus*) ou ont bruni (fleurs de *Viburnum*).

Les corolles bleuâtres (*Fritillaria persica*) sont décolorées.

Les corolles rouges (*Antirrhinum majus*) ont conservé une certaine coloration; les rouge-brunâtres (*Primula variabilis*) également.

La coloration du spadice d'*Arum maculatum* reste bien marquée; seulement, du violet foncé elle a passé à une teinte bleuâtre intense.

La coloration jaune et brune d'*Æthalium septicum* (plasmode et spores) s'est bien conservée.

Solution saturée de sel marin.—Pendant plusieurs années, les Algues marines rouges, vertes et brunes se sont bien conservées dans ce milieu. À la longue, de la moisissure s'est développée.

Essais récents.

Pour pouvoir présenter au Comité de la *British Association* un avis mieux motivé, il m'a paru désirable de soumettre un certain nombre d'objets végétaux, méthodiquement choisis, à une épreuve comparative au moyen de divers liquides conservateurs.

[1] Würtz, *Dict. de Chimie*, t. ii. p. 1516. [2] *Ibid.*

L'essai a été commencé il y a un mois seulement et il serait prématuré de vouloir conclure dès à présent. Cependant, il peut être opportun d'indiquer ici en quoi il consiste et quel en est le résultat provisoire.

Les liquides essayés sont au nombre de quatorze :

A. Liquide au sublimé (composition indiquée plus haut).
B. Sublimé glycériné (Liquide A + 15 pour cent de glycérine).
C. Solution de formol à 1 pour mille.
(1 pour mille aldéhyde formique dans l'eau de la ville de Bruxelles.[1])

D. Solution de formol à 2 pour mille.
E. „ „ à 5 „
F. „ „ à 1 pour cent.
G. Alcool éthylique à 20 „ (alcool 20, eau 80).
H. „ „ à 30 „
I. „ „ à 40 „
J. „ „ à 50 „
K. „ „ à 60 „
L. „ „ à 70 „
M. Alcool acidulé (alcool éthylique 50, eau 50, acide chlorhydrique concentré 2).
N. Alcool aluminié (alcool éthylique 50, eau 50, chlorure d'aluminium, Al^2Cl^6, 2).

Ce dernier essai était destiné à voir si le sel d'aluminium constituerait peut-être avec la chlorophylle une laque insoluble.

Des spécimens des objets suivants ont été mis le 26 décembre 1895 dans chacun de ces 14 liquides et conservés dans des flacons en verre, bouchés avec des bouchons en liège et placés au fond de mon laboratoire, c'est-à-dire à un endroit modérément éclairé :

1. Feuille de *Begonia Rex* (feuille verte argentée).
2. „ *Oplismenus imbecillis, fol. variegatis* (feuille verte panachée).
3. „ *Pandanus javanicus, fol. varieg.* (feuille verte panachée, très coriace).
4. „ *Selaginella Martensii* (feuille uniformément verte).
5. „ *Maranta Mackoyana* (feuille à plusieurs nuances).
6. „ *Abutilon tessellatum* (feuille tachetée de vert, de vert pâle et de blanc).
7. „ *Tradescantia zebrina, fol. varieg.* (feuille verte en dessus, rouge en dessous).
8. „ *Coleus sp.* (feuille nuancée de vert, de blanc et de rouge intense).
9. „ *Pilea callitrichoides* (petites feuilles charnues).
10. „ *Genista Spachiana* (folioles caduques).
11. Rameau d'*Asparagus plumosus* (tissus verts très jeunes)
12. Feuille d'*Asplenium diversifolium* (feuille sporangifère).
13. Fleur de *Goldfussia anisophylla* (fleur à suc violet).
14. „ *Coronilla glauca* (fleur à plastides jaunes).
15. „ *Centradenia rosea* (fleur à suc rose).
16. „ *Lamprococcus miniatus* (Broméliacées) (ovaire rouge minium, pétales bleus).
17. Feuille de *Myriophyllum proserpinacoides* (feuille glauque).

[1] Le titre vrai de la solution commerciale de formol à 40 pour cent environ employée pour ces essais avait été vérifié.

Dans tous les liquides aqueux (**A**–**F**), les tissus sont déjà devenus flasques ; les matières colorantes rouges, roses, bleues, solubles dans l'eau, ont disparu ; le jaune insoluble (*Coronilla*) s'est bien conservé ; la chlorophylle commence à brunir dans la plupart des feuilles, sauf *Selaginella*, *Pandanus* et *Oplismenus*, qui se sont, jusqu'ici, parfaitement conservés, avec leur teinte verte et leur panachure blanche.

Dans les alcools faibles (**G**–**J**) les tissus sont devenus flasques ; dans l'alcool à 60 pour cent (**K**) et surtout dans celui à 70 pour cent (**L**), ils le sont devenus beaucoup moins. Les tissus rouges, roses et bleus sont décolorés comme dans les liquides aqueux ; le jaune s'est moins bien conservé ; les tissus verts se décolorent ou brunissent.

Dans l'alcool acidulé (**M**) beaucoup de tissus ont bruni, mais ils sont en train de se décolorer ensuite. Les tissus rouges, roses et bleus ont perdu leur matière colorante ; la fleur jaune a pris une teinte sale.

L'alcool avec chlorure d'aluminium (**N**) n'a présenté aucun avantage réel.

Conclusion.—Des divers liquides essayés, aucun ne conserve d'une manière satisfaisante et durable la couleur des objets verts. Pour certains objets colorés (fleurs jaunes, spadices d'*Arum*, fleurs rouges d'*Antirrhinum*, *Primula*, etc.), les liquides aqueux (liquide au sublimé, ou formol à 1 pour cent) conviennent assez bien.

En somme, dans les Musées, les objets conservés dans les liquides ne seront agréables à l'œil qu'à la condition d'être uniformément décolorés, *blanchis*, par le procédé de de Vries. H. de Vries conserve les objets ainsi décolorés dans l'alcool ordinaire. On pourrait aussi, je pense, une fois qu'ils sont tout à fait décolorés, les conserver dans le liquide au sublimé (plus stable que le liquide au formol, plus économique que l'alcool), mais additionné d'alcool ou de glycérine de manière à abaisser autant qu'il est nécessaire son point de congélation.

Bien plus que les liquides, je recommanderai pour les Musées la conservation à sec.

II.—Conservation à Sec.

On sait que les tissus végétaux se conservent fort bien quand on les dessèche dans du sable chaud.

Ce procédé a été appliqué avec un succès remarquable par un pharmacien belge bien connu, feu Louis Cornélis de Diest (Belgique).

J'ai examiné récemment des fleurs conservées à la lumière par ce procédé depuis *plus de seize ans* et je puis déclarer qu'*il n'est guère possible de souhaiter mieux.* Les fleurs ont si admirablement gardé leur forme et, presque toutes, aussi leur couleur, qu'on les dirait cueillies depuis un instant. Les teintes blanches, roses (*Gloxinia*), rouges (*Hyacinthus*, *Pentstemon*), violettes (*Hyacinthus*, *Franciscea*), bleu-pâle (*Scilla*), jaunes (*Linaria vulgaris*) sont parfaites. Certains rouges sont devenus plus foncés qu'à l'état frais (*Digitalis purpurea*).

Parmi les sépales verts, datant de plus de 16 ans, quelques-uns ont assez bien conservé leur teinte ; d'autres ont bruni ou ont pâli. Le neveu et successeur de Louis Cornélis, M. Joseph Cornélis, pharmacien à Ciney (Belgique), m'assure que les feuilles, bourgeons et racines se conservent aussi bien que les fleurs : mais ce point mériterait d'être bien fixé par de nouveaux essais.

Le procédé employé a été publié par son auteur dans la *Belgique horticole* (août 1880). Il est d'application facile. M. Clautriau, que j'avais prié d'en faire l'essai, a obtenu un succès complet, comme pourront le constater mes honorables collègues de la Commission : je viens, en effet, de leur adresser par l'intermédiaire de M. le professeur J. B. Farmer un flacon avec les fleurs et les feuilles que M. Clautriau a ainsi desséchées. Ce sont les spécimens suivants :

Feuilles de :	Fleurs de :
Begonia Rex.	*Goldfussia anisophylla.*
Oplismenus imbecillis, fol. var.	*Coronilla glauca.*
Genista Spachiana.	*Centradenia floribunda.*
Asplenium diversifolium.	*Lamprococcus miniatus.*
Adiantum Capillus-Veneris.	*Monochætum ensiferum.*
Rameau de :	*Camellia japonica, fol. var.*
Asparagus plumosus.	*Azalea amœna.*
	Kennedya sp.
	Gesnera sp.

Voici la marche à suivre :

Le spécimen à conserver est piqué dans un pot à fleurs ou dans un cornet en papier, à moitié remplis de sable sec et propre. Puis, on verse doucement une nouvelle quantité de sable, de façon à recouvrir complètement l'objet. Il est laissé en cet état, soit en présence d'acide sulfurique sous une cloche où l'on fait le vide et que l'on peut placer ensuite dans un endroit chaud, soit simplement dans une étuve portée à 35°–40° C. À ce point de vue, les chambres thermostatiques ou les armoires chauffantes, comme il en existe maintenant dans la plupart de nos Instituts, conviennent fort bien. Après quelques jours (8–10 au plus), le spécimen doit être retiré du sable—avec beaucoup de précaution, à cause de sa grande fragilité. On le dépouille du sable qui y adhère souvent, au moyen d'un pinceau fin ou en laissant tomber sur lui du sable grossier d'une certaine hauteur. Il suffit maintenant de conserver l'objet dans un milieu bien sec. Le mieux est de le placer dans un flacon à large goulot,[1] fermé à l'émeri par un bouchon de verre creux dont la cavité est aux deux tiers remplie de fragments de chaux vive, retenus par un morceau de peau. Si le flacon n'est pas souvent ouvert, la chaux vive n'a pas besoin d'être renouvelée.

Comme les objets sont extrêmement cassants, il peut être utile de les immobiliser en les collant, par une goutte de gomme arabique.

D'après Cornélis, la dessiccation réussit d'autant mieux qu'elle a été plus rapide : c'est pour cette raison qu'il a employé le vide ; mais cela n'est nullement nécessaire.

Au sujet des changements de teintes que les fleurs ainsi traitées peuvent présenter, je crois bien faire en transcrivant les quelques renseignements publiés par Cornélis (*loc. cit.*) :

'Un certain nombre de fleurs changent de couleur par le fait de la dessiccation seule ; par exemple, la Mauve qui est rose devient bleue ; d'autres foncent en couleur ; ex. : la Passiflore, la Digitale pourprée, le Colchique, la Fumeterre, etc.

'L'action de la lumière sur les couleurs des fleurs est très-variable et il n'est jamais possible de dire *à priori* quel en sera le résultat. Certaines fleurs résistent parfaitement à la lumière, même à la lumière directe du

[1] Ces flacons dessiccateurs, connus ici sous le nom de 'flacons à peptone Cornélis,' se trouvent, par exemple, chez Vanderborght-Minne, rue du Berger, à Bruxelles.

soleil ; d'autres sont déjà influencées par la lumière diffuse ; enfin il y en a qui sont même décolorées dans une demi-obscurité. Parmi les fleurs, les jaunes sont les plus sensibles à l'action de la lumière ; plus de la moitié de celles expérimentées sont complètement décolorées. Trois plantes, l'*Abutilon Sellowi*, le *Fritillaria imperialis* et le *Vanda suavis*, présentent un phénomène toutefois inattendu : par la dessiccation ces fleurs prennent une couleur d'un brun roux et lorsqu'on les expose au soleil elles reprennent une couleur qui se rapproche assez de la primitive, excepté pour le *Fritillaria*, qui devient violet.

'Il est assez curieux de voir des fleurs reprendre leur couleur au soleil, alors que la plupart des autres la perdent.'

Conclusion.—En résumé, la dessiccation au sable, suivant le mode appliqué par J. Cornélis, donne des *résultats excellents* pour un grand nombre de spécimens végétaux intéressants à exhiber au public.

Au dire de l'auteur, c'est pour les fleurs jaunes qu'il convient le moins bien. Mais peut-être suffit-il de les soustraire à la lumière trop vive. On a vu, du reste, que, dans nos quelques essais, les couleurs jaunes se maintiennent justement très bien dans le liquide au sublimé ou dans celui au formol.

Algues marines.—J'ajouterai que l'on peut garder à sec les grandes Algues marines (*Fucus*, *Laminaria*, etc.) en leur conservant leur souplesse, si on les plonge d'abord, pendant 2–3 jours, dans l'eau de mer additionnée de $^1/_{10}$ de glycérine, et qu'on les laisse ensuite sécher à l'air.

III.—Préparation des Spécimens.

De Vries.—Il a déjà été question du procédé de de Vries pour la décoloration des tissus végétaux.

Vert de Méthyle.—D'un autre côté, j'ai obtenu de bons résultats dans quelques essais déjà anciens, en recolorant au moyen de vert de méthyle des tissus décolorés par l'alcool. Les feuilles destinées à être montrées aux élèves et conservées dans la glycérine aqueuse, ont ainsi repris, en apparence, leur teinte verte naturelle.

Iode.—Pour l'étude de la formation et de la disparition de l'*amidon* dans les feuilles, on obtient des spécimens très instructifs par la méthode successivement employée par Böhm, Hanstein et Sachs, et généralement connue sous le nom de 'Sachs' Jodprobe.' Ces objets seront conservés dans de l'alcool iodé étendu de deux volumes d'eau, en flacons bien bouchés.

Une méthode similaire m'a donné des préparations tout aussi démonstratives pour l'accumulation et l'emploi du *glycogène* chez les Champignons. Les pédicelles de *Phallus impudicus* conviennent tout spécialement.

IV.—Montage des Spécimens.

Photoxyline.—Pour mettre sous les yeux des visiteurs une série de spécimens dans l'alcool représentant, par exemple, les étapes du développement d'un Gastromycète, ou diverses périodes de la germination, ou les états successifs d'une fleur protérandrique, ou les stades de la digestion d'un insecte par une feuille de *Drosera*, etc., ou bien encore pour maintenir les objets dans une position immuable, il est souvent nécessaire de les fixer sur une lame de verre. Le meilleur procédé est l'emploi de la photoxyline.

Les objets frais ou sortis de l'alcool sont collés sur le verre au moyen d'une goutte d'une solution sirupeuse de photoxyline de Grübler, dans un mélange de parties égales d'éther et d'alcool absolu. On plonge ensuite la lame de verre avec l'objet, pendant 5 minutes, dans l'alcool à 70 pour cent. On retire et on conserve de préférence dans l'alcool fort, à 92 pour cent. La photoxyline est ainsi transparente et invisible.

L'alcool absolu dissoudrait la photoxyline ; l'alcool trop faible la rendrait trouble. L'alcool acidulé par HCl détache les objets.

Dans les liquides au formol, il y a également moyen d'attacher les objets avec de la photoxyline ; mais les détails du procédé ne me sont pas encore connus.

Lames de Verre bleu.—Quant aux spécimens rendus absolument blancs par le procédé de de Vries, je les ai vu fixer (à l'Université de Gand, si je ne me trompe) sur une lame de verre, non pas blanc, mais bleu-foncé. Cela est souvent d'un joli effet.

V.—Récipients et Fermeture.

Je n'ai rien de particulier à dire à ce sujet. Les flacons à faces parallèles sont, dans bien de cas, préférables aux flacons cylindriques ; mais ils sont d'un prix élevé.

J'ai parlé plus haut des 'flacons dessiccateurs Cornélis,' et de leur emploi.

La fermeture des récipients au moyen de bouchons en verre ou de lames de verre est plus élégante qu'au moyen de bouchons en liège. Rien à en dire. Si l'on veut obtenir un bouchage hermétique au moyen d'un bouchon en liège, il faut le plonger d'abord dans de la paraffine très-chaude, pour qu'il s'en imprègne. Puis, après l'avoir appliqué sur le flacon, ou recouvre d'une nouvelle couche de paraffine le bord du flacon et le bouchon lui-même.

VI.—Étiquetage.

Étiquettes.—Inutile de dire que l'étiquette doit être aussi claire que possible, indiquant au public non seulement le nom de l'objet et son origine, mais attirant encore l'attention sur les détails les plus intéressants. À ce point de vue, comme à tant d'autres, les collections du *Natural History Museum*, Cromwell Road, sont du reste des modèles, et c'est aux Continentaux à y prendre des leçons.

Encre.—À défaut d'une étiquette imprimée, il faut naturellement qu'on se serve d'une encre indélébile. Les encres dites à l'aniline sont à rejeter. Mon regretté collègue, M. le professeur Bommer, assurait que les encres Stephens' 'Blue Black' sont les meilleures pour l'étiquetage des collections. Je n'ai point à ce sujet d'expérience personnelle étendue.

Si le Comité le juge utile, je pourrai lui communiquer ultérieurement quelques détails complémentaires, ainsi qu'un certain nombre de renseignements bibliographiques.

APPENDIX II.

Report on the Preservation of Vegetable Specimens for Museums.
By Professor J. W. H. Trail, *M.A.*, *F.R.S.*

Killing.

All plants or parts intended for museum specimens should be killed as rapidly as possible, to prevent changes in the preservative fluids or while being dried. This may be effected by dipping them for a few minutes into boiling water, or (better) into strong alcohol, cold or hot.

Preservative Media.

Spirit.—I have used this medium for a number of years, usually diluted with 30 to 50 per cent. of water. I still employ it, but to a much less amount, and seldom as the only medium. It serves excellently after treatment with cupric acetate in suitable cases. Specimens treated in this way seldom discolour spirit sufficiently to require it to be changed. I have employed the acid spirit to decolourise specimens that would otherwise become dark in spirit; but I seldom now attempt or wish to obtain bleached preparations. The retention of the more or less natural colours renders specimens both more pleasing and more instructive.

Formic Aldehyde (*Formol*).—I have used this for over two years with varying results, employing solutions of from 0·5 to 5 per cent. in water. Even the weakest solutions have in some cases proved sufficient when the object is small relatively to the amount of the fluid; but in many cases there appeared a fungus after a few weeks in the weak solutions. I now employ habitually a 2 per cent. solution, except for fleshy specimens or where there is relatively little space for the fluid in the jar owing to the size of the specimen. Under these precautions I have not found the fungi appear. The colour of the specimens is not always well preserved, but they are usually superior to specimens treated with spirit alone in my experience. The 2 per cent. solution has in my experience retained the colours best.

Cupric Acetate and Acetic Acid.—I have experimented with the object of retaining the green colour in preparations in fluids by forming the compounds of chlorophyll and copper. The results have been very satisfactory in some cases, notably so in *Lycopodium* and *Selaginella*, and good, though with a bluish tinge in the green, in most plants that are free from tannin. Where tannin is present it combines with the copper and discolours the specimen; hence this method does not succeed where it occurs. The method is as follows: Acetic acid has cupric acetate dissolved in it to saturation, and 1 part of the solution is added to 4 of water, which should have been distilled if not naturally soft. Or 1 part of acetic acid may be added to 4 of water, and this solution may be saturated with cupric acetate. In some cases it is sufficient to employ 1 part of acid in 10 or even more of water. Sometimes one, sometimes another of these solutions has given the best results, according to the material to be treated. In each case the treatment is the same. The specimen, after having been washed clean, is submerged in the solution, and remains in it for at least a month; it suffers no harm even if left a good deal longer. When it is to be transferred to the permanent preservative fluid it is washed in water, to remove any particles of acetate from the surface, and is then at once put into its jar in spirit or in whatever other fluid is used. Specimens successfully treated in this way may be exposed to sunlight with impunity. Specimens are apt to become soft under this treatment.

The cupric acetate solution may be used again and again, but acetate should be added occasionally to keep a sufficiently strong solution.

Brine, Alum Solution, Wickersheimer's Solution, Glycerine (10 to 50 per cent. in water), *Barff's Boroglyceride* (1 in from 20 to 50 of water), and *Boracic Acid* (1 per cent. in water) have all given good results in some cases. The solutions of the salts are apt to become turbid and to allow the growth of fungi, especially if any part of the specimens is uncovered. It is better to wash both the specimens and the vessels with an alcoholic solution of mercuric chloride before mounting the specimens for permanent preservation.

Potassium Acetate, used with the same precaution as to disinfection, makes a useful medium in some cases in a saturated solution in water.

Acetic Acid diluted with from 1 to 4 parts water has been used by me with fair success as a preservative solution for some things.

[*Mercuric Chloride*, ½ ounce to one gallon of distilled or soft water, renewed every year or two, preserves fruits. Glycerine may be added to bring the fluid to the proper density.

Salicylic Acid, about 1 ounce to 5 gallons of water, with glycerine added in proportion to juiciness of fruits, usually from 8 to 15 per cent.

Salicylic Acid.—1 ounce is dissolved in 8 ounces of alcohol, which is added to 2 gallons of soft or distilled water. Recommended for dark fruits.

Zinc Chloride, 2 per cent. dissolved in water and filtered. Recommended for light-coloured and for yellow fruits.

Sulphurous Acid, 2 ounces of concentrated solution in 1 gallon of soft or distilled water. Said to be useful, but bleaches some and overcolours other fruits.

Sodium Bisulphite, ½ ounce, spirit 4 ounces, water 1 gallon. Dissolve the salt in half a pint of the water, add the rest of the water and the spirit, and filter.

Kerosene when pure is said to be good for fruits of Rubus.

I have not tried the methods within the brackets, owing to want of facilities while extension of buildings is going on.]

Dry Preparation.

For Herbarium.—For over twenty years I have employed wire frames, obtaining the requisite pressure by use of rug-straps or of old and pliant rope secured over the ends as well as the sides of the bundle. Pressure sufficient only to prevent shrinkage gives the best results. The wire frames permit of the easy application of artificial heat, and the results as to colour of all parts and as to retention of shape have been excellent, with a minimum of labour in changing papers. Plants that require specially careful handling and dissections are, of course, treated in thin sheets of paper, in which they lie till dry, the thin sheets being transferred unopened to the new sheets in changing the papers.

For 'Habit' and as Museum Specimens.—The specimens are exposed to dry air without special precautions, or are sometimes secured to prevent warping, or hung up in the position most likely to preserve the forms, a weight sometimes being suspended from each to prevent distortions in drying.

Some can be treated most satisfactorily by placing them in a box prepared with a sliding bottom and a wire partition near it to lay the plants on or to support them in it. Fine clean silver sand is then run around and between all parts of the specimen, and the box is placed for some days in a dry warm place until the plant is dried.

Preparation of Specimens.

Boiling has proved effective in preserving the natural arrangements of protoplasm, &c., in Spirogyra and other microscopic plants; and it has also been resorted to by me with advantage to prevent blackening of the tissues in some of the species notoriously apt to become black, both as herbarium specimens and in fluid.

I have also resorted to it with advantage in preparing succulent plants that are difficult to kill and to free of moisture, and also in lessening the tendency to the fall of the leaves in certain plants, such as *Erica.*

(*Exposure to Vapour of Chloroform, Ether*, or other poisonous gases till the plants are dead serves the same ends.)

Colouring or Staining.—I have employed this to bring into greater clearness the course of the bundles, but not to any great extent. Red or purplish-red flowers will retain their colour, or more often be coloured more brightly than natural, if dipped, before they are pressed, into a mixture of one part hydrochloric acid in four of spirit.

Drying Fungi.—I have tried the method devised by Mr. English ; but my results have not been satisfactory, though the form has in a good many been fairly well preserved. Hard fungi dry easily and well if exposed to air in a dry place.

Mounting Preparations.

Dry Preparations, including Herbarium Specimens.

Fixing to paper is done with fish-glue. The simplest and quickest method I find to be as follows :—A sheet of plate glass slightly larger than the herbarium sheet has a thin layer of glue smeared uniformly over it. The plant is then laid on this, and is pressed gently. Thus each part that will touch the paper has received a little of the glue, and on the specimen being laid on the paper it adheres wherever it should do so, and no other part is smeared. Of course this method is not suited for weak plants that could not be lifted without injury. The specimens after having been glued are placed under pressure for some hours.

Special dissections, seeds, and other small portions I place in a special envelope on the sheet, or under a piece of mica or of the gelatine used in Christmas crackers.

Preparations in Boxes are also fixed with fish-glue usually, unless the surface of attachment is very small, in which case they are secured by threads or wires to the bottom of the box.

Preparations in Fluids.—Photoxylin has been found to give sufficiently good results with many small objects, the slight opacity that is apt to show not being a serious objection to its use. Gelatine is used for larger objects.

Silk Thread has also proved very useful for some kinds of objects, allowing them to be easily fixed to mica or glass tablets, or to strips of hard paraffin, which do well sometimes. To the paraffin the specimens can sometimes be fixed conveniently by the use of a hot rod or wire to melt it at the point of contact. I have recently used xylonite for supports, but have scarcely had sufficient experience of it to warrant a definite conclusion. It appears to do best in solutions of formalin. Black xylonite loses its colour in spirit.

Poisoning Dry Preparations.

Mercuric Chloride is the substance of which I make most use for poisoning herbarium specimens, and also for disinfecting specimens and jars for fluid preparations. The herbarium specimens are most conveniently treated by dipping them into the solution, of the usual strength, in a shallow earthenware dish, handling them with wooden forceps, and placing them till quite dry under pressure between sheets of paper.

Carbon Disulphide is also most useful for fumigating bundles occasionally, the whole bundle being placed for a day or two in a large trough rendered air-tight by the usual method, the atmosphere in it being saturated with the vapour.

Exhibition of Specimens.

Morphological Preparations and Dissections to illustrate Systematic Characters, if mounted like herbarium specimens on stiff paper, and also ordinary herbarium specimens, can be well exhibited on any available wall-space by a method that I have used for some time, and that permits the rapid change of the specimens when desired, they being kept when not exhibited in the ordinary herbarium cases or in boxes. The sheets to be exhibited are placed in frames each consisting of a stiff back of card-board and front of glass, the two being separated by strips of wood, which in some are $\frac{3}{8}$ in. and in others only $\frac{3}{16}$ in. thick. The fourth side (top) is left open, and through it the sheet is dropped into the space. I use different sizes of frames, the largest being $17\frac{1}{2}$ in. by 11 in. in surface. To support the frames strips of wood are fixed against the wall, each strip being grooved so as to hold the frames both above and below itself, as shown in the sketches in the margin. The specimens are quite protected from injury and dust, and are very easily and rapidly inserted and removed at will.

Vessels for Specimens.

Fluid Preparations.—For these, after having tried all the various forms of jars and bottles that I could procure, I prefer the jar in most cases, and, where the expense is not an insurmountable obstacle, the rectangular jar with polished front. This is, of course, if the preparation is to be mounted for permanent preservation. For small objects I sometimes prefer bottles, either round or flat, as the narrower neck is more easily secured.

Dry Preparations I usually place in glass-topped boxes if it is desirable to protect them specially.

Methods of Sealing.

Hermetical Sealing.—I have employed this method with success for small objects that can be preserved in fluid or dry in tubes, *e.g.* some galls; but it is suited to only a limited number.

Corks for Bottles and Jars.—A coat of paraffin or of collodion helps a good deal to retard evaporation through corks, while not preventing their removal when wished.

Glass Tops.—I use these for the jars, the cover and the mouth of the jar both being ground. A convenient cement is isinglass dissolved in acetic acid, heated slightly to render it fit for use. This permits of the top being readily removed when necessary. It is rendered more secure by two coats of collodion painted over it when firm.

It is convenient to provide for the addition of fluid to replace any lost by evaporation after a time by having a small hole bored through the glass cover. This hole is closed with a cork. A more elaborate cement, composed of gum mastic, isinglass, and acetic acid, with a small admixture of gum galbanum and gum ammoniac, has proved useful and reliable in my experience.

Labelling.—I employ manuscript, type-written, or printed labels, as may be determined by the advantages in each case, and by the expense.

TRANSACTIONS OF THE SECTIONS.

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Section A.—MATHEMATICAL AND PHYSICAL SCIENCE

President of the Section—Professor J. J. Thomson, M.A., D.Sc., F.R.S.

THURSDAY, SEPTEMBER 17.

The President delivered the following Address:—

There is a melancholy reminiscence connected with this meeting of our Section, for when the British Association last met in Liverpool the chair in Section A was occupied by Clerk-Maxwell. In the quarter of a century which has elapsed since that meeting, one of the most important advances made in our science has been the researches which, inspired by Maxwell's view of electrical action, confirmed that view, and revolutionised our conception of the processes occurring in the electro-magnetic field. When the Association last met in Liverpool Maxwell's view was almost without supporters; to-day its opponents are fewer than its supporters then. Maxwell's theory, which is the development and extension of Faraday's, has not only affected our way of regarding the older phenomena of electricity, it has, in the hands of Hertz and others, led to the discovery of whole regions of phenomena previously undreamt of. It is sad to think that his premature death prevented him from reaping the harvest he had sown. His writings are, however, with us, and are a storehouse to which we continually turn, and never, I think, without finding something valuable and suggestive.

> 'Thus ye teach us day by day,
> Wisdom, though now far away.'

The past year has been rich in matters of interest to physicists. In it has occurred the jubilee of Lord Kelvin's tenure of the Professorship of Natural Philosophy at the University of Glasgow. Some of us were privileged to see this year at Glasgow an event unprecedented in the history of physical science in England, when congratulations to Lord Kelvin on the jubilee of his professorship were offered by people of every condition and country. Every scientific society and every scientific man is Lord Kelvin's debtor; but no society and no body of men owe him a greater debt than Section A of the British Association; he has done more for this Section than any one else, he has rarely missed its meetings, he has contributed to the Section papers which will make its proceedings imperishable, and by his enthusiasm he has year by year inspired the workers in this Section to renew with increased vigour their struggles to penetrate the secrets of Nature. Long may we continue to receive from him the encouragement and assistance which have been so freely given for the past half-century.

By the death of Sir W. R. Grove, the inventor of Grove's cell, we have lost a physicist whose name is a familiar one in every laboratory in the world. Besides the Grove cell, we owe to him the discovery of the gas battery, and a series of researches on the electrical behaviour of gases, whose importance is only now beginning to be appreciated. His essay on the correlation of the physical forces had great influence in promoting that belief in the unity of the various branches of physics which is one of the characteristic features of modern natural philosophy.

In the late Professor Stoletow, of Moscow, we have lost the author of a series of most interesting researches on the electrical properties of gases illuminated by ultra-violet light, researches which, from their place of publication, are, I am afraid, not so well known in this country as they deserve to be.

As one who unfortunately of late years has had only too many opportunities of judging of the teaching of science in our public and secondary schools, I should like to bear testimony to the great improvement which has taken place in the teaching of physics in these schools during the past ten years. The standard attained in physics by the pupils of these schools is increasing year by year, and great credit is due to those by whose labours this improvement has been accomplished. I hope I may not be considered ungrateful if I express the opinion that in the zeal and energy which is now spent in the teaching of physics in schools, there may lurk a temptation to make the pupils cover too much ground. You may by careful organisation and arrangement ensure that boys shall be taken over many branches of physics in the course of a short time; it is indeed not uncommon to find boys of 17 or 18 who have compassed almost the whole range of physical subjects. But although you may increase the rate at which information is acquired, you cannot increase in anything like the same proportion the rate at which the subject is assimilated, so as to become a means of strengthening the mind and a permanent mental endowment when the facts have long been forgotten.

Physics can be taught so as to be a subject of the greatest possible educational value, but when it is so it is not so much because the student acquires a knowledge of a number of interesting and important facts, as by the mental training the study affords in, as Maxwell said, 'bringing our theoretical knowledge to bear on the objects and the objects on our theoretical knowledge.' I think this training can be got better by going very slowly through such a subject as mechanics, making the students try innumerable experiments of the simplest and, what is a matter of importance in school teaching, of the most inexpensive kind, but always endeavouring to arrive at numerical results, rather than by attempting to cover the whole range of mechanics, light, heat, sound, electricity, and magnetism. I confess I regret the presence in examinations intended for school boys of many of these subjects.

I think, too, that in the teaching of physics at our universities there is perhaps a tendency to make the course too complex and too complete. I refer especially to the training of those students who intend to become physicists. I think that after a student has been trained to take accurate observations, to be alive to those pitfalls and errors to which all experiments are liable, mischief may in some cases be done if, with the view of learning a knowledge of methods, he is kept performing elaborate experiments, the results of which are well known. It is not given to many to wear a load of learning lightly as a flower. With many students a load of learning, especially if it takes a long time to acquire, is apt to crush enthusiasm. Now, there is, I think, hardly any quality more essential to success in physical investigations than enthusiasm. Any investigation in experimental physics requires a large expenditure of both time and patience; the apparatus seldom, if ever, begins by behaving as it ought; there are times when all the forces of nature, all the properties of matter, seem to be fighting against us: the instruments behave in the most capricious way, and we appreciate Coutts Trotter's saying, that the doctrine of the constancy of nature could never have been discovered in a laboratory. These difficulties have to be overcome, but it may take weeks or months to do so, and, unless the student is enthusiastic, he is apt to retire disheartened from the contest. I think, therefore, that the preservation of youthful enthusiasm is one of the most important points for consideration in the training of physicists. In my opinion this can best be done by allowing the student, even before he is supposed to be acquainted with the whole of physics, to begin some original research of a simple kind under the guidance of a teacher who will encourage him and assist in the removal of difficulties. If the student once tastes the delights of the successful completion of an investigation, he is not likely to go back, and will be better equipped for investigating the secrets of nature than if, like the White Knight of 'Alice in Wonderland,' he commences his career knowing how to measure or weigh every physical quantity under the sun, but with little desire or enthusiasm to have anything to do with any of them. Even for those students who intend to devote themselves to other pursuits than physical investigation, the benefits derived from original investigation as a means of general education can hardly be over-estimated; the necessity it entails of independent thought, perseverance in overcoming difficulties, and the weighing of evidence gives it an educational value which can hardly be rivalled. We have to congratulate ourselves that through the munificence of Mr. Ludwig Mond, in providing and endowing a laboratory for research, the opportunities for pursuing original investigations in this country have been greatly increased.

The discovery at the end of last year by Professor Röntgen of a new kind of radiation from a highly exhausted tube through which an electric discharge is passing has aroused an amount of interest unprecedented in the history of physical science. The effects produced *inside* such a tube by the cathode rays, the bright phosphorescence of the glass, the shadows thrown by opaque objects, the deflection of the rays by a magnet, have, thanks to the researches of Crookes and Goldstein, long been familiar to us, but it is only recently that the remarkable effects which occur outside such a tube have been discovered. In 1893 Lenard, using a tube provided with a window made of a very thin plate of aluminium, found that a screen impregnated with a solution of a phosphorescent substance became luminous if placed outside the tube in the prolongation of the line from the cathode through the aluminium window. He also found that photographic plates placed outside the tube in this line were affected, and electrified bodies were discharged; he also obtained by these rays photographs through plates of aluminium or quartz. He found that the rays were affected by a magnet, and regarded them as the prolongations of the cathode rays. This discovery was at the end of last year followed by that of Röntgen, who found that the region round the discharge tube is traversed by rays which affect a photographic plate after passing through substances such as aluminium or cardboard, which are opaque to ordinary light; which pass from one substance to another, without any refraction, and with but little regular reflection; and which are not affected by a magnet. We may, I think, for the purposes of discussion, conveniently divide the rays occurring in or near a vacuum tube traversed by an electric current into three classes, without thereby implying that they are necessarily distinctly different in physical character. We have (1) the cathode rays inside the tube, which are deflected by a magnet; (2) the Lenard rays outside the tube, which are also deflected by a magnet; and (3) the Röntgen rays, which are not, as far as is known, deflected by a magnet. Two views are held as to the nature of the cathode rays; one view is, that they are particles of gas carrying charges of negative electricity, and moving with great velocities which they have acquired as they travelled through the intense electric field which exists in the neighbourhood of the negative electrode. The phosphorescence of the glass is on this view produced by the impact of these rapidly moving charged particles, though whether it is produced by the mechanical violence of the impact, or whether it is due to an electro-magnetic impulse produced by the sudden reversal of the velocity of the negatively charged particle—whether, in fact, it is due to mechanical or electrical causes, is an open question. This view of the constitution of the cathode rays explains in a simple way the deflection of those rays in a magnetic field, and it has lately received strong confirmation from the results of an experiment made by Perrin. Perrin placed inside the exhausted tube a cylindrical metal vessel with a small hole in it, and connected this cylinder with the leaves of a gold-leaf electroscope. The cathode rays could, by means of a magnet, be guided so as either to pass into the cylinder through the aperture, or turned quite away from it. Perrin found that when the cathode rays passed into the cylinder the gold leaf of the electroscope diverged, and had a negative charge, showing that the bundle of cathode rays enclosed by the cylinder had a charge of negative electricity. Crookes had many years ago exposed a disc connected with a gold-leaf electroscope to the bombardment of the cathode rays, and found that the disc received a slight *positive* charge; with this arrangement, however, the charged particles had to give up their charges to the disc if the gold leaves of the electroscope were to be affected, and we know that it is extremely difficult, if not impossible, to get electricity out of a charged gas merely by bringing the gas in contact with a metal. Lord Kelvin's electric strainers are an example of this. It is a feature of Perrin's experiment that since it acts by induction the indications of the electroscope are independent of the communication of the charges of electricity from the gas to the cylinder, and since the cathode rays fall on the inside of the cylinder the electroscope would not be affected, even if there were such an effect as is produced when ultra-violet light falls upon the surface of an electro-negative metal when the metal acquires a positive charge. Since any such process cannot affect the total amount of electricity inside the cylinder, it will not affect the gold leaves of the electroscope; in fact, Perrin's experiments prove that the cathode rays carry a charge of negative electricity.

The other view held as to the constitution of the cathode rays is that they are waves in the ether. It would seem difficult to account for the result of Perrin's experiment on this view, and also I think very difficult to account for the magnetic deflection of the rays. Let us take the case of a uniform magnetic field: the experiments which have been made on the magnetic deflection of these rays seem to make it clear that in a magnetic field which is sensibly uniform, the path of these rays is curved; now if these rays were due to ether waves, the curvature of the path would show that the velocity of propagation of these waves varied from point to point of the path. That is, the velocity of propagation of these waves is not only affected by the magnetic field, it is affected differently at different parts of the field. But in a uniform field what is there to differentiate one part from another, so as to account for the variability of the velocity of wave propagation in such a field? The curvature of the path in a uniform field could not be accounted for by supposing that the velocity of this wave motion depended on the strength of the magnetic field, or that the magnetic field, by distorting the shape of the boundary of the negative dark space, changed the direction of the wave front, and so produced a deflection of the rays. The chief reason for supposing that the cathode rays are a species of wave motion is afforded by Lenard's discovery, that when the cathode rays in a vacuum tube fall on a thin aluminium window in the tube, rays having similar properties are observed on the side of the window outside the tube; this is readily explained on the hypothesis that the rays are a species of wave motion to which the window is partially transparent, while it is not very likely that particles of the gas in the tube could force their way through a piece of metal. This discovery of Lenard's does not, however, seem to me incompatible with the view that the cathode rays are due to negatively charged particles moving with high velocities. The space outside Lenard's tube must have been traversed by Röntgen rays: these would put the surrounding gas in a state in which a current would be readily started in the gas if any electromotive force acted upon it. Now, though the metal window in Lenard's experiments was connected with the earth, and would, therefore, screen off from the outside of the tube any effect arising from slow electrostatic changes in the tube, it does not follow that it would be able to screen off the electrostatic effect of charged particles moving to and from the tube with very great rapidity. For in order to screen off electrostatic effects, there must be a definite distribution of electrification over the screen: changes in this distribution, however, take a finite time, which depends upon the dimensions of the screen and the electrical conductivity of the material of which it is made. If the electrical changes in the tube take place at above a certain rate, the distribution of electricity on the screen will not have time to adjust itself, and the screen will cease to shield off all electrostatic effects. Thus the very rapid electrical changes which would take place if rapidly moving charged bodies were striking against the window might give rise to electromotive forces in the region outside the window, and produce convection currents in the gas which has been made a conductor by the Röntgen rays. The Lenard rays would thus be analogous in character to the cathode rays, both being convective currents of electricity. Though there are some points in the behaviour of these Lenard rays which do not admit of a very ready explanation from this point of view, yet the difficulties in its way seem to me considerably less than that of supposing that a wave in the ether can change its velocity when moving from point to point in a uniform magnetic field.

I now pass on to the consideration of the Röntgen rays. We are not yet acquainted with any crucial experiment which shows unmistakably that these rays are waves of transverse vibration in the ether, or that they are waves of normal vibration, or indeed that they are vibrations at all. As a working hypothesis, however, it may be worth while considering the question whether there is any property known to be possessed by these rays which is not possessed by some form or other of light. The many forms of light have in the last few months received a noteworthy addition by the discovery of M. Becquerel of an invisible radiation, possessing many of the properties of the Röntgen rays, which is emitted by many fluorescent substances, and to an especially marked extent by the uranium salts. By means of this radiation, which, since it can be polarised, is unquestionably light, photographs through opaque substances similar to, though not so beautiful as, those obtained by means of Röntgen rays can be taken, and, like the Röntgen rays, they cause an electrified body on which they shine to lose its charge, whether this be positive or negative.

The two respects in which the Röntgen rays differ from light is in the absence of refraction and perhaps of polarisation. Let us consider the absence of refraction first. We know cases in which special rays of the spectrum pass from one substance to another without refraction; for example, Kundt showed that gold, silver, copper, allow some rays to pass through them without bending, while other rays are bent in the wrong direction. Pflüger has lately found that the same is true for some of the aniline dyes when in a solid form. In addition to this, the theory of dispersion of light shows that there will be no bending when the frequency of the vibration is very great. I have here a curve, taken from a paper by Helmholtz, which shows the relation between the refractive index and the frequency of vibration for a substance whose molecules have a natural period of vibration, and one only; the frequency of this vibration is represented by OK in the diagram. The refractive index increases with the frequency of the light until the latter is equal to the frequency of the natural vibration of the substance; the refractive index then diminishes, becomes less than unity, and finally approaches unity, and is practically equal to it when the frequency of the light greatly exceeds that of the natural vibration of the molecule. Helmholtz's results are obtained on the supposition that a molecule of the refracting substance consists of a pair of oppositely electrified atoms, and that the specific inductive capacity of the medium consists of two parts, one due to the ether, the other to the setting of the molecules along the lines of electric force.

Starting from this supposition we can easily see without mathematical analysis that the relation between the refractive index and the frequency must be of the kind indicated by the curve. Let us suppose that an electromotive force of given amplitude acts on this mixture of molecules and ether, and let us start with the frequency of the external electromotive force less than that of the free vibrations of the molecules: as the period of the force approaches that of the molecules, the effect of the force in pulling the molecules into line will increase; thus the specific inductive capacity, and therefore the refractive index, increases with the frequency of the external force; the effect of the force on the orientation of the molecules will be greatest when the period of the force coincides with that of the molecules. As long as the frequency of the force is less than that of the molecules, the external field tends to make the molecules set so as to increase the specific inductive capacity of the mixture; as soon, however, as the frequency of the force exceeds that of the molecules, the molecules, if there are no viscous forces, will all topple over and point so as to make the part of the specific inductive capacity due to the molecules of opposite sign to that due to the ether. Thus, for frequencies greater than that of the molecules, the specific inductive capacity will be less than unity. When the frequency of the force only slightly exceeds that of the molecules, the effect of the external field on the molecules is very great, so that if there are a considerable number of molecules, the negative part of the specific inductive capacity due to the molecules may be greater than the positive part due to the ether, so that the specific inductive capacity of the mixture of molecules and ether would be negative; no waves of this period could then travel through the medium—they would be totally reflected from the surface.

As the frequency of the force gets greater and greater, its effect in making the molecules set will get less and less, but the waves will continue to be totally reflected until the negative part of the specific inductive capacity due to the molecules is just equal to the positive part due to the ether. Here the refractive index of the mixture is zero. As the frequency of the force increases, its effect on the molecules gets less and less, so that the specific inductive capacity continually approaches that due to the ether alone, and practically coincides with it as soon as the frequency of the force is a considerable multiple of that of the molecules. In this case both the specific inductive capacity and the refractive index of the medium are the same as that of the ether, and there is consequently no refraction. Thus the absence of refraction, instead of being in contradiction to the Röntgen rays, being a kind of light, is exactly what we should expect if the wave-length of the light were exceedingly small.

The other objection to these rays being a kind of light is, that there is no very conclusive evidence of the existence of polarisation. Numerous experiments have been made on the difference between the absorption of these rays by a pair of tourmaline plates when their axes are crossed or parallel. Many observers have failed to observe any difference at all between the absorption in the two cases. Prince Galitzine and M. de Karnojitsky, by a kind of cumulative method, have obtained photographs which seem to show that there is a slightly greater absorption when the axes are crossed than there is when the axes are parallel. There can, however, be no question that the effect, if it exists at all, is exceedingly small compared with the corresponding effect for visible light. Analogy, however, leads us to expect that to get polarisation effects we must use, in the case of short waves, polarisers of a much finer structure than would be necessary for long ones. Thus a wire bird-cage will polarise long electrical waves, but will have no effect on visible light. Rubens and Du Bois made an instrument which would polarise the infra red rays by winding very fine wires very close together on a framework; this arrangement, however, was too coarse to polarise visible light. Thus, though the structure of the tourmaline is fine enough to polarise the visible rays, it may be much too coarse to polarise the Röntgen rays if these have exceedingly small wave-lengths. As far as our knowledge of these rays extends, I think we may say that though there is no direct evidence that they are a kind of light, there are no properties of the rays which are not possessed by some variety of light.

It is clear that if the Röntgen rays are light rays, their wave-lengths are of an entirely different order from those of visible light. It is perhaps worth notice that on the electro-magnetic theory of light we might expect two different types of vibration if we suppose that the atoms in the molecule of the vibrating substance carried electrical charges. One set of vibrations would be due to the oscillations of the bodies carrying the charges, the other set to the oscillation of the charges on these bodies. The wave-length of the second set of vibrations would be commensurate with molecular dimensions; can these vibrations be the Röntgen rays? If so, we should expect them to be damped with such rapidity as to resemble electrical impulses rather than sustained vibrations.

If we turn from the rays themselves to the effects they produce, we find that the rays alter the properties of the substances through which they are passing. This change is most apparent in the effects produced on the electrical properties of the substances. A gas, for example, while transmitting these rays is a conductor of electricity. It retains its conducting properties for some little time after the rays have ceased to pass through it; but Mr. Rutherford and I have lately found that the conductivity is destroyed if a current of electricity is sent through the Röntgenised gas. The gas in this state behaves in this respect like a very dilute solution of an electrolyte. Such a solution would cease to conduct after enough electricity had been sent through it to electrolyse all the molecules of the electrolyte. When a current is passing through a gas exposed to the rays, the current destroys and the rays produce the structure which gives conductivity to the gas; when things have reached a steady state the rate of destruction by the current must equal the rate of production by the rays. The current can thus not exceed a definite value, otherwise more of the conducting gas would be destroyed than is produced.

This explains the very characteristic feature that in the passage of electricity through gases exposed to Röntgen rays the current, though at first proportional to the electromotive force, soon reaches a value where it is almost constant and independent of the electromotive force, and we get to a state when a tenfold increase in the electromotive force only increases the current by a few per cent. The conductivity under the Röntgen rays varies greatly from one gas to another, the halogens and their gaseous compounds, the compounds of sulphur, and mercury vapour, are among the best conductors. It is worthy of note that those gases which are the best conductors when exposed to the rays are either elements, or compounds of elements, which have in comparison with their valency very high refractive indices.

The conductivity conferred by the rays on a gas is not destroyed by a considerable rise in temperature; it is, for example, not destroyed if it be sucked through metal tubing raised to a red heat. The conductivity is, however, destroyed if the gas is made to bubble through water; it is also destroyed if the gas is forced through a plug of glass wool. This last effect seems to indicate that the structure which confers conductivity on the gas is of a very coarse kind, and we get confirmation of this from the fact that a very thin layer of gas exposed to the Röntgen rays does not conduct nearly so well as a thicker one. I think we have evidence from other sources that electrical conduction is a process that requires a considerable space—a space large enough to inclose a very large number of molecules.

Thus Koller found that the specific resistances of petroleum, turpentine, and distilled water, when determined from experiments made with very thin layers of these substances, were very much larger than when determined from experiments with thicker layers. Even in the case of metals there is evidence that the metal has to be of appreciable size if it is to conduct electricity. The theory of the scattering of light by small particles shows that, if we assume the truth of the electro-magnetic theory of light, the effects should be different according as the small particles are insulators or conductors. When the small particles are non-conductors, theory and experiment concur in showing that the direction of complete polarisation for the scattered light is at right angles to the direction of the incident light, while if the small particles are conductors, theory indicates that the direction of complete polarisation makes an angle of 60° with the incident light. This result is not, however, confirmed by the experiments made by Professor Threlfall on the scattering of light by very small particles of gold. He found that the gold scattered the light in just the same way as a non-conductor, giving complete polarisation at right angles to the incident light. This would seem to indicate that those very finely divided metallic particles no longer acted as conductors. Thus there seems evidence that in the case of conduction through gases, through badly conducting liquids, and through metals, electric conduction is a process which requires a very considerable space and aggregations of large numbers of molecules. I have not been able to find any direct experimental evidence as to whether the same is true for electrolytes. Experiments on the resistance of thin layers of electrolytes would be of considerable interest, as according to one widely accepted view of electrolysis conduction through electrolytes, so far from being effected by aggregations of molecules, takes place by means of the ion, a structure simpler than that of the molecule, so that if this represents the process of electrolytic conduction, there would not seem room for the occurrence of an effect which occurs with every other kind of conduction.

In this building it is only fitting that some reference should be made to the question of the movement of the ether. You are all doubtless acquainted with the heroic attempts made by Professor Lodge to set the ether in motion, and how successfully the ether resisted them. It seems to be conclusively proved that a solid body in motion does not set in motion the ether at an appreciable distance outside it; so that if the ether is disturbed at all in such a case, the disturbance is not comparable with that produced by a solid moving through an incompressible fluid, but must be more analogous to that which would be produced by the motion through the liquid of a body of very open structure, such as a piece of wire netting, where the motion of the fluid only extends to a distance comparable with the diameter of the wire, and not with that of the piece of netting. There is another class of phenomena relating to the movement of the ether which is, I think, deserving of consideration, and that is the effect of a varying electro-magnetic field in setting the ether in motion. I do not remember to have seen it pointed out that the electro-magnetic theory of light implicitly assumes that the ether is not set in motion even when acted on by mechanical forces. On the electro-magnetic theory of light such forces do exist, and the equations used are only applicable when the ether is at rest. Consider, for example, the case of a plane electric wave travelling through the ether. We have parallel to the wave front a varying electric polarisation, which on the theory is equivalent to a current; at right angles to this, and also in the wave-front, we have a magnetic force. Now, when a current flows through a medium in a magnetic field there is a force acting on the medium at right angles to the plane, which is parallel both to the current and to the magnetic force; there will thus be a mechanical force acting on each unit volume of the ether when transmitting an electric wave, and since this force is at right angles to the current and to the magnetic force, it will be in the direction in which the wave is propagated. In the electro-magnetic theory of light, however, we assume that this force does not set the ether in motion, as unless we made this assumption we should have to modify our equations, as the electro-magnetic equations are not the same in a moving field as in a field at rest. In fact, a complete discussion of the transmission of electro-magnetic disturbances requires a knowledge of the constitution of the ether, which we do not possess. We now assume that the ether is not set in motion by an electro-magnetic wave. If we do not make this assumption we must introduce into our equation quantities representing the components of the velocity of the ether, and unless we know the constitution of the ether, so as to be able to deduce these velocities from the forces acting on it, there will be in the equations of the electro-magnetic field more unknown quantities than we have equations to determine. It is, therefore, a very essential point in electromagnetic theory to investigate whether or not there is any motion of the ether in a varying electro-magnetic field. We have at the Cavendish Laboratory, using Professor Lodge's arrangement of interference fringes, made some experiments to see if we could detect any movement of the ether in the neighbourhood of an electric vibrator, using the spark which starts the vibrations as the source of light. The movement of the ether, if it exists, will be oscillatory, and with an undamped vibrator the average velocity would be zero; we used, therefore, a heavily damped vibrator, with which the average velocity might be expected to be finite. The experiments are not complete, but so far the results are entirely negative. We also tried by the same method to see if we could detect any movement of the ether in the neighbourhood of a vacuum-tube emitting Röntgen rays, but could not find any trace of such a movement. Professor Threlfall, who independently tried the same experiment, has, I believe, arrived at the same conclusion.

Unless the ether is immovable under the mechanical forces in a varying electromagnetic field, there are a multitude of phenomena awaiting discovery. If the ether does move, then the velocity of transmission of electrical vibrations, and therefore of light, will be affected by a steady magnetic field. Such a field, even if containing nothing but ether, will behave towards light like a crystal, and the velocity of propagation will depend upon the direction of the rays. A similar result would also hold in a steady electric field. We may hope that experiments on these and similar points may throw some light on the properties of that medium which is universal, which plays so large a part in our explanation of physical phenomena, and of which we know so little.

The following Report and Papers were read:—

1. *Report on the Establishment of a National Physical Laboratory.*

See Reports, p. 82.

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2. *On the Evolution of Stellar Systems. By* Isaac Roberts, *D.Sc., F.R.S.*

The evidence of stellar evolution which it is now proposed to submit may be presented in either of two forms:—(1) By tracing back from the visually finished stars to the material of which they may have been built up; this we may term the analytical method. (2) By tracing their development from an amorphous material to the visually finished stars; this would be the synthetical method. The first of these will now be considered.

It should be noted that the evidence has been obtained by processes which are not subject to the disturbing influence of human or personal imperfections.

A series of photographs, untouched by handwork, were shown, and the objects as they undoubtedly exist in the sky were thus submitted to judgment.

A small selection of characteristic photographs were exhibited by lantern projections on a screen.

The first was a photograph of the sky in the constellation *Auriga*, which was taken with an exposure of the plate during 90 minutes, and attention was drawn to the remarkable groups, curves, and lines of stars which were clearly shown upon it. Some of them are constituted of bright stars of nearly equal magnitude; some are of faint stars, also of nearly equal magnitude; some are of both bright and faint stars, and there is much regularity in the spacing distance between the stars in the several groups. These appearances are persistently found upon all photographs, taken with a long exposure, in any part of the sky where the stars are numerous.

In order to emphasise these statements, two photographs of stars in the constellation *Argo* and one in *Cassiopeia* were shown on the screen, and upon them also was seen the appearances referred to; and hundreds of photographs of other regions of the sky could be shown in further confirmation of these features.

The explanation offered to account for the grouping of the stars, that they were so placed from the beginning, is not the only one. Photographs were then shown which suggest, if they do not demonstrate, stellar evolution.

The spiral nebula in *Pisces* clearly shows that the spirals consist of nebulous matter with faint stars immersed in it, and of bright stars apparently in their completed forms. The curvatures and the general arrangements of these stars, both bright and faint, can be readily matched with similar curves seen on the photographs already shown; but the faint stars which are immersed in the nebulosity are not yet in the completed form, and will not arrive at that stage until the whole of the nebulosity has been absorbed, when they will stand out clearly separated like the other stars.

The spiral nebula in the constellation *Ursa Major*, like the last, has spirals formed of nebulous matter, with numerous starlike condensations in it; and six well-defined stars are involved at irregular intervals. The nebulous condensations are not so regular in their outlines as are those on the first photograph, and are suggestive of a more recent period in their development.

The spiral nebula in *Ursa Major*, like the two others, consists of faint starlike condensations immersed in the convolutions. There are also five well-formed stars involved, but the stellar condensations are less fully developed in this nebula.

The fourth photograph was of the spiral nebula in *Canes Venatici*, and it was observed that the convolutions are more strongly shown in this than in the other nebulæ; also that they consist of several well-formed stars, whilst the star-like condensations show various degrees of development, from the likeness of a nebulous star to that of diffused nebulosity.

The fifth photograph, the spiral nebula in *Triangulum*, shows the spirals to be crowded with stars and star-like condensations in the midst of diffused nebulosity.

The convolutions are less symmetrical in their outlines than are those of the other spirals exhibited.

The evidence, part of which had been laid before the Section, is reasonably conclusive that some, if not many, of the stars which we see in curves and in groups strewn over the sky have been formed in the manner pointed out. There are, besides this, other methods of stellar evolution, shown in other photographs, such as condensations into stars of nebulæ which have not at present symmetrical structures and outlines—of globular nebulæ and of annular nebulæ; but these were not described.

If it be true that stars are evolved from spiral and other forms of nebulosity, it may be asked, Whence came the nebulous matter? We can answer with confidence that it exists in very large quantities over extensive areas, and in many parts of the sky; and that it exists there in the form of gas, or, more probably, as Professor Norman Lockyer urges, in his 'Meteoritic Hypothesis,' of meteors or meteoric dust.

There is also evidence that collisions between bodies in space take place—perhaps large bodies may collide, with the result that their component materials would again be converted into gas, meteoric dust, and meteoric stones. Whatever the sources of the nebular material may be, we know that collisions in space would supply the energy requisite for the formation of the spiral nebulæ, of the existence and the forms of which now we have ample proof.

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3. *On Periodic Orbits.* *By* G. H. Darwin, *F.R.S.*

If a planet, say Jove, of unit mass, moves in a circular orbit round the sun, of mass $(n^2-1)^{\frac{1}{2}}$, at unit distance, the equations of motion of an infinitesimal third body, referred to heliocentric origin, with x axis passing through Jove, are

$$\frac{d^2x}{dt^2}-2n\frac{dy}{dt}=\frac{d\Omega}{dx},$$
$$\frac{d^2y}{dt^2}+2n\frac{dx}{dt}=\frac{d\Omega}{dy},$$

and the Jacobian integral is

$$\left(\frac{dx}{dt}\right)^2+\left(\frac{dy}{dt}\right)^2=2\Omega-C,$$

where C is a constant. The function Ω is given by

$$2\Omega=(n^2-1)^{\frac{1}{2}}\left(r^2+\frac{2}{r}\right)+\left(\rho^2+\frac{2}{\rho}\right),$$

where r, ρ are the heliocentric and jovicentric radii vectores.

The curves defined by $2\Omega=C$ give a partition of space into regions where the velocity is real, and those where it is imaginary.

From these curves are obtained an inferior limit to the heliocentric distance of a superior planet, and superior limits to the heliocentric and jovicentric distances of an inferior planet and of a satellite.

There are four critical cases, corresponding to the four exact solutions of the problem, in which the three bodies move round without relative motion.

Solutions of these equations, which are represented by closed curves, are called periodic orbits, and if they are re-entrant after a single circuit, they are called simply periodic orbits.

The object in view is to obtain a complete synopsis of simply periodic orbits, and of their stabilities, for all values of C. This can only be done in a concrete case, and the sun's mass is taken as ten times that of Jove, and the orbits are determined by the method of quadratures.

The field to be covered is so large that up to the present time it has been found necessary to pass over the retrograde orbits and the superior planets; and only a portion of the cases of inferior planets and satellites have been as yet considered. A number of figures were shown, amongst which may be mentioned some exhibiting orbits of oscillating satellites, and orbits with cusps and loops. Perhaps the most curious cases are those representing the orbits of satellites, which present three new moons in a month, and another with five full moons in a month.

The consideration of the stability of the orbits shows that there are stable satellites close to Jove, or at some distance from Jove; but that there is a tract between these two in which no stable motion can take place. This conclusion appears to throw some light on Bode's empirical law as to the distribution of planets and satellites.

A paper containing an account of this investigation will appear in the Acta Mathematica of Stockholm.

FRIDAY, SEPTEMBER 18.

The following Papers were read:—

1. *On Cathode Rays and their probable connection with Röntgen Rays. By* Professor PHILIPP LENARD, *Aachen.*

Until a few years ago it was impossible to make experiments on cathode rays under modified conditions, because it was impossible to vary their surroundings without at the same time altering the circumstances under which they were produced. Hertz's discovery that thin sheets of metals were transparent to the cathode rays has enlarged the field of experiment. By making a small aluminium window in one end of the discharge-tube the rays can now be allowed to go out from the space where they were generated; they can thus be investigated without altering the conditions of generation, and therewith the properties of the rays themselves. The cathode rays emerge into air at ordinary pressure, but they are very rapidly absorbed by it, so that at a distance of from 6 to 8 centimetres no trace of them is visible on a screen capable of phosphorescence. The free atmosphere proves, moreover, to be a turbid medium to these rays, their propagation behind shadow-casting objects being similar to the propagation of light in milk. Other gases of equal density behave in the same way. But as the density of a gas is diminished by lowering its pressure, it becomes more transparent and less turbid. In the highest vacuum that can be produced there is no limit to the transmission of the rays, and behind a diaphragm they are quite as sharp as rays of light are under the same circumstances. From the fact that the rays are not stopped by a space containing only minute traces of matter it is concluded that they are processes going on in the ether.

The absorption of the rays in various substances can also be investigated. It is found to be in every case approximately proportional to the density of the medium, whether this be solid or gaseous, and whatever be its chemical nature.

The rays are deflected by a magnet, and it was found that in this respect there were different kinds of cathode rays, those which are produced when the discharge-tube was more exhausted being less deflectible than those produced when it was less exhausted. The deflectibility of the rays depends also in other respects on the circumstances of their production; it is, however, quite unalterable by any change in the observing-space. Whatever the nature or the pressure of the gas in this space was, the deflectibility of the rays remained the same whenever it could be tested—*i.e.* whenever the density of the gas was such as allowed rays of some sharpness to be obtained. This was the case, for instance, in common air below about one tenth of an atmosphere, and in hydrogen of ordinary or any smaller pressure. The deflectibility of the rays was also found to be the same before and after traversing an air-tight sheet of aluminium set up in the observing-space.

The deflectibility of a cathode ray once produced being thus quite unalterable, its magnitude may serve as a characteristic to denote any particular kind of cathode ray. Rays of smaller deflectibility were found to be less easily absorbed and diffused by all substances than rays of greater deflectibility. It might therefore be expected that there exists an extreme form of cathode rays which is not perceptibly deflected by a magnet, and which is accordingly very slightly absorbed and diffused by all substances, but which would have the same property of being absorbed by all substances approximately in proportion to their density. The rays discovered by Röntgen agree in these respects with such cathode rays; they agree with them also in other respects, and, in fact, no observation yet made contradicts the hypothesis that the Röntgen rays are of the same nature as the cathode rays, being an extreme form of cathode ray with zero deflectibility.

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2. *On the Laws of Conduction of Electricity through Gases exposed to the Röntgen Rays. By* Professor J. J. THOMSON, *F.R.S., and* E. RUTHERFORD.

[Published in the *Phil. Mag.*, Nov. 1896, pp. 392–417.]

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3. *On the Transparency of Glass and Porcelain to the Röntgen Rays. By* A. W. RÜCKER, *F.R.S., and* W. WATSON, *B.Sc.*

The transparency to the X-rays of a number of different pieces of the same kind of glass up to a total thickness of 5·1 mm. was determined by the photometric method.

The results can be expressed very approximately by the formula

$$I = I_0\{0{\cdot}2 + 0{\cdot}8 \times 0{\cdot}35794_t\},$$

where I_0 is the intensity of the phosphorescent light when no absorbing medium is interposed, and I the intensity when the X-rays have passed through t mm. of the glass used. This suggests that the rays emitted by the tube consist of two great groups, to one of which the glass is very transparent, while the remainder are absorbed according to the ordinary law.

Observations were then made on the ratio between the transparency of different kinds of porcelain to that of glass of the same thickness. The specimens were in part lent by the authorities of the South Kensington Museum, and were in part selected from a small collection belonging to one of the authors.

The mean results were as follows:—

Phosphatic Soft Paste	Bow opaque. Chelsea-Derby opaque to	0·42
	Chelsea	0·27
	Crown Derby	0·37
Soft Paste	Worcester	0·36
Hard Paste	Bristol Cottage Ware	0·56
Soft, but glass-like Paste	Nantgarw	0·80
	Swansea	0·86
Hard Paste	Bristol	1·05
	Oriental	0·93

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4. *Measurement of Electric Currents through Air at different Densities down to one Five-millionth of the Density of Ordinary Air. By* Lord KELVIN, J. T. BOTTOMLEY, *and* MAGNUS MACLEAN.

The apparatus used in these experiments consisted of (1) a cylindrical tube 13 cms. long and $1\frac{1}{2}$ cm. diameter, with two aluminium wires as terminals ground to points 1·5 cm. apart; (2) a large Wimshurst electrostatic machine of 24 plates; (3) a high-resistance mirror galvanometer to measure the current between the aluminium-point terminals inside the tube; (4) an electrostatic voltmeter to measure the difference of potential between the terminals of the tube; (5) a five-fall Sprengel pump, by means of which the density of the air inside the tube could be reduced to any desired extent. The galvanometer was placed on a block of paraffin between one terminal of the electric machine and one terminal of the glass tube. Its deflections were read by a telescope and its sensibility was arranged by external magnets, so that one division of deflection corresponded to 0·3 mikroampere. Our method of experimenting was to keep the density of the air constant while we varied the difference of potential between the terminals of the tube, and taking simultaneous readings on the voltmeter and on the galvanometer. The electric potential was varied either by varying the speed of rotation of the machine or by varying the distance between the needle-point terminals of the machine, or by a combination of both.

We found that at ordinary atmospheric density it requires a difference of potential of between 2,000 and 3,000 volts at the terminals of the tube before the galvanometer indicates any current. As the difference of potential is now increased, the current through the galvanometer increases at a greater ratio, so that if a curve be drawn with differences of potential as abscissæ and galvanometer readings or currents as ordinates, the curve is always concave towards the axis of current. Through this particular tube the currents at 3,000, 5,000, and 8,000 volts difference of potential were 7·2, 17·6, and 63·2 mikroamperes respectively. As the density of the air was diminished, the difference of potential necessary to start a current, as indicated by the galvanometer, gradually diminished also, till, at a density of about $\frac{1}{1000}$ of the ordinary density, a few score volts were sufficient to start a current. For the same difference of potential the current increased as the density of the air diminished; or, otherwise, the same current was obtained by smaller differences of potential as the density of the air was reduced. Thus a current of about 56 mikroamperes was obtained by differences of potential of 7,400, 1,090, 700, 370, 405, 570 volts, when the densities of the air were 1 (ordinary density), 0·058, 0·0093, 0·0007, 0·00006, 0·000024 respectively; or, otherwise, when the air pressures were 750, 44, 7, $\frac{1}{2}$, $\frac{1}{22}$, $\frac{1}{55}$ millimetres of mercury respectively.

As the air density was still further reduced, the difference of potential necessary to start a current increased, and the current for the same difference of potential diminished. Thus, when the density of the air was reduced to one five-millionth of the density of air at ordinary atmospheric pressure and temperature, differences of potential of 3,000, 5,000, and 8,000 volts gave currents of 1·3, 4·4, and 14·6 mikroamperes respectively.

If a curve be drawn for a constant difference of potential, with air densities as abscissæ and currents as ordinates, we find the curve rising as the air density is diminished to about $\frac{1}{1000}$ or $\frac{1}{1500}$ of ordinary density; then falling again as the density is still further reduced to about a five-millionth of ordinary density. This is the lowest density we have experimented with, but we have no reason to doubt that at very much lower densities we would still be able to get measurable currents through the tube.

We are now experimenting with a tube 13 cms. long and $1\frac{1}{2}$ cm. diameter, having ball terminals of $\frac{1}{2}$ cm. diameter and about 2 mm. apart. The investigation is not complete enough for publishing any results.

5. *The Duration of X-Radiation at each Spark.*

By FRED. T. TROUTON, *M.A., D.Sc.*

The object of these experiments was to ascertain how long a Crookes' tube continued at each spark to give out Röntgen radiation.

The method adopted was to rotate a metallic-toothed wheel (cut out of sheet zinc) interposed between a tube and a sensitive photographic plate. Only one spark is allowed to pass by making one brake of the primary of the inductive coil used. The departure from sharpness of outline of the image of the moving teeth on development is observed and measured in terms of the width of a tooth. If the speed of rotation is known, the length of time the effective radiation persists can be at once deduced.

A mercury brake worked simply by hand was generally used. The tube was distant from the plate about eight centimetres.

When the wheel is rotated sufficiently fast, a drawing out of the image is always observed; but the amount of this drawing out in each case is found to vary in an important way with circumstances, and is probably but a measure of the length of time the E.M.F. remains above the value necessary for discharge, and thus ultimately depends upon the arrangements used—the coil, &c.

If a spark gap in parallel with the tube be provided, the drawing out is cut short by the passage of a spark at the gap. How early this occurs depends on the distance between the sparking points. In this way comparatively sharp-looking images are obtainable without otherwise altering the arrangements.

The time the radiation lasted, as measured from the photographs obtained in this way, varied from, roughly, the $\frac{1}{800}$ to the $\frac{1}{10000}$ of a second. In the first case the points were too far apart for a spark to pass; in the latter the points were as near as possible consistent with getting any photographic effect.

Experiments can also be made by using a phosphorescent screen, but the measurements are not capable of being made with the same certainty; however, it is a more convenient way to demonstrate the existence of the early cut-off in the duration of the radiation caused by a parallel spark.

When the brake of the primary is made by hand by means of the usual hammer arrangements, the results sometimes are difficult to explain. Often three images appear as if three sparks occurred, each image being drawn out. This might be merely due to something oscillatory in the circuits, but for the fact that the character of the drawing out is peculiar, the half shadow region shading the wrong way. That is to say, instead of passing uniformly in shade from the longer exposed parts to the parts always covered while the radiation lasted, there is a fluctuation in intensity, so that a tooth is bounded first by a dark line or band, while the region longer exposed outside this is not so black.

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6. *On the Relations between Kathode Rays, Röntgen Rays, and Becquerel Rays.* *By* Professor SILVANUS P. THOMPSON, *F.R.S.*

The author described experiments, made with vacuum tubes of several shapes, to test several points in the relations between the various kinds of rays. It was found that when kathode rays were caused to fall on an oblique platinum piece in the interior of the tube, true kathodic shadows could be obtained in the rays reflected from the platinum surface, from metallic and other objects interposed between this target and the walls of the tube. These shadows were deflected by magnets, and were affected in size by electrifying the interposed objects. At the same time, and when the tube was sufficiently highly exhausted, Röntgen-ray shadows were obtained on a luminescent screen outside; but these shadows, unlike the shadows of the reflected kathodic rays within the tube, were not deflected by either magnetic or electrostatic influences. Experiments on filtering the kathodic rays, direct and reflected, through screens of aluminium of various thicknesses showed that the more deflectable rays were more easily stopped by screens than the less deflectable; and that the power of producing luminescence in different bodies differed for rays of different deflectability. Uranium, as a target, appeared to be more active than platinum in evoking emission of Röntgen rays.

SATURDAY, SEPTEMBER 19.

The Section was divided into two Departments.

The following Reports and Papers were read:—

DEPARTMENT I.—PHYSICS.

1. *Report on the Comparison of Magnetic Standards.*
See Reports, p. 87.

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2. *Report on the Comparison and Reduction of Magnetic Observations.*
See Reports, p. 231.

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3. *Adjourned Discussion on* Professor S. P. THOMPSON'S *Paper on the Relation between Kathode Rays, Röntgen Rays, and Becquerel's Rays.*

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4. *On Hyperphosphorescence.*
By Professor SILVANUS P. THOMPSON, *D.Sc., F.R.S.*

This phenomenon, discovered by the author independently at the same time with M. Henri Becquerel, consists in the persistent emission by certain substances, notably by metallic uranium and its salts, of invisible rays which closely resemble Röntgen rays in their photographic action, and in their power of penetrating aluminium, and of producing diselectrification.

The author finds the order of transparency of substances to be different for these rays from that which exists for Röntgen's rays. He has also observed photographic action through opaque screens of paper by light emitted from phosphorus slowly oxidising in air. The hyperphosphorescence of uranium in the metallic state is about equal in darkness and when exposed to light, but with uranium nitrate the continued stimulation of light promotes the emission of these rays. No similar rays exist either in arc light or in sunlight as observed in London.

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5. *Observations on the X-Rays.* *By* H. H. F. HYNDMAN.

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6. *On the Component Fields of the Earth's Permanent Magnetism.*
By Dr. L. A. BAUER.

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7. *On a One-Volt Standard Cell with Small Temperature Coefficient.*
By W. HIBBERT.

The author and Mr. Sewell have worked for two years at improving a cell first made by Helmholtz. The elements are zinc and mercury, in a solution of chloride of zinc. To get a potential difference of one volt the solution must be pure, and have a density of about 1·380.

The temperature coefficient is only one ten-thousandth of a volt for 1° Centigrade.

The cell has many other advantages. Its resistance remains constant, and is lower than in most other cells used as standards. Notwithstanding this, the cell protects itself against a charging current from other sources, as well as from disturbing tendency due to short circuit.

The reason for this immunity from permanent disturbance is not yet clear, and the authors are engaged in investigating it.

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8. *On Reostene, a new Resistance Alloy.* *By* J. A. HARKER, *D.Sc., and* A. DAVIDSON.

This communication is a description of the physical properties of a new alloy for electric resistance coils, which has the extremely high specific resistance of forty-five as compared with copper. Its temperature coefficient is comparatively small, 0·0011 per ohm per degree Centigrade, and from a large number of tests with heavy currents, under varying conditions, it was found to alter only very slightly with time. The paper was illustrated with a model and several samples, and the apparatus by which the specimens were maintained at a known temperature during the measurements of resistance was also shown.

DEPARTMENT II.—MATHEMATICS.

1. *Report on the G (r, ν) Integrals.*—See Reports, p. 70.

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2. *Report on Bessel Functions and other Mathematical Tables.* See Reports, p. 98.

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3. *Results connected with the Theory of Differential Resolvents.* *By the* Rev. ROBERT HARLEY, *M.A., F.R.S.*

The linear differential equations whose forms are recorded in this paper stand in a very close and important relation to the trinomial forms of algebraic equations. For, on the one hand, the complete integration of the differential equations determines the form of the roots of the algebraic equations, and, on the other, the general solution of the algebraic equations determines the complete integrals of the several differential equations; so that the relation is reciprocal. In fact, the algebraic equations and their corresponding differential equations are co-resolvents.

In a paper printed in the British Association Report for 1878, at pp. 466–8, it is shown that if y be a function of x, and a, b, c arbitraries independent of x and y, any root y of the algebraic equation

$$ay^m + by^r + cx = 0 \quad . \; . \; . \quad (a)$$

will satisfy the linear differential equation

$$[\mathrm{D}]^{m-r}\left[\frac{r}{m-r}\mathrm{D} - \frac{n}{m-r}\right]^r y^n = (-)^m \frac{a^r c^m}{b^m c^r}\left[\frac{m}{m-r}\mathrm{D} - \frac{n}{m-r} - 1\right]^m x^{m-r} y^n \quad . \; . \quad (\mathrm{A})$$

or, when r is greater than m,

$$[\mathrm{D}]^{r-m}\left[\frac{m}{r-m}\mathrm{D} - \frac{n}{r-m}\right]^m y^n = (-)^r \frac{b_m c^r}{a^r c^m}\left[\frac{r}{r-m}\mathrm{D} - \frac{n}{r-m} - 1\right]^r x^{r-m} y^n \quad . \; . \quad (\mathrm{A}')$$

and any root of

$$ay^n + bxy^r + c = 0 \quad . \; . \; . \; . \; . \quad (b)$$

will satisfy

$$[D]^m y^n = (-)^m \frac{b^m c^r}{a^r c^m}\left[\frac{r}{m}D + \frac{n}{m} - 1\right]^r \left[\frac{m-r}{m}D - \frac{n}{m} - 1\right]^{m-r} x^m y^n \quad . \; . \; (B)$$

or $(r>m)$

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

in which $D = x\frac{d}{dx}$, and the usual factorial notation, viz.:

$$[\theta]^a = \theta(\theta-1)(\theta-2) \; . \; . \; . \; (\theta-a+1)$$

is adopted.

By the process employed in the above cited paper we are also led to the following results:—

Any root of

$$axy^m + by^r + c = 0 \quad . \; . \; . \; . \; (c)$$

will satisfy

$$[D]^r \left[\frac{m-r}{r}D + \frac{n}{r}\right]^{m-r} y^n = (-)^m \frac{a^r c^m}{b^m c^r}\left[\frac{m}{r}D + \frac{n}{r} - 1\right]^m x^r y^n \quad . \; . \; . \; (C)$$

or $(r>m)$

$$[D]^r y^n = (-)^r \frac{a^r c^m}{b^m c^r}\left[\frac{m}{r}D + \frac{n}{r} - 1\right]^m \left[\frac{r-m}{r}D - \frac{n}{r} - 1\right]^{r-m} x^r y^n \quad . \; . \; (C')$$

And any root of

$$ay \;\; + bxy^r + cx = 0 \quad . \; . \; . \; (d)$$

will satisfy

$$\left[\frac{m}{r}D - \frac{n}{r}\right]^m y^n = (-) \;\; \frac{b^m c^r}{a^r c^m}[D-1]^r \left[\frac{m-r}{r}D - \frac{n}{r} - 1\right]^{m-r} x^r y^n \quad . \; . \; . \; (D)$$

or $(r>m)$

$$\left[\frac{m}{r}D - \frac{n}{r}\right]^m \left[\frac{r-m}{r}D + \frac{n}{r}\right]^{r-m} y^n = (-)^r \frac{b^m c^r}{a^r c^m}[D-1]^r x \, y^n \quad . \; . \; . \; (D')$$

The complete integral of each of the above differential equations is of the form

$$c_1 y_1^n + c_2 y_2^n \; . \; . \; . \; + c_m y_m^n,$$

or

$$c_1 y_1^n + c_2 y_2^n \; . \; . \; . \; + c_r y_r^n,$$

according as m or r is the greater, and $y_1, y_2, \ldots y_m$ or y_r are the m or r roots of the connected algebraic equation.

The same results may be obtained by suitable substitutions, or interchanges, and reduction by known theorems. Thus (a), (A), (A′) may be changed into (b), (B), (B′) respectively by the substitution

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

or into (c), (C), (C′) respectively by the substitution

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

or into (d), (D), (D′) respectively by the substitution

$$\begin{pmatrix} a, & c, & m, & r, & x \\ c, & a, & -m, & r-m, & x^{-1} \end{pmatrix}$$

Or (b), (B), (B′) may be changed into (c), (C), (C′) respectively by means of the interchanges

$$\begin{pmatrix} a, & b \\ \cdot & \cdot \end{pmatrix}, \begin{pmatrix} m, & r \\ \cdot & \cdot \end{pmatrix}$$

And (*c*), (C), (C′) into (*d*), (D), (D′) respectively by writing x^{-1} for x. In this way the accuracy of the results has been sufficiently confirmed.

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4. *Connexion of Quadratic Forms.*
By Lieut.-Colonel ALLAN CUNNINGHAM, *R.E., Fellow of King's Coll. Lond.*

Two quadratic partitions of the same integer (N) are said to be *conformal*, when derivable from one another by mere multiplication by a unit factor, *e.g.*, $m\tau^2 + nv^2 = 1$; when not so interchangeable they are said to be *non-conformal.*

Let N be an integer expressed in two *non-conformal* quadratic forms.

$$N = \theta v^2 + mw^2 = \theta x^2 + ny^2; \ (\theta, m, n \text{ integers}; \ m \neq n).$$

$$\text{Then } N = \theta \cdot \frac{m(wx)^2 - n(yv)^2}{mw^2 - ny^2}.$$

It is shown that a third non-conformal partition may be hence *directly* computed by the known processes of conformal multiplication and conformal division combined, when θ is of suitable form, &c.

$$\text{i. } \theta = \pm 1; \ \text{ii. } \theta v_0{}^2 + mw_0{}^2 = \pm 1 = \theta x_0{}^2 + ny_0{}^2;$$
$$\text{iii. } \pm\theta\sigma^2 = m\tau^2 - nv^2; \ \text{iv. } \pm\theta\sigma^2 = \tau^2 - mnv^2.$$

Also, in Cases i., ii., iii., any one of the three forms is derivable by the same procedure from the other two.

Ex. $N = a^2 + b^2 = v^2 + mw^2 = x^2 - my^2$, forms such a Triad that each form is directly derivable from the other two as above.

This is a very useful process for *directly* effecting a quadratic partition of a *very large* number from two given non-conformal partitions.

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5. *On the Plotting out of Great Circle Routes on a Chart.*
By H. M. TAYLOR, *M.A., Fellow of Trinity College, Cambridge.*

It is proposed that on the charts used by ocean-going vessels a series of curves should be engraved, each curve representing accurately a great Circle.

It is shown how such a series of curves may, without the use of mathematical calculations, be made use of to plot out on the chart, with much accuracy, the Great Circle route between any two points.

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6. *On the Stationary Motion of a System of Equal Elastic Spheres in a Field of no Forces when their Aggregate Volume is* NOT *Infinitely Small compared with the Space in which they Move.* *By* S. H. BURBURY, *F.R.S.*

The object of this paper is to prove that the velocities of spheres near to one another are correlated.

1. Consider first the system in which the molecules are material points, between which there are no collisions, with their velocities distributed according to Maxwell's law. The chance that any n molecules shall have component velocities $u_1 \, v_1 \, . \, . \, . \, w_n$ is then

$$A\epsilon^{-h\Sigma(u^2+v^2+w^2)} du_1 \, dv_1 \, . \, . \, . \, dw_n,$$

and this motion is stationary.

Let ρ be the number of molecules per unit volume.

Let R be a radius at present arbitrary. Definition. Let $\xi \, \eta \, \zeta$ at any point P, and at any instant, be the component velocities of the centre of inertia of all the molecules which at that instant are contained within a sphere of radius R described about P.

2. If an equal sphere be described about a neighbouring point P′, and P P′ = δs,

the volume common to the two spheres is $\frac{4}{3}\pi R^3 - \pi R^2\delta s$, or $\frac{4}{3}\pi R^3\left(1-\frac{3\delta s}{4R}\right)$. So the value of ξ for the new sphere is $\xi - \frac{3\delta s}{4R}\xi + \frac{3\delta s}{4R}x$, where x is a vector for which positive and negative values are equally probable, and for which on average $\overline{x^2} = \overline{\xi^2}$. So we find $\frac{d\xi}{ds} = \frac{3}{4R}(x-\xi) = -\frac{3\xi}{4R}$ on average if ξ be given. In the same way we find the mean value of $\left(\frac{d\xi}{ds}\right)^2$ to be $\frac{3\xi^2}{4R^2}$, that is, proportional to ξ^2.

3. Now consider the function

$$M = \iiint dxdydz \iiint \epsilon^{-h(w_x^2+w_y^2+w_z^2)} dw_x dw_y dw_z w_x w_z \frac{d\xi}{dz},$$

in which $w_x\ w_y\ w$ are the component velocities of a molecule, and the integration includes all space and all values of $w_x\ w_y\ w_z$. If we follow individual molecules, $w_x\ w_y\ w_z$ remain unchanged in the absence of collisions. But if we regard $w_x\ w_y\ w_z$ as belonging to those molecules which are for the time being within a fixed space, $w_x\ w_y\ w$ vary with the time by the passage of molecules into or out of the space.

Now in stationary motion M is constant, and $\frac{dM}{dt} = 0$, that is

$$\iiint dxdydz \iiint \epsilon^{-hw^2} dw_x dw_y dw \times \left\{ w_x w_z \frac{d}{dt}\frac{d\xi}{dz} + \frac{d\xi}{dz}\frac{d}{dt}(w_x w_z) \right\} = 0, \text{ in which}$$

$$w^2 = w_x^2 + w_y^2 + w_z^2 \quad \ldots\ldots\ldots\ldots \quad \text{(I.)}$$

We have now to express $\frac{d}{dt}(w_x w_z)$.

Suppose, near a certain point P, $\frac{d\xi}{dz}$ is positive.

Form the integral I for a small cylindrical space AB, containing P, whose ends are unit area of two planes A and B, respectively parallel to xy. Then we find that $\frac{d\xi}{dz}\frac{d}{dt}(w_x w_z)$ has throughout AB the mean value $-\frac{2hw^4}{3\,.\,5}\cdot\frac{3}{4}\cdot\frac{\overline{\xi^2}}{R^2}$.

And therefore

$$\frac{dM}{dt} = 0 = \iiint dxdydz \iiint \epsilon^{-h(w_x^2+w_y^2+w^2)} dw_x dw_y dw_z$$

$$\times \left\{ w_x w_z \frac{d}{dt}\frac{d\xi}{dz} - \frac{2hw^4}{3\,.\,5}\cdot\frac{3}{4}\frac{\xi^2}{R^2} \right\} \quad \ldots \quad \text{(II.)}$$

Transition to Finite Spheres.

4. We now pass to the case in which our molecules, instead of being material points, are finite spheres, each of unit mass and diameter c. The first effect of this alteration is to increase the quantity of momentum transferred across any plane per unit of area and time in the ratio $1 : 1+k$, where $k = \frac{2}{3}\pi c^3\rho$. But this increases both the terms of I or II in the same ratio, and therefore $\frac{dM}{dt}$, so far as this is concerned, remains zero.

5. But collisions alter the term $\frac{d}{dt}(w_x w_z)$, because at each collision the direction of motion changes for each of the colliding spheres. The state of the medium near P being as assumed in Art. 3, viz. $\frac{d\xi}{dz}$ positive, consider two planes, one the

plane of xy, and the other $z = \nu c$, $\lambda\ \mu\ \nu$ being direction cosines of a diameter c. For our present purpose we may take $\xi = 0$ on plane of xy, and the value of ξ on the second plane is $\nu c \frac{d\xi}{dz}$. Consider two spheres, one on the plane of xy, the other on the second plane, and suppose their relative velocity to be V, and its direction cosines $\lambda\ \mu\ \nu$. If the number per unit of volume of pairs of molecules having relative velocity V . . . V + dV be $A\epsilon^{-\frac{h}{2}V^2} V^2 dV$, the number having near P $\lambda\ \mu\ \nu$ for direction cosines of V is in excess of the normal by $-A\epsilon^{-\frac{h}{2}V^2} V^2 dV \lambda \nu c h V \frac{d\xi}{dz}$. Let θ be the angle between V and the line of centres at collision. If we form the integral value of $\lambda\nu V^2$ *for all collisions* taking place per unit of volume and time near P under the circumstances assumed, it is

$$-\lambda\nu A\epsilon^{-\frac{h}{2}V^2} V^2 dV \pi c^2 \rho V \lambda \nu c h V^3 \frac{d\xi}{dz} \int_0^{\frac{\pi}{2}} \cos^2\theta \sin\theta\, d\theta;$$

that is $-\frac{\pi c^3 \rho}{3} \overline{\lambda^2 \nu^2} A\epsilon^{-\frac{h}{2}V^2} V^6 dV h \frac{d\xi}{dz}$.

6. Again, let $\lambda'\ \mu'\ \nu'$ be the values of $\lambda\ \mu\ \nu$ after collision. Then we find easily

$$\nu' = -\nu \cos 2\theta + \sqrt{1-\nu^2} \sin 2\theta \cos\phi,$$
$$\lambda' = -\lambda \cos 2\theta - \frac{\lambda\nu}{\sqrt{1-\nu^2}} \sin 2\theta \cos\phi,$$

ϕ being the angle between the plane containing $\lambda\ \mu\ \nu$ and z, and the plane containing $\lambda\ \mu\ \nu$ and the point of contact. Whence we find the integral value of $\lambda'\nu'$ for all collisions per unit of volume and time to be greater than

$$\int_0^{\frac{\pi}{2}} d\theta \sin\theta\cos\theta \int_0^{\pi} d\phi(-\nu\cos 2\theta + \sqrt{1-\nu^2}\sin 2\theta\cos\phi)(-\lambda\cos 2\theta - \frac{\lambda\nu}{\sqrt{1-\nu^2}}\sin 2\theta\cos\phi),$$

which is zero. Let $\lambda V = V_x$, $\nu V = V_z$. Hence if $\lambda'\nu' = 0$, $\frac{\delta}{\delta t}(\overline{V_x V_z}) = \frac{\pi c^3 \rho}{3} \overline{\lambda^2\nu^2} h V^4 \frac{d\xi}{dz}$

$$= \frac{\pi c^3 \rho}{3} \frac{1}{3\,.\,5} h V^4 \frac{d\xi}{dz}, \text{ because on average } \lambda^2\nu^2 = \frac{1}{3\,.\,5};$$

and changing the variable, we obtain

$$\frac{\delta}{\delta t}(w\ w\ ) = \frac{\pi c^3 \rho}{3} \cdot \frac{1}{3\,.\,5} h w^4 \frac{d\xi}{dz}.$$

Therefore, if $\frac{\delta}{\delta t}$ relate to the change due to collisions only,

$$\iiint dx\,dy\,dz \iiint \epsilon^{-h(w_x^2 + w_y^2 + w_z^2)} dw_x\,dw_y\,dw_z \frac{d\xi}{dz} \frac{\delta}{\delta t}(w_x w_z)$$
$$= \tfrac{1}{3} \iiint dx\,dy\,dz \iiint \epsilon^{-h(w_x^2 + w_y^2 + w_z^2)} dw_x\,dw_y\,dw \cdot \frac{\pi c^3 \rho}{3\,.\,5} \cdot h w^4 \frac{3\overline{\xi^2}}{4R^2} \text{ by Art. 2.}$$

7. We see then that if $\frac{d}{dt}$ denote the whole time variation, the expression

$$w_x w_z \frac{d}{dt}\frac{d\xi}{dz} + \frac{d\xi}{dz}\frac{d}{dt}(w_x w_z),$$

which was zero on average, has now, as the result of collisions, acquired a positive value $\frac{\pi c^3 \rho}{3} \frac{h w^4}{3\,.\,5} \cdot \frac{3}{4} \frac{\overline{\xi^2}}{R^2}$.

If we stop there $\frac{dM}{dt} \neq 0$, and the motion is not stationary. The way to make it stationary in the medium of finite spheres is to write $\xi+\xi'$ for ξ, $\eta+\eta'$ for η, $\zeta+\zeta'$ for ζ, where $\xi'\ \eta'\ \zeta'$ are three vectors for which positive and negative values are equally probable and for which $\overline{\xi'^2}\ \overline{\eta'^2}\ \overline{\zeta'^2}$ are very small compared with $\overline{\xi^2}$ &c. Further they are chosen at haphazard independently of $\xi\ \eta\ \zeta$, so that $\xi\xi'=\eta\eta'=\zeta\zeta'=0$ on average. The object is to find the ratio $\overline{\xi'^2} : \overline{\xi^2}$.

The introduction of $\xi'\ \eta'\ \zeta'$ does not directly affect $w_x w_z$ on average, but it affects $\frac{d}{dt}(w_x w_z)$ as found in Art. 3. In lieu of ξ^2 in that article we must now write $(\xi+\xi')^2$, that is, since $\xi\xi'=0$ on average, $\xi^2+\xi'^2$. Our equation II. now becomes

$$\frac{dM}{dt}=\iiint dxdydz\iiint \epsilon^{-h(w_x^2+w_y^2+w_z^2)}dw_xdw_ydw_z$$
$$\times\left\{w_xw_z\frac{d}{dt}\frac{d\xi}{dz}-\frac{2}{3\,.\,5}hw^4\,.\,\frac{3}{4}\frac{\overline{\xi^2}}{R^2}\right.$$
$$\left.+\frac{hw^4}{3\,.\,5}\pi c^3\rho\frac{1}{2}\,\frac{\overline{\xi^2+\xi'^2}}{R^2}-\frac{2\,hw^4}{3\,.\,5}\,.\,\frac{3}{4}\frac{\overline{\xi'^2}}{R^2}\right\}.\quad\text{(III.)}$$

The first line is zero by II. The second line is zero if $\overline{\xi'^2}=\frac{\pi c^3\rho}{3}(\overline{\xi^2}+\overline{\xi'^2})=\frac{k}{2}(\overline{\xi^2}+\overline{\xi'^2})$, where $k=\frac{2}{3}\pi c^3\rho$. Or $\overline{\xi'^2}=\frac{k}{1-k}\,\frac{\overline{\xi^2}}{2}=\frac{k}{2}\overline{\xi^2}$ if k^2, k^3, &c., but not k, be negligible. Evidently $\overline{\xi'^2}+\overline{\eta'^2}+\overline{\zeta'^2} : \overline{\xi^2}+\overline{\eta^2}+\overline{\zeta^2} :: \overline{\xi'^2} : \overline{\xi^2}$; and as this ratio is independent of R and n, it gives the solution for all values of R and n.

8. When the chance that n molecules within a sphere of radius R shall have velocities $u_1\ \ldots\ u_1+du_1$ &c. $w_n\ \ldots\ w_n+dw_n$ is proportional to $\epsilon^{-h\Sigma(u^2+v^2+w^2)}$ $du_1\ \ldots\ dw_n$, we know that the mean value of the energy of the motion of their common centre of gravity, or $\frac{n}{2}\,(\overline{\xi^2}+\overline{\eta^2}+\overline{\zeta^2})$, is $\frac{3}{4h}$.

If, therefore, the energy of this motion be $\frac{n}{2}(\overline{\xi^2}+\overline{\eta^2}+\overline{\zeta^2})+\frac{n}{2}(\overline{\xi'^2}+\overline{\eta'^2}+\overline{\zeta'^2})$, as in the medium of finite spheres we now see it must be, that is $\frac{3}{4h}+\frac{n}{2}(\overline{\xi'^2}+\overline{\eta'^2}+\overline{\zeta'^2})$, it is impossible that the above chance can any longer be represented by

$$\epsilon^{-h\Sigma(u^2+v^2+w^2)}du_1\ \ldots\ dw_n.$$

The term containing $uu'+vv'+ww'$ *necessarily* appears in the index.

The case is the same as if, the molecules being in motion according to the ordinary law, we gave to each of the n spheres the additional component velocities $\xi'\ \eta'\ \zeta'$, at the same time maintaining h constant. It can then be proved that the above chance is proportional under those circumstances to $\epsilon^{-hQ}du_1\ \ldots\ dw_n$, and

$$Q=\tfrac{1}{2}\Sigma\,(u^2+v^2+w^2)-\frac{4h}{3}(\overline{\xi'^2}+\overline{\eta'^2}+\overline{\zeta'^2})\Sigma\Sigma(uu'+vv'+ww').$$

But we have seen that for small values of k in stationary motion $\overline{\xi'^2}+\overline{\eta'^2}+\overline{\zeta'^2}=\frac{k}{2}(\overline{\xi^2}+\overline{\eta^2}+\overline{\zeta^2})=\frac{3k}{4nh}$, where n is the number of molecules within the R sphere, and therefore the coefficient of $(uu'+vv'+ww')$ in Q is $-\frac{k}{n}$.

9. If now we write $h_1=h\,(1+\frac{n-1}{n}k)$, hQ becomes

$$h_1\{(a\Sigma(u^2+v^2+w^2)+b\ \Sigma\Sigma\,(uu'+vv'+ww')\}$$

with

$$2a=1+\frac{n-1}{n}k$$

$$b = -\frac{k}{n}.$$

And we can now describe the motion of the medium of finite spheres as follows: If it be given that there are n spheres within a spherical space S, but nothing is known of their positions within S, the chance that they shall have velocities $u_1 \ldots u_1 + du_1 \ldots w_n \ldots w_n + dw_n$ is proportional to $\epsilon^{-h_1 Q} du_1 \ldots dw_n$, and $Q = a\Sigma(u^2 + v^2 + w^2) + b\Sigma\Sigma(uu' + vv' + ww')$, and

$$2a = 1 + \frac{n-1}{n}k$$

and

$$b = -\frac{k}{n}, \text{ provided } k \text{ be small.}$$

10. If T be the whole kinetic energy of the n molecules, T_r the kinetic energy of their motion relative to their common centre of inertia,

$$Q = T + kT_r,$$

and Q is that which is constant in a vertical column under the action of gravity.

11. The function M which we have used, if we add to it the corresponding terms in $\frac{d\xi}{dy}$, $\frac{d\zeta}{dx}$, &c., can be shown to be the rate of time variation of

$$H = \iiint(\xi^2 + \eta^2 + \zeta^2)dxdydz.$$

The investigation shows that H increases or diminishes with the time according as $\frac{n}{2}(\xi'^2 + \eta'^2 + \zeta'^2)$ is below or above the limit $\frac{3k}{4h}$.

12. Dr. Ladislas Natanson, in his 'Sur l'Interprétation cinétique de la Fonction de Dissipation,' defines as follows:—Let $\xi\ \eta\ \zeta$ be the component velocities of the centre of inertia of the molecules in 'un élément de volume contenant $n.dxdydz$ molécules,' while $u\ v\ w$ are the velocities of a molecule relative to that centre of inertia. (I have interchanged Dr. Natanson's letters.) Then he takes

$$H = \iiint(\xi^2 + \eta^2 + \zeta^2)dxdydz,$$

$$E = \iiint(u^2 + v^2 + w^2)dxdydz$$

throughout the space filled by molecules. And he shows that in nature H tends to diminish, its energy being converted into the energy, E, of molecular motion.

Dr. Natanson's definition (though I am not contesting its suffici ncy for his own purpose) is inapplicable to molecules of finite dimensions, because a system of such molecules 'un élément de volume contenant $n.dxdydz$ molécules' does not exist. But the function which in this case corresponds to Natanson's function H is

$$\iiint(\xi'^2 + \eta'^2 + \zeta'^2)dxdydz,$$

which does, as we have seen, tend to a limit, though not to the limit zero.

13. The theorem of Arts. 5 and 6, and therefore the whole of this investigation, would apply to the case where the molecules, instead of being conventional elastic spheres, are centres of repulsive force, only the exact value of $\frac{d}{dt}(\overline{V_x V_z})$ will not be the same. It would still be of the same sign as $\frac{d\xi}{dz}$, which is the essential characteristic.

7. *On some Difficulties connected with the Kinetic Theory of Gases.* *By* G. H. Bryan, *Sc.D.*

The recent attacks of M. Bertrand on Maxwell's investigations emphasise the view that all proofs of the Boltzmann-Maxwell distribution involve *some* assumption or other, and that such assumptions are only justifiable in attenuated assemblages of molecules such as constitute an ideal gas. But if the thermal properties of gases are *really* due to molecular motions, as the kinetic theory supposes, the same must be true of the corresponding properties of matter in its other states; so that a kinetic theory of solids and liquids *also must exist* even though the complete investigation of that theory may present insuperable difficulties to the mathematician. Now, the most important physical property for which the kinetic theory has to account is that of *temperature*, and the existence of such a quantity depends on the fact that if a body A be in thermal equilibrium with B, and also with C, then B will be in thermal equilibrium with C; in other words, the condition of thermal equilibrium between A and B must be expressible in the form

$$f_1(\mathrm{A}) = f_2(\mathrm{B}) \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where the left-hand side involves no variables depending on the state of B, and the right-hand side involves no variables depending on the state of A.

On the assumption that the temperature of a body is proportional to the mean kinetic energy of translation of its molecules, the condition of equal temperature requires that if the mean translational energies of two sets of molecules A and B are equal, no energy will be transferred from A to B. Now if we take only two molecules M and *m*, moving in the same straight line, the condition for no transference of energy between them is *not* that their kinetic energies shall be equal. Indeed, Prof. Tait has shown that this condition holds good if the molecules of A and B are distributed according to the Boltzmann-Maxwell distribution, but not in general.

The author is at present investigating what restrictions are imposed on the law of distribution of molecular velocity in order that the condition of thermal equilibrium *may* be expressible in the form (1), in other words, in order that temperature may exist. The analysis is somewhat complicated, but it may be safely concluded, even at the present stage, that the existence of temperature cannot be inferred from dynamical considerations alone, independently of the law of distribution. It will be necessary for us to regard the laws of thermodynamics as the fundamental assumptions of a general kinetic theory of matter rather than as the results to be proved, and we must therefore deduce from those laws the nature of the molecular motion which we call heat.

MONDAY, SEPTEMBER 21.

The following Papers and Reports were read:—

1. *On the Communication of Electricity from Electrified Steam to Air.* *By* Lord Kelvin, *F.R.S.*, Dr. Magnus Maclean, *and* Alexander Galt.

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2. *On the Molecular Dynamics of Hydrogen Gas, Oxygen Gas, Ozone, Peroxide of Hydrogen, Vapour of Water, Liquid Water, Ice, and Quartz Crystal.* *By the* Right Hon. Lord Kelvin, *G.C.V.O.*, *F.R.S.*

In a communication, 'On the Different Crystalline Configurations possible with the same Law of Force according to Boscovich,' to the last meeting (July 20) of the Royal Society of Edinburgh a purely mathematical problem of fundamental importance for the physical theory of crystals—the equilibrium of any number of points acting on one another with forces in the lines joining them—was considered in the simplest case of Boscovichian statics; that in which the mutual force between every pair of atoms is the same for the same distance between any two atoms of the whole assemblage. The next simplest case is that in which there are two kinds of atom, *h*, *o*, with the distinction that the force between two *h's* and the force between two *o's* and the force between an *h* and an *o* are generally different at the same distance. The mutual force between two *h's* is, of course, always the same at the same distance. So also is the mutual force between two *o's* and between an *h* and an *o*.

The object of the present communication is to find how much of the known properties of the substances named in the title can be explained with no further assumption except the conferring of inertia upon a Boscovich atom.

The known chemical and physical properties to be provided for are:

1. That in each of the gases named the molecule is divisible into two; which is the meaning of the symbols H_2, O_2, used to denote them in chemistry.

2. That Ozone (O_3) is a possible, though not a very stable, gaseous molecule, consisting of a group of Oxygen atoms of which the constituents readily pass into the configuration (O_2) of Oxygen gas.

3. That Peroxide of Hydrogen (H_2O_2, or perhaps HO) is a possible, but not a very stable, combination, which, for all we know, may exist as a liquid or a dry gas, but which is only generally known as a solution in water (of density 1·45 in the highest concentration hitherto reached), readily absorbing Hydrogen or parting with Oxygen so as to form H_2O.

4. That water (H_2O) is an exceedingly stable compound in the gaseous, liquid, or crystalline form, according to circumstances of temperature and pressure.

5. That dry mixtures of Hydrogen and Oxygen gases, and also mixtures of these gases with water in the same inclosure, have been kept by many experimenters for weeks or months, and perhaps for years, inclosed in glass vessels, without any combination of the two gases having been detected.

6. That Ice contracts by about 8 per cent. in melting, and that ice-cold water, when warmed, contracts till it reaches a maximum density at about 4° C., and expands on further elevation of temperature.

7. For Quartz crystal—

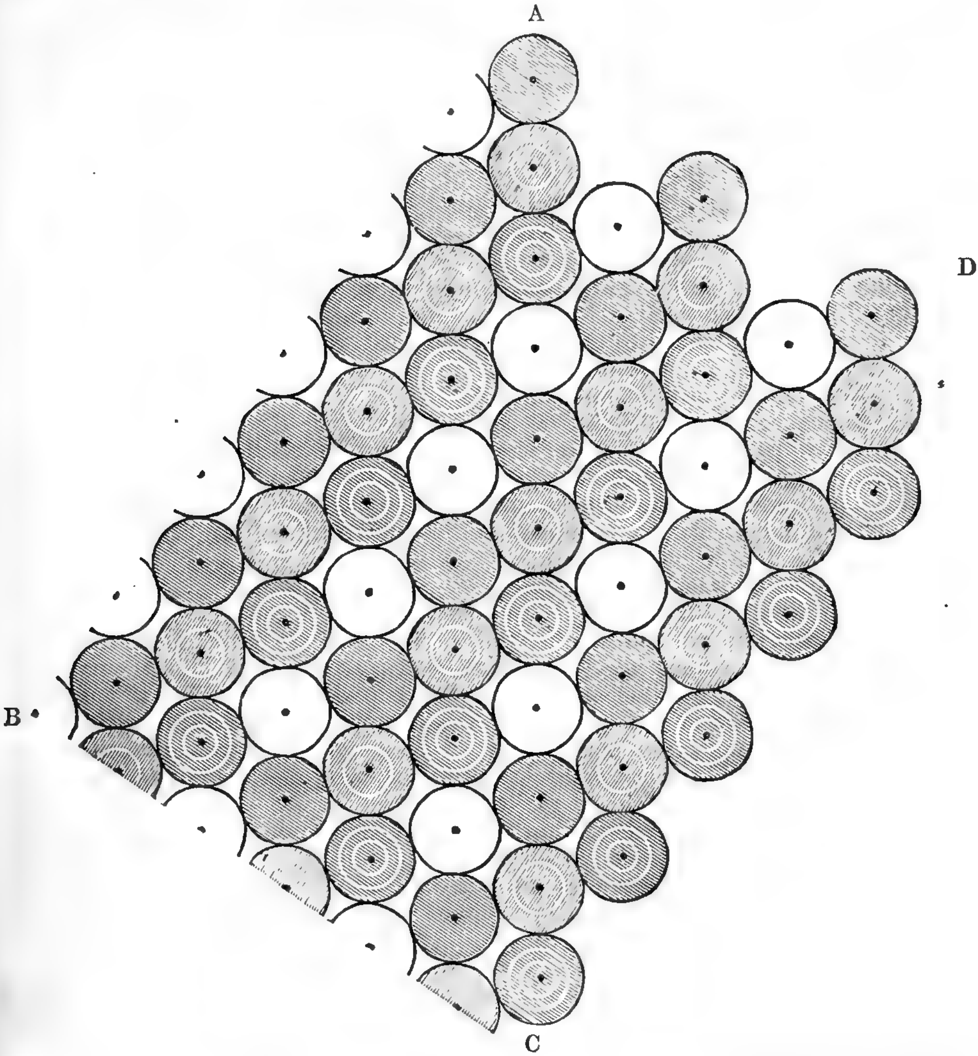
(*a*) The difference between neighbouring corners of the hexagonal prism.

(*b*) The similarity between each face and its neighbour on either side turned upside down (the axis of the prism supposed vertical).

(*c*) The right-handed and left-handed chiralities of different crystals in nature with, so far as known, an equal chance of one chirality or the other in any crystal that may be found.

In the present communication it is shown that all the properties stated in this schedule can be conceivably explained by making H consist of two Boscovich atoms (*h*, *h*), and O of two others (*o*, *o*). This essentially makes H_2 consist of four *h*'s at the corners of an equilateral tetrahedron, and O_2 a similar configuration of four *o*'s. It naturally shows Ozone as six *o*'s at the corners of a regular octahedron. It makes H_2O (the gaseous molecule of water) consist of two *o*'s with two *h*'s attached to one of them and two other *h*'s attached to the other; the *h*'s of each *o* getting as near to the other *o* as the mutual repulsion of the *h*'s allows. This configuration and the modification it experiences in the formation of crystals of ice are illustrated by models which accompany the communication.

To understand what is probably the true configuration of ice-crystal, we are helped by first considering a double cubic assemblage of point-atoms, such that each point-atom is in the centre of a cube having eight point-atoms for its corners. This double cubic assemblage may be imagined as consisting of two simple cubic assemblages, so placed that one atom of each assemblage is in the centre of a cube of atoms of the other. The annexed diagram shows, in the centres of the circles which it contains, atoms of a double cubic assemblage, which lie in the plane of a pair of remote parallel edges, A D, B C, of one set of constituent cubes. It shows *all* the atoms in the lines of this plane which it contains except certain omissions in the lines A D, D C, made specially on account of the present application of the diagram. The circles of simple shading and of shading interrupted by two small concentric circles constitute one of the simple cubic assemblages; the unshaded and the circles with shading interrupted by one concentric circle constitute the other cubic assemblage. A C, B D are parallel to body diagonals, A B, D C are parallel to face diagonals, of the cubes. Annul now all the atoms at



the centres of the blank circles.[1] Lastly, stretch the diagram perpendicularly to A C in the same definite ratio of perhaps about 3 to 1. It then represents what we may believe to be probably the true molecular structure of ice-crystal: the circles with simple shading and with shading interrupted by two concentric circles denoting hydrogen atoms, and the circles with shading interrupted by single concentric circles the oxygen atoms.

The named properties of Quartz are explained by supposing the crystalline molecule to consist of three of the chemical molecules (OSiO) to be placed together in a manner readily imagined according to a suggestion which I communicated to

[1] The assemblage thus constituted is precisely that described in Section 24, and in footnote on Section 69 of 'Molecular Constitution of Matter,' *Proc. R.S.E.*, July 1889, reprinted as Art. xcvii. of Vol. III. of 'Mathematical and Physical Papers.' I was led to it in the course of my investigation of a Boscovichian elastic solid, having two independent moduluses of resistance to compression and of rigidity. ('Elasticity of a Crystal according to Boscovich,' *Proc. R.S.*, June 1893).

the British Association at its Southport meeting in 1883. Models showing right-handed and left-handed specimens of these crystalline molecules and the configuration in which they must be placed to form a rock crystal ending in its well-known six-sided pyramid are before the meeting to illustrate the present communication.

In a communication which I hope to make to the Royal Society of Edinburgh at an early meeting essential details of the configurations now suggested, and of the mutual forces between the atoms required by the conditions to be fulfilled, will be considered.

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3. *A Magnetic Detector of Electrical Waves.* *By* E. RUTHERFORD, *M.A.*

It has long been known that a steel needle placed in a spiral round which an ordinary Leyden jar discharge is passed is magnetised. The magnetism of the needle is generally confined to the surface, and the way in which the magnetisation varies from the surface inwards may be directly determined by dissolving the needle slowly in acid before a magnetometer.

If a magnetised piece of steel wire be subjected to the discharge, the magnetic moment is always reduced, whatever the direction of the discharge. The screening action of thin cylinders of metal for the discharge may be immediately shown by placing them between the solenoid and detector needle. With a thin copper cylinder the needle remained unaffected, while a few turns of tinfoil gave a small effect.

A short steel wire magnetised to saturation also has the remarkable property of being able to distinguish between the two first half oscillations of the discharge. If the needle is saturated, in one direction the first half oscillation can produce no effect on the magnetism of the needle, since it is already saturated, while in the opposite direction it produces its full effect. From the comparisons of the fall of magnetic moment of the needle in the two cases, the damping of the discharge may be deduced. By an application of this method also the apparent resistance of air breaks of different lengths to the discharge was deduced, and the resistance of iron wires for currents of high frequency of alternation obtained. Instead of a single wire a compound needle of short thin steel wires insulated from each other by paraffin was used. This was a sensitive means of detecting and comparing oscillation of small intensity. If a circle of wire 30 cm. in diameter be taken, and the discharge passed round only a small portion of its arc, there is quite a large effect on the detector needle at the centre.

If a discharge is sent *longitudinally* through a short magnetised steel wire, the magnetic moment is always reduced, due to the circular magnetisation of the surface layers of the wire. Using a thin wire in series with the circuit, oscillations of very small frequency may thus be detected.

A compound detector needle of fine wire placed in a solenoid of two or three turns is a very simple and convenient means of investigating waves along wires and determining nodes and antinodes.

A compound detector needle was also found to be a sensitive means of detecting Hertzian waves in free space at large distances from the vibrator.

A collection of twenty or thirty fine steel wires, each about 1 cm. long, was taken and formed into a compound detector needle, each wire being insulated from the other to prevent eddy currents. A fine wire solenoid of several hundred turns was wound over it. When the small solenoid was placed in series with receiving wires, a wave falling on the receiver set up oscillations in that circuit, and the needle is more or less demagnetised according to the intensity of the wave. Using large vibrators effects were obtained at a distance of over half a mile between the vibrator and receiver.

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4. *On a Complete Apparatus for the Study of the Properties of Electric Waves.* *By* Professor JAGADIS CHUNDER BOSE, *M.A.*, *D.Sc.*

A complete electro-magnetic radiation apparatus was exhibited with which the following determinations may be made:—

A. Verification of the laws of reflection.
 1. Plane mirrors.
 2. Curved mirrors.

B. Phenomena of refraction.
 1. Prisms.
 2. Total reflection.
 3. Opacity caused by multiple refraction and reflection.
 4. Determination of the indices of refraction.

C. Selective absorption.
 1. Electrically coloured media.

D. Phenomena of interference.

E. Double refraction and polarisation.
 1. Polarising gratings.
 2. " crystals.
 3. Double refraction produced by crystals.
 4. " " other substances.
 5. " " strain.
 6. Circular polarisation. } Experiments still in progress.
 7. Magnetic rotation. }
 8. Electro-polariscope and polarimeter.

The complete apparatus consists of (1) A radiating apparatus emitting electric waves of short length; (2) A receiver used as a detector of electric radiation; and (3) Various accessories for the study of the different phenomena.

Arrangement of the Apparatus.—The radiating apparatus and the receiver are mounted on stands sliding in an optical bench. Experiments are carried out with divergent or parallel beam of electric radiation. To obtain a parallel beam, a cylindrical lens of sulphur or ebonite is mounted in a square tube. This lens tube fits on the radiator tube, and is stopped by a guide when the oscillatory spark is at the principal focal line of the lens. The radiator tube is further provided with a series of diaphragms by which the amount of radiation may be varied.

For experiments requiring angular measurement, a spectrometer circle is mounted on one of the sliding stands. The spectrometer carries a circular platform on which the various reflectors, refractors, &c., are placed. The platform carries an index, and can rotate independently of the circle on which it is mounted. The receiver is carried on a radial arm (provided with an index) and points to the centre of the circle. An observing telescope may also be used with an objective made of ebonite with a linear receiver at the focal plane. But an ordinary receiver provided with a funnel is all that is necessary for ordinary experiments.

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5. *Report on Meteorological Observations on Ben Nevis.*
See Reports, p. 166.

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6. *Report on Solar Radiation.*—See Reports, p. 241.

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7. *Report on Seismological Observations.*—See Reports, p. 180.

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8. *Report on Meteorological Photographs.*—See Reports, p. 172.

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9. *The Effect of Atmospheric Refraction on the Apparent Diurnal Movement of Stars, and a Method of allowing for it in Astronomical Photography.* By Professor A. A. Rambaut, *M.A., Sc.D.*

The variation in the degree of refraction which the light of a star undergoes in passing through the earth's atmosphere, apart from irregularities which arise from local disturbances in the strata of air, affects the apparent movement of a star, so that the angular motion depends upon its position in the sky.

When approaching its upper culmination the hour angle of a star is diminished by refraction, but to a continually diminishing extent, and consequently the motion of a star at this part of its course appears slower than it actually is. After culmination the result is similar, the refraction in this case throwing the apparent, more and more to the following side of the true, image as the distance from the meridian increases.

When the observer's object is merely to obtain *pictures* of star groups the work can be so arranged that each group is photographed when it arrives at or near the meridian. It is different, however, when it is intended to utilise the plates for the detection of stellar parallax. In connection with this research, it is desirable that a large proportion of the photographs should be taken when the stars are near the apses of their parallactic ellipses, and this condition often necessitates the photographing of stars at very large hour angles.

If the apparent western hour angle of a star at any moment be denoted by h, the effect of refraction in hour angle by Δh, the right ascension by a, and the sidereal time by θ; then

$$h = \theta - a + \Delta h$$

$$\text{and } \frac{dh}{d\theta} = 1 + \frac{d\Delta h}{d\theta}.$$

Hence the expression $\frac{d\Delta h}{d\theta}$ measures the rate at which the apparent movement gains on sidereal time.

If ϕ denotes the latitude and δ the declination, and if we assume m, n, μ, ν, such that

$$\tan m = \cot \phi \cos h, \qquad \cot \mu = \tan \phi \cos h,$$
$$\cot n = \sin m \tan h, \qquad \cot \nu = \cos \mu \tan h,$$

then we may write

$$\frac{dh}{d\theta} = 1 - \frac{\beta \cos \phi}{\cos \delta} \frac{\sin \nu \sin (\mu + \delta)}{\sin^2 n \sin^2 (m + \delta)} \quad . \quad . \quad . \quad . \quad (a)$$

in which β is the refraction constant.

If the telescope were required to follow the star with absolute precision it would be necessary to construct a clockwork system which would drive the instrument at a rate varying continually with the hour angle according to the law expressed by this formula. In practice, however, it is sufficient to alter the rate at intervals, the length of which will depend upon the rapidity of the refraction changes, provided always that the error thus introduced does not exceed a certain definite limit.

A description of the method of making this alteration, a full account of how formula (a) is deduced, and diagrams showing the appropriate rate for any given hour angle and declination, and the length of exposure for which a uniform rate is permissible, will be found in the 'Monthly Notices' of the Royal Astronomical Society.

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10. *On the Sailing Flight of Birds.* By G. H. Bryan, *Sc.D., F.R.S.*

That birds are capable, under certain circumstances, of supporting themselves indefinitely in the air without expending energy by flapping their wings is a matter of common observation. To account for this apparent realisation of 'perpetual motion' various theories have been proposed, and amongst these the most important are the three which suppose the seat of available energy to lie in—

(1) Upward air-currents (Mr. Maxim).

(2) Variations of the wind-velocity at different heights above the ground (Lord Rayleigh).

(3) Variations of the wind-velocity from one instant to another, the wind habitually blowing in gusts separated by lulls (Dr. S. P. Langley and others).

Before proceeding further, another source of energy may be mentioned, namely, the presence of *vortices, i.e.,* miniature whirlwinds or cyclones, in the atmosphere. Even on a perfectly calm day one of these little vortices may sometimes be seen travelling across a road, carrying up a funnel-shaped cloud of dust. According to mathematical theory, a vortex always consists of the same particles of fluid; and, even under the modified conditions which occur in nature, our experience of cyclones tells us that such vortices are remarkable for their persistency, and their motions are so regular that it would be easy for birds to take advantage of them. This would account for the fact that birds so often congregate in a certain spot when in sailing flight.

Against the third hypothesis it has been objected—

(i.) That to take advantage of every puff of wind in such a way as to be lifted up by it would be an extremely difficult feat of aërial gymnastics, whereas birds appear to circle in the air without requiring to exercise any particular alertness or agility.

(ii.) That the variations in wind-velocity are not sufficient to sustain the weight of a bird in the air.

In answer to the first objection, it is to be observed that if the bird's centre of mass is slightly *below* the wing-surface—especially if the wings are slightly curved upwards—the action will be purely automatic. We may illustrate this point perhaps better by considering the parallel effect in the seeds of many composite plants (such as the common 'dandelion'), which are supported in the air by a parachute placed at some distance above them. If a sudden gust of wind blows upon such a seed, the parachute is set in motion more rapidly than the seed, causing the structure to heel over so as to receive the wind on the under surface of the parachute, and this lifts the seed. When the wind subsides, the greater inertia of the seed carries it on in front of the parachute, causing the latter to again present its under side to the air, which again lifts the seed. The more the seed is blown about, the more it rises in the air.

This action would take place automatically in the same way in any body whose supporting parachute, aëroplane, or wing surface was slightly *above* its centre of mass. The height of the supporting surface should not be too great, otherwise the body would heel over too much, and would make so great an angle with the horizon that the lift would be considerably reduced.

The effect evidently depends on the *inertia* of the body, and the lift could therefore be increased by increasing the body's *mass.* But this would also increase the *weight* of the body in the same proportion, so that no advantage would be gained.

The difficulty is overcome in the case of the sailing bird by the increased buoyancy which it is able to obtain from the air in consequence of the horizontal speed at which it travels, and herein, to my mind, lies the answer to the second objection. Dr. S. P. Langley[1] has found (1) that a horizontal plane under the action of gravity falls to the ground more slowly if it is travelling through the air with horizontal velocity than it would do if allowed to fall vertically, and (2) that the horse-power required to support a body in horizontal flight by means of an aëroplane is less for high than for low speeds. Hence it readily follows that the bird's forward motion causes it to fall through a smaller height between successive gusts of wind than it would do if it were at rest, and that when a *side* wind strikes the bird (*i.e.* a wind at right angles to the bird's course), the lift is considerably increased in consequence of the bird's forward velocity.

[1] *Experiments on Aërodynamics.*

According to this theory, the sailing bird derives its energy from fluctuations in the resolved part of the wind-velocity, *at right angles* to the bird's course. Such side winds would, in particular, be brought into action first on one side and then on the other whenever the bird passed through the centre of an atmospheric vortex. The exact part played by variations of wind-velocity *in the direction of the bird's course* is more difficult to understand, but it seems improbable that such variations alone could account for the phenomena. If the bird were moving slowly enough to receive the wind sometimes in front and sometimes from behind, it would at intermediate instants be at rest relative to the wind, and would then obtain the minimum degree of support. If it were moving rapidly through the air, the latter would always strike the bird in front, so that its horizontal motion would be constantly retarded.

Anyone watching a flock of birds will observe that they often actually *are* carried up by a sudden side-gust of wind in the manner here described, showing that if this is not the only cause of the phenomena presented by the sailing bird, it is at any rate *one* of the causes. So much has been written on the subject that it is impossible to say how far these remarks may have been anticipated by other writers; but I think they may help to clear up some of the difficulties which have been experienced in accounting for the sailing flight of birds.

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11. *On the Stanhope Arithmetical Machine of* 1780. *By the* Rev. R. Harley, *M.A., F.R.S.*

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12. *The Exploration of the Upper Air by means of Kites.* *By* A. Laurence Rotch.

This is a preliminary account of experiments being conducted at the Blue Hill Meteorological Observatory, Roadville, Massachusetts. The author, after referring to previous instances of the use of kites for meteorological purposes, gives details of the apparatus and methods employed at Blue Hill in kite observations, which were commenced in 1891, and are still being carried on. The kites are, some of trapezoidal, and some of Hargreaves' cellular, form, and are controlled by pianoforte wire of 300 lb. tensile strength. The pull on the wire is not allowed to exceed 125 lb. Two self-recording aluminium instruments are used, one recording, on a single cylinder, barometric pressure, temperature, and humidity. The other records temperature, humidity, and wind-velocity.

Each is suspended between two kites to diminish oscillation.

As an illustration of the importance of the use of kites in weather prediction may be mentioned the fact, which has been demonstrated at Blue Hill, that in the United States, at least, warm and cold waves commence in the upper regions before they are felt at the ground. The conditions at mountain stations only approximate to those prevailing in the free air. Kites are superior to captive balloons, as being both cheaper and capable of flying through a greater range of wind velocity, and to greater altitudes.

TUESDAY, SEPTEMBER 22.

The following Reports and Papers were read:—

1. *Interim Report on Electrolysis and Electro-chemistry.* See Reports, p. 230.

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2. *Report of the Electrical Standards Committee.*—See Reports, p. 150.

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3. *The Total Heat of Water.—By* W. N. Shaw, *M.A., F.R.S.*
Appendix III. of Report on Electrical Standards.—See Reports, p. 162.

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4. *Note on the Measurement of Electrical Resistance.*
By E. H. Griffiths, *M.A., F.R.S.*

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5. *Researches in Absolute Mercurial Thermometry.*
By S. A. Sworn, *M.A. (Oxon.), F.C.S., Assoc. R.C.Sc.I.*

This work practically consists of the life-history of the instruments. It is therein shown, as the result of observations carried on for four years, that the zero point of a mercurial thermometer (when fully corrected for the above constants) is a complicated function of time and temperature environment. It will be proved experimentally that the so-called 'depression of the freezing point' is not a constant, but that the magnitude of the depression is a function depending upon the previous environment and the duration of the cause of the depression.

WEDNESDAY, SEPTEMBER 23.

The Section was divided into two Departments.

The following Papers and Report were read:—

Department I.

1. *Measurement by means of the Spectroscope of the Velocity of Rotation of the Planets. By* James E. Keeler, *Sc.D., Allegheny Observatory.*

The method of determining the velocity of rotation of a planet by means of the spectroscope was suggested at a comparatively early date, but it is only quite recently that accurate measures have been made. Such measures, in which the spectrum is photographed, instead of being observed directly, have been made by Deslandres, Bélopolsky, Campbell, and by the author. The slit of the spectroscope is always made to coincide as nearly as possible with the equator of the image of the planet, so that the inclination of the planetary lines on the photographed spectrum may be as great as possible, and measurement of this angle gives, when the linear dispersion and size of the image of the planet are known, the equatorial velocity of rotation.

In the *Astrophysical Journal* for May, 1895, the author gives a convenient formula for reducing the observations when the planet is in opposition. It is

$$V = \frac{\rho D L \tan\phi}{2\lambda\cos\beta}.$$

If the planet is not nearly in opposition, so that the earth and sun as seen from it are separated by the angular distance a, we must write $1 + \cos a$ in the denominator instead of 2. (Deslandres, *C.R.* 120, 417; Poincaré, *C.R.* **120**, 420.) The formula then becomes

$$V = \frac{\rho D L \tan\phi}{\lambda(1+\cos a)\cos\beta},$$

and this is the formula which has been employed in reducing the observations which follow.

From a considerable number of photographs of Jupiter, four of the best, taken on the following dates, were selected for measurement:—

1895, February 24, region $b-$D, orthochromatic plate.
1895, March 21, „ $b-$D, „ „
1896, April 22, „ G – F, ordinary plate.
1896, May 6, „ G – F, „ „

The following table contains the data, taken in part from Marth's ephemeris, which are required for the reduction of the photographs :—

Date of Photograph		α	β	Eq. Diam.	ρ
	D H	° ′	° ′	″	m.
1895, February	24 8	10 22	2 05	41·09	0·654
„ March	21 $8\frac{1}{2}$	11 05	2 01	37·91	0·263
1896, April	22 8	10 53	0 34	38·00	0·4286
„ May	6 8	10 33	0 32	36·48	0·4114

Focal length of telescope for b = 4640. mm.
„ „ „ $H\gamma$ = 4653.
L = velocity of light in kilometres = 299860.

Results.

Photograph of February 24, 1895.

λ	D	tan ϕ	V km.
5230	23·65	·0326	10·37
5270	24·75	·0470	15·54
5328	26·20	·0404	14·11
5372	27·25	·0434	15·50
5430	28·75	·0434	16·17
5456	29·40	·0296	11·22
		Mean	13·82

Photograph of March 21, 1895.

λ	D	tan ϕ	V km.
5230	23·65	·0656	19·14
5270	24·75	·0464	14·06
5328	26·20	·0484	15·50
5372	27·25	·0390	12·77
5430	28·75	·0460	15·72
5456	29·40	.0390	13·56
		Mean	15·12

Photograph of April 22, 1896.

λ	D	tan ϕ	V km.
4352	11·30	·0744	12·53
4415	12·35	·0644	11·68
4427	12·70	·0626	11·64
4476	13·80	·0614	12·28
4495	14·40	·0660	13·42
4529	14·75	·0490	10 35
		Mean	11·98

Photograph of May 6, 1896.

λ	D	tan ϕ	V km.
4315	10·60	·0816	12·47
4370	11·65	·0846	14·03
4427	12·70	·0774	13·81
4476	13·80	·0590	11·32
4495	14·10	·0594	11·59
4529	14·75	·0544	11·02
		Mean	12·37

Giving double weight to the last two photographs, for which the dispersion is about twice that of the first two, the result of all the measures is

$$V = 12{\cdot}94 \text{ km.} \pm 0{\cdot}27 \text{ km.}$$

Deslandres found V = 12·5, 11·9, 12·1, 11·7. Bélopolsky found V = 11·42.

The computed value is 12·1 to 12·8, according to the value of the equatorial diameter of Jupiter which is assumed.

Bélopolsky has pointed out that his spectroscopic observations of both Jupiter and Saturn give a smaller velocity than that deduced from observations of spots, and he suggests, in explanation of this fact, that Jupiter may be a body like that considered in Schmidt's theory of the sun, so that rays apparently proceeding from the limb really come from a considerable depth, where the velocity of rotation is less. The observations above given do not support this view, since the velocity deduced from them is a little too great. It is altogether probable that the discrepancies noted by Bélopolsky are due to errors of observation. If, however, the slit were not properly placed, a velocity slightly too small would be obtained, since the angular velocity of the surface diminishes with increasing latitude, and falls off quite rapidly in the region near the equator.

In 1895 the author succeeded in showing, by an extension of the same method, that the velocity at any point on the ring of Saturn is that of a particle moving in obedience to Kepler's third law, and hence that the ring is not a solid body. Attempts to determine the rotation of Venus have so far been unsuccessful.

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2. *On the Photo-electric Sensitisation of Salts by Cathodic Rays.* *By* Professor J. ELSTER *and* Professor GEITEL, *Wolfenbüttel, Germany.*

The results of the investigation made by the authors may be summed up as follows:—

Cathodic rays falling upon the chlorides of cæsium, rubidium, potassium, sodium, lithium, clear fluorspar, and even powdered glass, convert these salts into substances which are incapable of retaining a negative charge of electricity when exposed to light belonging to the visible part of the spectrum.

All circumstances capable of abolishing the colours produced by cathodic radiation also destroy the photo-electric sensitiveness.

A complete account of the investigation will shortly be published in Wiedemann's 'Annalen.'

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3. *On Certain Photographic Effects.* *By* Professor P. DE HEEN.

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4. *Some Experiments on Absorption and Fluorescence.* *By* JOHN BURKE, *B.A.*

Fluorescent bodies are generally more or less transparent to the rays they emit. The experiments were with a view to detecting whether any difference exists between the absorption when a body is fluorescing and when not. The comparisons were made with a form of double slit photometer in which photography was employed, described at length in the paper. Allowing for the various sources of error which may possibly arise, there still remains a marked difference between the intensity of the light transmitted in the two cases, amounting in some instances to a difference of 40 per cent. in the absorptive power. Thus a substance such as uranium glass would appear to be less transparent to the yellow rays from a candle in daylight than in the dark. The latter part of the paper deals with the influence of dissociation on fluorescence and with the theory of fluorescence itself.

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5. *On Homogeneous Structures and the Symmetrical Partitioning of them, with application to Crystals.*[1] *By* WILLIAM BARLOW.

This paper is the outcome of several years' study of the geometrical possibilities of symmetrical space relations, the importance of which in regard to crystals has long been recognised, and whose value in relation to the fundamental concepts of matter generally is of late becoming more and more appreciated. The inquiry is a purely geometrical one, and is therefore independent of any particular concept as to the ultimate nature of matter.

The basis of the investigation is a definition of homogeneity of structure which runs as follows:—

A homogeneous structure is one every point within which, if we regard the

[1] Published in full in the *Mineralogical Magazine*, vol. xi. p. 119; and also in *Groth's Zeitschrift für Krystallographie*, vol. xxvii. p. 449.

structure as without boundaries, has corresponding to it an infinitude of other points whose situations in the structure are precisely similar, so that all of the infinite number of geometrical point-systems respectively obtained by taking all similarly situated points are regular infinite point-systems defined by Sohncke as systems of points such that the arrangement about any one of these points of the rest of the points of the system is the same as it is about any other of them.'[1]

This definition is not limited in its application to point-systems or assemblages of particles; it may be obeyed by any kind of structure, whether material or merely geometrical, whether filling space or continuously ramifying through it, or distributed through it in discrete patches. It may, too, be obeyed by structures whose parts are in motion, provided the similarity extends to the movements of similar parts; but the similar movements need not be simultaneous; they may, for example, resemble the rhythmically related movements of *combined figure skating*.

The models employed to show the nature of the repetition in space which characterises different types of homogeneous structure consist of symmetrically arranged dolls' hands, the reason for employing these objects being that they are familiar and and at the same time of so exceptional a shape as to avoid any suggestion that a particular form is essential for the ultimate parts of a structure.

Primarily the structures are to be regarded as not partitioned into parts, the type of homogeneity being expressed in a more general manner when there is no partitioning.

The number of different types of symmetrical arrangement presented by all unpartitioned homogeneous structures is 230.

As to the symmetrical partitioning of homogeneous structures the author points out that many different types of partitioning into molecular units are possible for each type of structure, and appends a fragment of a table of the types of partitioning which pertain to the different types of structure belonging to the cubic system.

Department II.

1. *Report on the Sizes of Pages of Periodicals.*
See Reports, p. 86.

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2. *On Disturbance in Submarine Cables. By* W. H. Preece, *C.B., F.R.S.*

This paper deals with the several problems connected with the difficulties in working sub-marine cables, and especially when used for telephonic purposes. It is fully reported in the 'Electrician' for September 27, 1896.

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3. *On Carbon Megohms for High Voltages. By* W. M. Mordey.

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4. *On an Instrument for measuring Magnetic Permeability. By* W. M. Mordey.

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5. *A Direct-reading Wheatstone Bridge. By* A. P. Trotter, *B.A.*

The author describes a Wheatstone slide bridge which is made direct-reading upon a scale of equal parts. This is accomplished by making the ratio-arms of a

[1] *Sohncke's Entwickelung einer Theorie der Krystallstruktur*, p. 28.

second slide-wire of equal resistance to the slide-wire on which the galvanometer contact works, the zero for the galvanometer slide-wire being taken at a point so far along the wire that the piece between this point and the end shall be equal to the length of the other slide-wire between the end and the other contact of the galvanometer circuit. Nickel steel wire is used for the slides.

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6. *The Division of an Alternating Current in Parallel Circuits with Mutual Induction.* *By* FREDERICK BEDELL.

A divided circuit with mutual induction between the two branches is the same as a transformer with the primary and secondary circuits connected in parallel. The problem may be treated in the same manner as that of the transformer. The electromotive force equations for the two circuits are similar, the internal electromotive forces in each being equal to the same impressed electromotive force. The electromotive force of mutual induction will be positive or negative according to the sense or direction in which the coils are connected. If the coils are connected so that the ampere turns of the two coils assist each other, the electromotive force of self and mutual induction will be of the same sign, and the coefficient of mutual induction will be positive. If the coils are connected so that the two oppose each other, the electromotive force of mutual induction will be opposed in sign to that of self-induction. The coefficient of mutual induction may accordingly be plus M or minus M. Writing the electromotive force as a function of the time, the electromotive force equations for the two circuits are:

$$e = f(t) = R_1 i_1 + L_1 D i_1 \pm M D i_2 \; ;$$
$$e = f(t) = R_2 i_2 + L_2 D i_2 \pm M D i_1 \; ;$$

where e and i represent current and electromotive force, R and L represent resistance and self-induction, and D stands for the operator $\frac{d}{dt}$. The solution of these equations gives us the values for the currents in the two circuits, and their phase relations. Where the coils are opposed and nearly similar, the angle of phase difference between the currents depends largely upon the amount of magnetic leakage.

The graphical treatment of the problem shows this relation more clearly. The electromotive force to overcome the resistance of each circuit is represented by a vector in the direction of the current. The electromotive forces of self and mutual induction are at right angles to the currents in their respective circuits. This gives us three vectors for the electromotive forces in either circuit, and the sum of these three vectors in either circuit is equal to the electromotive force impressed upon the two circuits. The direction of the vector representing the electromotive force of mutual induction depends upon the sense in which the coils are connected.

The equivalent resistance and self-induction of the two coils together, whether they are additive or opposed, may be found by resolving the electromotive force into two components, one in the direction of the main current, and the other at right angles to it. The resultant of these components may be obtained graphically and from them the values of the equivalent resistance R^1, and the equivalent self-induction L^1. The equivalent resistance and self-induction of their branches may be obtained in the same manner.

Particular cases may be discussed by assuming definite values for the constants of the circuits or definite relations between them.

Section B.—CHEMISTRY.

President of the Section.—Dr. Ludwig Mond, F.R.S.

THURSDAY, SEPTEMBER 17.

The President delivered the following Address:—

In endeavouring to fix upon a suitable theme for the address I knew you would to-day expect from me, I have felt that I ought to give due consideration to the interests which tie this magnificent city of Liverpool, whose hospitality we enjoy this week, to Section B of the British Association.

I have therefore chosen to give you a brief history of the manufacture of chlorine, with the progress of which this city and its neighbourhood have been very conspicuously and very honourably connected, not only as regards quantity—I believe this neighbourhood produces to-day nearly as much chlorine as the rest of this world together—but more particularly by having originated, worked out, and carried into practice several of the most important improvements ever introduced into this manufacture. I was confirmed in my choice by the fact that this manufacture has been influenced and perfected in an extraordinary degree by the rapid assimilation and application of the results of purely scientific investigations and of new scientific theories, and offers a very remarkable example of the incalculable value to our commercial interests of the progress of pure science.

The early history of chlorine is particularly interesting, as it played a most important *rôle* in the development of chemical theories. There can be no doubt that the Arabian alchemist Geber, who lived eleven hundred years ago, must have known that 'Aqua Regia,' which he prepared by distilling a mixture of salt, nitre, and vitriol, gave off on heating very corrosive, evil-smelling, greenish-yellow fumes, and all his followers throughout a thousand years must have been more or less molested by these fumes whenever they used Aqua Regia, the one solvent of the gold they attempted so persistently to produce.

But it was not until 1774 that the great Swedish chemist Scheele succeeded in establishing the character of these fumes. He discovered that on heating manganese with muriatic acid he obtained fumes very similar to those given off by 'Aqua Regia,' and found that these fumes constituted a permanent gas of yellowish-green colour, very pungent odour, very corrosive, very irritating to the respiratory organs, and which had the power of destroying organic colouring matters.

According to the views prevalent at the time, Scheele considered that the manganese had removed phlogiston from the muriatic acid, and he consequently called the gas dephlogisticated muriatic acid.

When during the next decade Lavoisier successfully attacked, and after a memorable struggle completely upset, the phlogiston theory and laid the foundations of our modern chemistry, Berthollet, the eminent 'father' of physical chemistry—the science of to-day—endeavoured to determine the place of Scheele's gas in the new theory. Lavoisier was of opinion that all acids, including muriatic acid, contain oxygen. Berthollet found that a solution of Scheele's gas in water, when exposed to the sunlight, gives off oxygen and leaves behind muriatic acid. He considered this as proof that this gas consists of muriatic acid and oxygen, and called it oxygenated muriatic acid.

In the year 1785 Berthollet conceived the idea of utilising the colour-destroying powers of this gas for bleaching purposes. He prepared the gas by heating a mixture of salt, manganese, and vitriol. He used a solution of the gas in water for bleaching, and subsequently discovered that the product obtained by absorbing the gas in a solution of caustic potash possessed great advantages in practice.

This solution was prepared as early as 1789, at the chemical works on the Quai de Javelle, in Paris, and is still made and used there under the name of 'Eau de Javelle.'

James Watt, whose great mind was not entirely taken up with that greatest of all inventions—his steam-engine—by which he has benefited the human race more than any other man, but who also did excellent work in chemistry—became acquainted in Paris with Berthollet's process, and brought it to Scotland. Here it was taken up with that energy characteristic of the Scotch, and a great stride forward was made when, in 1798, Charles Tennant, the founder of the great firm, which has only recently lapsed into the United Alkali Company, began to use milk of lime, in place of the more costly caustic potash, in making a bleaching liquid; and a still greater advance was made when, in the following year, Tennant proposed to absorb the chlorine by hydrate of lime, and thus to produce a dry substance, since known under the name of bleaching powder, which allowed the bleaching powers of chlorine to be transported to any distance.

In order to give you a conception of the theoretical ideas prevalent at this time, I will read to you a passage from an interesting treatise on the art of bleaching published in 1799 by Higgins. In his chapter 'On bleaching with the oxygenated muriatic acid, and on the methods of preparing it' he explains the theory of the process as follows:—

'Manganese is an oxyd, a metal saturated with oxygen gas. Common salt is composed of muriatic acid and an alkaline salt called soda, the same which barilla affords. Manganese has greater affinity to sulphuric acid than to its oxygen, and the soda of the salt greater affinity to sulphuric acid than to the muriatic acid gas; hence it necessarily follows that these two gases (or rather their gravitating matter) must be liberated from their former union in immediate contact with each other; and although they have but a weak affinity to one another, they unite in their nascent state, that is to say, before they individually unite to caloric, and separately assume the gaseous state; for oxygen gas and muriatic acid gas already formed will not unite when mixed, in consequence principally of the distance at which their respective atmospheres of caloric keep their gravitating particles asunder. The compound resulting from these two gases still retains the property of assuming the gaseous state, and is the oxygenated muriatic gas.'

Interesting as these views may appear, considering the time they were published, you will notice that the *rôle* played by the manganese in the process and the chemical nature of this substance were not at all understood. The law of multiple proportions had not yet been propounded by John Dalton, and the researches of Berzelius on the oxides of manganese were only published thirteen years later, in 1812. The green gas we are considering was still looked upon as muriatic acid, to which oxygen had been added, in contradistinction to Scheele's view, who considered it as muriatic acid, from which something, viz., phlogiston, had been abstracted.

It was Humphry Davy who had, by a series of brilliant investigations carried out in the Laboratory of the Royal Institution between 1808 and 1810, accumulated fact upon fact to prove that the gas hitherto called oxygenated muriatic acid did not contain oxygen. He announced in an historic paper, which he read before the Royal Society on July 12, 1810, his conclusion that this gas was an elementary body, which in muriatic acid was combined with hydrogen, and for which he proposed the name 'chlorine,' derived from the Greek χλωρός, signifying 'green,' the colour by which the gas is distinguished.

The numerous communications which Humphry Davy made to the Royal Society on this subject form one of the brightest and most interesting chapters in the history of chemistry. They have recently been reprinted by the Alembic Society, and I cannot too highly recommend their study to the young students of our science.

I need not remind those who have followed the history of chemistry how hotly and persistently Davy's views were combated by a number of the most eminent chemists of his time, led by Berzelius himself; how long the chlorine controversy divided the chemical world; how triumphantly Davy emerged from it; how completely his views were recognised; and how very instrumental they have been in advancing theoretical chemistry.

The hope, however, which Davy expressed in that same historic paper, 'that these new views would perhaps facilitate one of the greatest problems in economical chemistry, the decomposition of the muriates of soda and potash,' was not to be realised so soon. Although it had changed its name, chlorine was still for many years manufactured by heating a mixture of salt, manganese, and sulphuric acid in leaden stills, as before.

This process leaves a residue consisting of sulphate of soda and sulphate of manganese, and for some time attempts were made to recover the sulphate of soda from these residues, and to use it for the manufacture of carbonate of soda by the Le Blanc process. On the other hand, the Le Blanc process, which had been discovered and put into practice almost simultaneously with Berthollet's chlorine process, decomposed salt by sulphuric acid, and sent the muriatic acid evolved into the atmosphere, causing a great nuisance to the neighbourhood.

Naturally, therefore, when Mr. William Gossage had succeeded in devising plant for condensing this muriatic acid, the manufacturers of chlorine reverted to the original process of Scheele, and heated manganese with the muriatic acid thus obtained. Since then the manufacture of chlorine had become a by-product of the manufacture of soda by the Le Blanc process, and remained so till very recently.

For a great many years the muriatic acid was allowed to act upon native ores of manganese in closed vessels of earthenware or stone, to which heat could be applied, either externally or internally. These native manganese ores, containing only a certain amount of peroxide, converted only a certain percentage of the muriatic acid employed into free chlorine, the rest combining with the manganese and iron contained in the ore, and forming a brown and very acid solution, which it was a great difficulty for the manufacturer to get rid of. Consequently, many attempts were made to regenerate peroxide of manganese from these waste liquors, so as to use it over again in the production of chlorine.

These, however, for a long time remained unsuccessful, because the exact conditions for super-oxidising the protoxide of manganese by means of atmospheric air were not yet known.

Meantime, viz., in 1845, Mr. Dunlop introduced into the works created by his grandfather, Mr. Charles Tennant, at St. Rollox, a new and very interesting method for producing chlorine, which was in a certain measure a return to the process used by the alchemists.

Indeed, the first part of this process consisted in decomposing a mixture of salt and nitre with oil of vitriol—a reaction that had been made use of for so many centuries! The chlorine so obtained is, however, not pure, but a mixture of chlorine with oxides of nitrogen and hydrochloric acid, which Mr. Dunlop had to find means to eliminate.

For separating the nitrous oxides, Mr. Dunlop adopted the method introduced twenty years before by the great Gay-Lussac in connection with vitriol-making, viz., absorption by sulphuric acid, and the nitro-sulphuric acid thus formed he also utilised in the same way as that obtained from the towers which still bear Gay-Lussac's illustrious name, viz., by using it in the vitriol process in lieu of nitric acid. He then freed his chlorine gas from hydrochloric acid by washing with water, and so obtained it pure. This process possessed two distinct advantages:—(1) it yielded a very much larger amount of chlorine from the same amount of salt; and (2) the nitric acid, which was used for oxidising the hydrogen in the hydrochloric acid, was not lost, because the oxides of nitrogen to which it was reduced answered the purpose for which the acid itself had previously been employed. But this process was very limited in its application, as it could only be worked to the extent to which nitric acid was used in vitriol-making.

The process has been at work at St. Rollox for over fifty years, and, as far as I know, is still in operation there; but I am not aware that it has ever been taken up elsewhere.

Within the last few years, however, several serious attempts have been made to give to this process a wider scope by regenerating nitric acid from the nitro-sulphuric acid and employing it over and over again to produce chlorine from hydrochloric acid. Quite a number of patents have been taken out for this purpose, all employing atmospheric air for reconverting the nitrous oxides into nitric acid, and differing mainly in details of apparatus and methods of work, and several of these have been put to practical test on a fairly large scale in this neighbourhood, and also in Glasgow, Middlesbrough, and elsewhere. As I do not want to keep you here the whole afternoon, I have to draw the line somewhere as to what I shall include in this brief history of the manufacture of chlorine, and have had to decide to restrict myself to those methods which have actually attained the rank of manufacturing processes on a large scale. As none of the processes just referred to have attained that position, you will excuse me for not entering into further details respecting them.

Mr. Dunlop's process only produced a very small portion of the chlorine manufactured at that time at St. Rollox, the remainder being made, as before, from native manganese and muriatic acid, leaving behind the very offensive waste liquors I have mentioned before, which increased from year to year, and became more and more difficult to get rid of. The problem of recovering from these liquors the manganese in the form of peroxide Mr. Dunlop succeeded in solving in 1855.

He neutralised the free acid and precipitated the iron present by treating these liquors with ground chalk in the cold and settling out, and in later years filter-pressing the precipitate, which left him a solution of chloride of manganese, mixed only with chloride of calcium. This was treated with a fresh quantity of milk of chalk, but this time under pressure in closed vessels provided with agitators and heated by steam, under which conditions all the manganese was precipitated as carbonate of manganese. This precipitate was filtered off and well drained, and was then passed on iron trays mounted on carriages through long chambers, in which it was exposed to hot air at a temperature of 300° C., the process being practically made continuous, one tray at the one end being taken out of these chambers, and a fresh tray being put in at the other end. One passage through these chambers sufficed to convert the carbonate of manganese into peroxide, which was used in place of, and in the same way as, the native manganese.

The whole of the residual liquors made at the large works at St. Rollox have been treated by this process with signal success for a long number of years. For a short time the process was discontinued in favour of the Weldon process (of which I have to speak next); but after two years Dunlop's process was taken up again, and, to the best of my knowledge, it is still in operation to this day. It has, however, just like Mr. Dunlop's first chlorine process, never left the place of its birth (St. Rollox), although it was for a period of over ten years without a rival.

In 1866 Mr. Walter Weldon patented a modification of a process proposed by Mr. William Gossage in 1837 for recovering the manganese that had been used in the manufacture of chlorine. Mr. Gossage had proposed to treat the residual liquors of this manufacture by lime, and to oxidise the resulting protoxide of manganese by bringing it into frequent and intimate contact with atmospheric air. This process—and several modifications thereof subsequently patented—had been tried in various places without success. Mr. Weldon, however, did succeed in obtaining a very satisfactory result, possibly—even probably—because, not being a chemist, he did not add the equivalent quantity of lime to his liquor to precipitate the manganese, but used an excess. However, Mr. Weldon, if he was not a chemist at that time, was a man of genius and of great perseverance. He soon made himself a chemist, and having once got a satisfactory result, he studied every small detail of the reaction with the utmost tenacity until he had thoroughly established how this satisfactory result could be obtained on the largest scale with the greatest regularity and certainty.

He even went further, and added considerably to our theoretical knowledge of the character of manganese peroxide and similar peroxides by putting forward the view that these compounds possess the character of weak acids. He explained in this way the necessity for the presence of an excess of lime or other base if the oxidation of the precipitated protoxide of manganese by means of atmospheric air was to proceed at a sufficiently rapid rate. He pointed out that the product had to be considered as a manganite of calcium, a view which has since been thoroughly proved by the investigations of Goergen and others; and it is only fair to state that Weldon's process is not only a process for recovering the peroxide of manganese originally used, but that he introduced a new substance, viz., manganite of calcium, to be continuously used over and over again in the manufacture of chlorine.

Mr. Weldon had the good fortune that his ideas were taken up with fervency by Colonel Gamble of St. Helens, and that Colonel Gamble's manager, Mr. F. Bramwell, placed all his experience as a consummate technical chemist and engineer at Mr. Weldon's disposal, and assisted him in carrying his ideas into practice. The result was that a process which many able men had tried in vain to realise for thirty years became in the hands of Mr. Weldon and his coadjutors within a few years one of the greatest successes achieved in manufacturing chemistry.

The Weldon process commences by treating the residual liquor with ground chalk or limestone, thus neutralising the free acid and precipitating any sulphuric acid and oxide of iron present. The clarified liquor is run into a tall cylindrical vessel, and milk of lime is added in sufficient quantity to precipitate all the manganese in the form of protoxide. An additional quantity of milk of lime, from one-fifth to one-third of the quantity previously used, is then introduced, and air passed through the vessel by means of an air-compressor. After a few hours all the manganese is converted into peroxide; the contents of the vessel are then run off; the mud, now everywhere known as 'Weldon mud,' is settled, and the clear liquor run to waste. The mud is then pumped into large closed stone stills, where it meets with muriatic acid, chlorine is given off, and the residual liquor treated as before.

You note that this process works without any manipulation, merely by the circulation of liquids and thick magmas which are moved by pumping machinery. As compared to older processes it also has the great advantage that it requires very little time for completing the cycle of operations, so that large quantities of chlorine can be produced by a very simple and inexpensive plant. These advantages secured for this process the quite unprecedented success that within a few years it was adopted, with a few isolated exceptions, by every large manufacturer of chlorine in the world; yet it possessed a distinct drawback, viz., that it produced considerably less chlorine from a given quantity of muriatic acid than either native manganese of good quality or Mr. Dunlop's recovered manganese. At that time, however, muriatic acid was produced as a by-product of the Le Blanc process so largely in excess of what could be utilised that it was generally looked upon as a waste product of no value. Mr. Weldon himself was one of the very few who foresaw that this state of things could not always continue. The ammonia soda process was casting its shadow before it. Patented in 1838 by Messrs. Dyar and Hemming it was only after the lapse of thirty years (during which a number of manufacturing chemists of the highest standing had in vain endeavoured to carry it into practice) that this process was raised to the rank of a manufacturing process through the indomitable perseverance of Mr. Ernest Solvay, of Brussels, and his clear perception of its practical and theoretical intricacies. A few years later, in 1872, Mr. Weldon already gave his attention to the problem of obtaining the chlorine of the salt used in this process in the form of muriatic acid. He proposed to recover the ammonia from the ammonium chloride obtained in this manufacture by magnesia instead of lime, thus obtaining magnesium chloride instead of calcium chloride, and to produce muriatic acid from this magnesium chloride by a process patented by Clemm in 1863, viz., by evaporating the solution, heating the residue in the presence of steam, and condensing the acid vapours given off.

Strange to say, this same method had been patented by Mr. Ernest Solvay within twenty-four hours before Mr. Weldon lodged his specification. It has been frequently tried with many modifications, but has never been found practicable. Soon afterwards Mr. Weldon, with the object of reducing the muriatic acid required by his first process, proposed to replace the lime in this process by magnesia, and so to produce a manganite of magnesia. After treating this with muriatic acid and liberating chlorine he proceeded to evaporate the residual liquors to dryness, during which operation all the chlorine they contain would be disengaged as hydrochloric acid and collected in condensers, while the dry residue, after being heated to dull redness in the presence of air, would be reconverted into manganite of magnesia.

This process was made the subject of long and extensive experiments at the works of Messrs. Gamble at St. Helens, but did not realise Mr. Weldon's expectations. It, however, led to some further interesting developments, to which I shall refer later on.

Those of you who were present at the last meeting of the British Association in this city will remember that this Section had the advantage of listening to a paper by Mr. Weldon on his chlorine process, and also to another highly interesting paper by Mr. Henry Deacon of Widnes 'on a new chlorine process without manganese.' And those of you who came with the then President of the Section (Professor Roscoe) to Widnes to visit the works of Messrs. Gaskell, Deacon, and Co. will well remember that at these works they saw side by side Weldon's process and Deacon's process in operation, and no one present will have forgotten the thoughtful, flashing eyes and impressive face of Mr. Deacon when he explained to his visitors the theoretical views he had formed as regards his process.

Mr. Deacon had made a careful study of thermo-chemistry, which had been greatly developed during the preceding decade by the painstaking, accurate, and comprehensive experiments of Julius Thomsen and of Berthelot, and had led the latter to generalisations which, although not fully accepted by scientific men, have been of immense service to manufacturing chemistry.

Mr. Deacon came to the conclusion that, if a mixture of hydrochloric acid with atmospheric air was heated in the presence of a suitable substance capable of initiating the interaction of these two gases by its affinity to both, it would to a very great extent be converted into chlorine with the simultaneous formation of steam, because the formation of steam from oxygen and hydrogen gives rise to the evolution of a considerably larger quantity of heat than the combination of hydrogen and chlorine. Mr. Deacon found that the salts of copper were a very suitable substance for this purpose, and took out a patent for this process in 1868. He entrusted the study of the theoretical and practical problems connected with this process to Dr. Ferdinand Hurter, who carried them out in a manner which will always remain memorable, and will never be surpassed, as an example of the application of scientific methods to manufacturing problems, and which soon placed this beautiful and simple process on a sound basis as a manufacturing operation.

In the ordinary course of manufacture the major part—about two-thirds—of the hydrochloric acid is obtained mixed with air and a certain amount of steam, but otherwise very little contaminated. Instead of condensing the muriatic acid from this mixture of gases by bringing it into contact with water, Mr. Deacon passed it through a long series of cooling pipes to condense the steam, which of course absorbed hydrochloric acid, and formed a certain quantity of strong muriatic acid. The mixture of gases was then passed through an iron superheater to raise it to the required temperature, and thence through a mass of broken bricks impregnated with sulphate or chloride of copper contained in a chamber or cylinder called a decomposer, which was protected from loss of heat by being placed in a brick furnace kept sufficiently hot. In this apparatus from 50 to 60 per cent. of the hydrochloric acid in the mixture of gases was burnt to steam and chlorine. In order to separate this chlorine from the steam and the remaining hydrochloric acid the gases were washed with water, and subsequently with sulphuric acid. The mixture now consisted of nitrogen and oxygen, containing about 10 per cent. of chlorine gas, which could be utilised without any difficulty in the manufacture of bleach liquors and chlorate of potash, and which Mr. Deacon also succeeded in using for the manufacture of bleaching powder, by bringing it into contact in specially constructed chambers with large surfaces of hydrate of lime. Within recent years this latter object has been attained in a more expeditious and perfect manner by continuous mechanical apparatus (of which those constructed by Mr. Robert Hasenclever and Dr. Carl Langer have been the most successful), in which the hydrate of lime is transported in a continuous stream by single or double conveyors in an opposite direction to the current of dilute chlorine, and the bleaching powder formed delivered direct into casks, thereby avoiding the intensely disagreeable work of packing this offensive substance by hand.

Mr. Deacon's beautiful and scientific process thus involves still less movement of materials than the very simple process of Mr. Weldon, because in lieu of large volumes of liquids he only moves a current of gas through his apparatus, which requires a minimum of energy. The only raw material used for converting hydrochloric acid into chlorine is atmospheric air, the cheapest of all at our command. The hydrochloric acid which has not been converted into chlorine by the process is all obtained, dissolved in water, as muriatic acid, and is not lost, as in previous processes, but is still available to be converted into chlorine by other methods, or to be used for other purposes.

In spite of these distinct advantages, this process took a long time before it became adopted as widely as it undoubtedly deserved. This was mainly due to the fact that the economy in the use of muriatic acid which it effected was at the time when the process was brought out, and for many years afterwards, no object to the majority of chlorine manufacturers, who were still producing more of this commodity than they could use. Moreover, there were other reasons. The plant required for this process, although so simple in principle, is very bulky in proportion to the quantity of chlorine produced, and, as I have pointed out, the process only succeeded in converting about one-third of the hydrochloric acid produced into chlorine, the remainder being obtained as muriatic acid, which had in most instances to be converted into chlorine by the Weldon process; so that the Deacon process did not constitute an entirely self-contained method for this manufacture. This defect, of small moment as long as muriatic acid was produced in excessive quantities, was only remedied by an invention of Mr. Robert Hasenclever a short number of years ago; when by the rapid development of the ammonia soda process the previously existing state of things had been completely changed, and when, at least on the Continent, muriatic acid was no longer an abundant and valueless by-product, but, on the contrary, the alkali produced by the Le Blanc process had become a by-product of the manufacture of chlorine. Mr. Hasenclever, in order to make the whole of the muriatic acid he produces available for conversion into chlorine by the Deacon process, introduces the liquid muriatic acid in a continuous stream into hot sulphuric acid contained in a series of stone vessels, through which he passes a current of air. He thus obtains a mixture of hydrochloric acid and air, well adapted for the Deacon process, the water of the muriatic acid remaining with the sulphuric acid, from which it is subsequently eliminated by evaporation. In this way the chlorine in the hydrochloric acid can be almost entirely obtained in its free state by the simplest imaginable means, and with the intervention of no other chemical agent than atmospheric air. Since their introduction the Deacon process has supplanted the Weldon process in nearly all the largest chlorine works in France and Germany, and is now also making very rapid progress in this country.

Mr. Weldon, when he decided to give up his manganite of magnesia process, by no means relaxed his efforts to work out a chlorine process which should utilise the whole of the muriatic acid. While working with manganite of magnesia he found that magnesia alone would answer the purpose without the presence of the peroxide of manganese. He obtained the assistance of M. Pechiney, of Salindres, and in conjunction with him worked out what has become known as the 'Weldon-Pechiney' process, which was first patented in 1884.

This process consists in neutralising muriatic acid by magnesia, concentrating the solution to a point at which it does not yet give off any hydrochloric acid, and then mixing into it a fresh quantity of magnesia so as to obtain a solid oxychloride of magnesium. This is broken up into small pieces, which are heated up rapidly to a high temperature without contact with the heating medium, while a current of air is passing through them. The oxychloride of magnesium containing a large quantity of water, this treatment yields a mixture of chlorine and hydrochloric acid with air and steam, the same as the Deacon process, and this is treated in a very similar way to eliminate the steam and the acid from the chlorine. The acid condensed is, of course, treated with a fresh quantity of magnesia, so that the whole of the chlorine which it contains is gradually obtained in the free state.

The rapid heating to a high temperature of the oxychloride of magnesium without contact with the heating medium was an extremely difficult practical problem, which has been solved by M. Pechiney and his able assistant, M. Boulouvard, in a very ingenious and entirely novel way.

They lined a large wrought-iron box with fire-bricks, and built inside of this vertical fire-brick walls with small empty spaces between them, thus forming a number of very narrow chambers, so arranged that they could all be filled from the top of the box, and emptied from the bottom. These chambers they heated to a very high temperature by passing a gas flame through them, thus storing up in the brick walls enough heat to carry out and complete the decomposition of the magnesium oxychloride, with which the chamber was filled when hot enough.

Mr. Weldon himself called this apparatus a 'baker's oven,' in which trade certainly the same principle has been employed from time immemorial; but to my knowledge it had never before been used in any chemical industry. This process has been at work at M. Pechiney's large alkali works at Salindres, and is now at work in this country at the chlorate of potash works of Messrs. Allbright and Wilson at Oldbury, a manufacture for which it offers special advantages. Mr. Weldon and M. Pechiney had expected that this process would become specially useful in connection with the ammonia soda process by preparing in the way proposed by Mr. Solvay and Mr. Weldon in 1872 a solution of magnesium chloride as a by-product of this manufacture, but instead of obtaining muriatic acid from this solution by Clemm's process, to treat it by the new process, so as to obtain the bulk of the chlorine at once in the free state. But M. Pechiney did no more succeed than his predecessors in recovering the ammonia by means of magnesia in a satisfactory way.

Quite recently, however, it has been applied to obtain chlorine in connection with the ammonia soda process by Dr. Pick, of Czakowa, in Austria. He recovers the ammonia, as usual, by means of lime, and converts the solution of chloride of calcium, obtained by a process patented by Mr. Weldon in 1869, viz., by treatment with magnesia and carbonic acid under pressure, into chloride of magnesium with the formation of carbonate of lime. The magnesium chloride solution is then concentrated and treated by the Weldon-Pechiney process.

I have repeatedly referred during this brief history to the great change which has been brought about in the position of chlorine manufacture by the development of the ammonia soda process, and have pointed out that the muriatic acid which for a long time was the by-product of the Le Blanc process, without value, thereby became gradually its main and most valuable product, while the alkali became its by-product.

I have told you how, very early in the history of this process, Mr. Solvay and Mr. Weldon proposed means to provide for this contingency, and how Mr. Weldon continued to improve these means until the time of his death. Mr. Solvay, on his part, also followed up the subject with that tenacity and sincerity of purpose which distinguish him, his endeavours being mainly directed to producing chlorine direct from the chloride of calcium running away from his works by mixing it with clay and passing air through the mixture at very high temperatures, thus producing chlorine and a silicate of calcium, which could be utilised in cement-making. The very high temperatures required prevented, however, this process from becoming a practical success.

I have already told you what a complicated series of operations Dr. Pick has lately resorted to in order to obtain the chlorine from this chloride of calcium. Yet the problem of obtaining chlorine as a by-product of the ammonia soda process presents itself as a very simple one.

This process produces a precipitate of bicarbonate of soda and a solution of chloride of ammonium by treating natural brine or an artificially made solution of salt, in which a certain amount of ammonia has been dissolved, with carbonic acid. In their original patent of 1838 Messrs. Dyar and Hemming proposed to evaporate this solution of ammonium chloride and to distil the resulting dry product with lime to recover the ammonia. Now all that seemed to be necessary to obtain the chlorine from this ammonium chloride was to substitute another oxide for lime in the distillation process, which would liberate the ammonia and form a chloride which on treatment with atmospheric air would give off its chlorine and reproduce the original oxide. The whole of the reactions for producing carbonate of soda and bleaching powder from salt would thus be reduced to their simplest possible form; the solution of salt, as we obtain it in the form of brine direct from the soil, would be treated with ammonia and carbonic acid to produce bicarbonate and subsequently monocarbonate of soda; the limestone used for producing the carbonic acid would yield the lime required for absorbing the chlorine, and produce bleaching powder instead of being run into the rivers in combination with chlorine in the useless form of chloride of calcium; and both the ammonia used as an intermediary in the production of soda and the metallic oxide used as an intermediary in the production of chlorine would be continuously recovered.

The realisation of this fascinating problem has occupied me for a great many years. In the laboratory I obtained soon almost theoretical results. A very large number of oxides and even of salts of weak acids were found to decompose ammonium chloride in the desired way; but the best results (as was to be clearly anticipated from thermo-chemical data) were given by oxide of nickel.

When, however, I came to carry this process out on a large scale, I met with the most formidable difficulties, which it took many years to overcome successfully.

The very fact that ammonium chloride vapour forms so readily metallic chlorides when brought in contact at an elevated temperature with metals or oxides, or even silicates, led to the greatest difficulty, viz., that of constructing apparatus which would not be readily destroyed by it.

Amongst the metals we found that platinum and gold were the only ones not attacked at all. Antimony was but little attacked, and nickel resisted very well if not exposed to too high a temperature, so that it could be, and is being, used for such parts of the plant as are not directly exposed to heat. The other parts of the apparatus coming in contact with the ammonium chloride vapour I ultimately succeeded in constructing of cast and wrought iron, lined with fire-bricks or Doulton tiles, the joints between these being made by means of a cement consisting of sulphate of baryta and waterglass.

After means had been devised for preventing the breaking of the joints through the unequal expansion of the iron and the earthenware, the plant so constructed has lasted very well.

Oxide of nickel, which had proved the most suitable material for the process in the laboratory, gave equally good chemical results on the large scale, but occasionally a small quantity of nickel chloride was volatilised through local over-heating, which, however, was sufficient to gradually make up the chlorine conduits. We therefore looked out for an active material free from this objection. Theoretical considerations indicated magnesia as the next best substance, but it was found that the magnesium chloride formed was not anhydrous, but retained a certain amount of the steam formed by the reaction, which gave rise to the formation of a considerable quantity of hydrochloric acid on treatment with hot air. In conjunction with Dr. Eschellman (who carried out the experiments for me), I succeeded in reducing the quantity of this hydrochloric acid to a negligible amount by adding to the magnesia a certain amount of chloride of potassium, which probably has the effect of forming an anhydrous double chloride.

This mixture of magnesia and potassium chloride is, after the addition of a certain quantity of china clay, made into small pills in order to give a free and regular passage throughout their entire mass to the hot air and other gases with which they have to be treated. In order to avoid as far as possible the handling and consequent breaking of these pills, I vapourise the ammonium chloride in a special apparatus, and take the vapours through these pills and subsequently pass hot air through. and then again ammonium chloride vapour, and so on, without the pills changing their place.

The vapourisation of the ammonium chloride is carried out in long cast-iron retorts lined with thin Doulton tiles, and placed almost vertically in a furnace which is kept by producer gas at a very steady and regular temperature. These retorts are kept nearly full with ammonium chloride, so as to have as much active heating surface as possible. From time to time a charge of ammonium chloride is introduced through a hopper at the top of these retorts, which is closed by a nickel plug. The ammonium chloride used is very pure, being crystallised out from its solution as produced in the ammonia soda manufacture by a process patented by Mr. Gustav Jarmay, which consists in lowering the temperature of these solutions considerably below 0° C. by means of refrigerating machinery. The retorts will therefore evaporate a very large amount of ammonium chloride before it becomes necessary to take out through a door at their bottom the non-volatile impurities which accumulate in them. The ammonium chloride vapour is taken from these retorts by cast-iron pipes lined with tiles and placed in a brick channel, in which they are kept hot, to prevent the solidification of the vapour, to large upright wrought-iron cylinders which are lined with a considerable thickness of fire-bricks, and are filled with the magnesia pills, which are, from the previous operations, left at a temperature of about 300° C. On its passage through the pills the chlorine in the vapours is completely retained by them, the ammonia and water vapour formed pass on and are taken to a suitable condensing apparatus. The reaction of the ammonium chloride vapour upon magnesia being exo-thermic, the temperature of the pills rises during this operation, and no addition of heat is necessary to complete it. The temperature, however, does not rise sufficiently to satisfactorily complete the second operation, viz., the liberation of the chlorine and the re-conversion of the magnesium chloride into magnesium oxide by means of air. This reaction is slightly endo-thermic, and thus absorbs a small amount of heat, which has to be provided in one way or another. I effect this by heating the pills to a somewhat higher temperature than is required for the action of the air upon them, viz., to 600° C., by passing through them a current of a dry inert gas free from oxygen heated by a Siemens-Cowper stove to the required temperature. I use for this purpose the gas leaving the carbonating plant of the ammonia soda process.

This current of gas also carries out of the apparatus the small amount of ammonia which was left in between the pills. It is washed to absorb this ammonia, and after washing this same gas is passed again through the Siemens-Cowper stove, and thus constantly circulated through the apparatus, taking up the heat from the stove and transferring it to the pills. When these have attained the required temperature, the hot inert gas is stopped and a current of hot air passed through, which has also been heated to 600° C. in a similar stove. The air acts rapidly upon the magnesium chloride, and leaves the apparatus charged with 18 to 20 per cent. of chlorine and a small amount of hydrochloric acid. The chlorine comes gradually down, and when it has reached about 3 per cent. the temperature of the air entering the apparatus is lowered to 350° C. by the admixture of cold air to the hot air from the stove; and the weak chlorine leaving the apparatus is passed through a second stove, in which its temperature is raised again to 600° C., and passed into another cylinder full of pills which are just ready to receive the hot-air current. A series of four cylinders is required to procure the necessary continuity for the process.

The chlorine gas is washed with a strong solution of chloride of calcium, which completely retains all the hydrochloric acid, and is then absorbed in an apparatus invented by Dr. Carl Langer, by hydrate of lime, which is made to pass by a series of interlocked transporting twin-screws in an opposite direction to the current of gas, and produces very good and strong bleaching powder, in spite of the varying strength of the chlorine gas. The hydrochloric acid absorbed by the solution of calcium chloride can by heating this solution be readily driven out and collected.

This process has now been in operation on a considerable scale at our works at Winnington for several years, with constantly improving results, notably with regard to the loss of ammonia, which has gradually been reduced to a small amount. The process has fully attained my object, viz., to enable the ammonia soda process to compete, not only in the production of carbonate of soda, but also in the production of bleaching powder, with the Le Blanc process.

Nevertheless, I have hesitated to extend this process as rapidly as I should otherwise have done, because very shortly after I had overcome all its difficulties, entirely different methods from those hitherto employed for the manufacture of chlorine were actively pushed forward in different parts of the globe, for which great advantages were claimed, but the real importance and capabilities of which were and are up to this date very difficult to judge. I refer to the processes for producing chlorine by electrolysis.

During the first decade of this century, Humphry Davy had by innumerable experiments established all the leading facts concerning the decomposing action of an electric current upon chemical compounds. Amongst these he was the first to discover that solutions of alkaline chlorides, when submitted to the action of a current, yield chlorine. His successor at the Royal Institution, Michael Faraday, worked out and proved the fundamental law of electrolysis, known to everybody as 'Faraday's Law,' which has enabled us to calculate exactly the amount of current required to produce by electrolysis any definite quantity of chlorine. Naturally, since these two eminent men had so clearly shown the way, numerous inventors have endeavoured to work out processes based on these principles for the production of chlorine on a manufacturing scale, but only during the last few years have these met with any measure of success.

It has taken all this time for the classical work of Faraday on electro-magnetism to develop into the modern magneto-electric machine, capable of producing electricity in sufficient quantity to make it available for chemical operations on a large scale; for you must keep in mind that an electric installation sufficient to light a large town will only produce a very moderate quantity of chemicals.

In applying electricity to the production of chlorine various ways have been followed, both as to the raw materials and as to the apparatus employed. While most inventors have proposed to electrolyse a solution of chloride of sodium, and to produce thereby chlorine and caustic soda, I am not aware that up to this day any quantity of caustic soda made by electrolysis has been put on to the market.

Only two electrolytic works producing chlorine on a really large scale are in operation to-day. Both electrolyse chloride of potassium, producing as a by-product caustic potash, which is of very much higher value than caustic soda, and of which a larger quantity is obtained for the same amount of current expended. These works are situated in the neighbourhood of Stassfurt, the important centre of the chloride of potassium manufacture. The details of the plant they employ are kept secret, but it is known that they use cells with porous diaphragms of special construction, for which great durability is claimed. There are at this moment a considerable number of smaller works in existence, or in course of erection in various countries, intended to carry into practice the production of chlorine by electrolysis by numerous methods, differing mainly in the details of the cells to be used; but some of them also involving what may be called new principles. The most interesting of these are the processes in which mercury is used alternately as cathode and anode, and salt as electrolyte. They aim at obtaining in the first instance chlorine and an amalgam of sodium, and subsequently converting the latter into caustic soda by contact with water, which certainly has the advantage of producing a very pure solution of caustic soda. Mr. Hamilton Castner has carried out this idea most successfully by a very beautiful decomposing cell, which is divided into various compartments, and so arranged that by slightly rocking the cell the mercury charged with sodium in one compartment passes into another, where it gives up the sodium to water, and then returns to the first compartment, to be recharged with sodium. His process has been at work on a small scale for some time at Oldbury, near Birmingham, and works for carrying it out on a large scale are now being erected on the banks of the Mersey, and also in Germany and America.

Entirely different from the foregoing, but still belonging to our subject, are methods which propose to electrolyse the chlorides of heavy metals (zinc, lead, copper, &c.) obtained in metallurgical operations or specially prepared for the purpose, among which the processes of Dr. Carl Hoepfner deserve special attention. They eliminate from the electrolyte immediately both the products of electrolysis, chlorine on one side and zinc and copper on the other, and thus avoid all secondary reactions, which have been the great difficulty in the electrolysis of alkaline chlorides.

All these processes have, however, still to stand the test of time before a final opinion can be arrived at as to the effect they will have upon the manufacture of chlorine, the history of which we have been following, and this must be my excuse for not going into further details. I have endeavoured to give you a brief history of the past of the manufacture of chlorine, but I will to-day not attempt to deal with its future. Yet I cannot leave my subject without stating the remarkable fact that every one of these processes which I have described to you is still at work to this day, even those of Scheele and Berthollet, all finding a sphere of usefulness under the widely varying conditions under which the manufacture of chlorine is carried on in different parts of the world.

Let me express a hope that a hundred years hence the same will be said of the processes now emerging and the processes still to spring out of the inventor's mind. Rapid and varied as has been the development of this manufacture, I cannot suppose that its progress is near its end, and that Nature has revealed to us all her secrets as to how to procure chlorine with the least expenditure of trouble and energy. I do not believe that industrial chemistry will in future be diverted from this Section and have to wander to Section A under the ægis of applied electricity. I do not believe that the easiest way of effecting chemical changes will ultimately be found in transforming heat and chemical affinity into electricity, tearing up chemical compounds by this powerful medium, and then to recombine their constituents in such form as we may require them. I am sure there is plenty of scope for the manufacturing chemist to solve the problems before him by purely chemical means, of some of which we may as little dream to-day as a few years ago it could have been imagined that nickel would be extracted from its ores by means of carbon monoxide.

At a meeting of this Association which brings before us an entirely new form of energy, the Röntgen rays, which have enabled us to see through doors and walls and to look inside the human body; which brings before us a new form of matter, represented by Argon and Helium, which, as their discoverers, Lord Rayleigh and Professor Ramsay, have now abundantly proved, are certainly elementary bodies, inasmuch as they cannot be split up further, but are not chemical elements, as they possess no chemical affinity and do not enter into combinations—at a meeting at which such astounding and unexpected secrets of nature are revealed to us, who would call in doubt that, notwithstanding the immense progress pure and applied sciences have made during this century, new and greater and farther-reaching discoveries are still in store for ages to come?

The following Papers and Reports were read:—

1. *On Reflected Waves in the Explosion of Gases.* *By* Professor H. B. Dixon, E. H. Strange, *and* E. Graham.

The authors exhibited some photographs which show the return sound-wave produced by the explosion-wave in gases when it reaches the end of the tube. The gases were fired in a thick glass tube closed by a steel plug. The flash was photographed on a very rapidly moving film. By measuring the velocity of these sound-waves the authors estimate the maximum temperature of the gases immediately in the wake of the explosion-wave. The maximum temperatures lie between 3,000° and 4,000° C. They are thus of the same order as those given by Bunsen, by Berthelot, and by Mallard and Le Chatelier for the temperature of the explosion itself.

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2. *The Action of Metals and their Salts on Ordinary and on Röntgen Rays: a Contrast.* *By* Dr. J. H. Gladstone *and* W. Hibbert.

This paper is an extension of previous work on the special properties of metals and salts, and may be considered as an application of Röntgen rays to chemical research.

In regard to the rays of ordinary light solid metals absorb them completely, and are therefore opaque. If, however, the metals combine with an electronegative radicle, they lose their power of absorbing light, except a few which show the phenomena of selective absorption. Solutions of salts resemble the crystallised solid in their action on light.

With regard to Röntgen rays, on the contrary, metals exhibit every degree of opacity or transparency, from lithium—which is practically non-absorptive—to such metals as gold and platinum, which are practically opaque. The salts of these metals are not transparent, but the metal in them seems to have the same effect on the Röntgen rays as in the uncombined condition. This seems to be equally true when the salts are dissolved in water.

The order of absorption follows that of atomic weight, as found by Barrett and others, not that of density or combining proportion. The absorption of the Röntgen rays by a salt solution appears to be that of both constituents of the salt added together plus that of the solvent.

The work was principally carried on in the laboratory of the Polytechnic, Regent Street, London. Photographs were exhibited.

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3. *Limiting Explosive Proportions of Acetylene and Detection and Measurement of the Gas in the Air.* *By* Professor Frank Clowes, *D.Sc. (Lond.)*

The value of acetylene as an illuminant and the discovery of its ready production from calcium carbide have led to the manufacture of this gas in some quantity, and acetylene will probably be dealt with in still larger volume in the near future. It becomes, therefore, important to devise methods of detecting its presence in the air, arising from leakage and escape, and to measure the percentage of the gas present at any place. It is also important to ascertain what proportions of the gas, when present in mixture with air, will lead to explosion if the mixture should be kindled.

The Detection of Small Proportions of the Gas will not be readily effected by its smell when it is prepared in a state of purity; at present the smell is made much more pronounced by the impurities which the commercial gas contains. Further, the smell will not in any case furnish a means of measuring the proportion present in the air. The method applied by the writer to the detection and measurement of fire-damp and coal-gas in the air, however, serves for detecting and measuring acetylene as well. A small hydrogen flame jet to either 5 or 10 millimetres in height, as may be necessary, shows a pale but well-defined 'cap' in air containing any proportion of acetylene less than the lowest explosive proportion. When the hydrogen flame is exposed to the air to be tested for acetylene in a darkened space, it is at once tinged yellowish-green. The bluish pale cap has the following heights with varying proportions of acetylene, when the hydrogen flame is 10 millimetres in height:—

0·25	per cent.	gives	17	mm.	cap.
0·5	,,	,,	19	,,	,,
1·0	,,	,,	28	,,	,,
2·0	,,	,,	48	,,	,,

When the hydrogen flame is reduced to 5 millimetres:—

2·5	per cent.	gives	56	mm.	cap.
2·75	,,	,,	79	,,	,,

A convenient portable form of apparatus was shown by the writer, which enabled air to be passed readily over the standard hydrogen flame in a darkened vessel, and which quickly furnished the reading of the height of the cap.

In Determining the Limits of Explosibility, when acetylene is mixed in gradually increasing proportion with air and kindled, the writer adopted a simple method referred to at the last meeting of the Association. It was found that air must contain at least 3 per cent. of acetylene before it can be kindled by a flame and the mixture caused to burn throughout. As the proportion of acetylene is increased, the explosive character is augmented. When 22 per cent. of acetylene is present, carbon begins to separate during the burning. The amount of carbon which separates increases until the explosive character of the mixture disappears; this point is reached when 82 per cent. of acetylene is present in the air.

The limiting percentages in air which are explosible are accordingly as follows, and may be compared with those already determined by the writer for other combustible gases:—

Acetylene	3 to 82
Hydrogen	5 ,, 72
Carbon monoxide	13 ,, 75
Ethylene	4 ,, 22
Methane	5 ,, 13

It will be seen that acetylene gives a wider range of explosive proportions than any other of these gases does. Probably this is due to its endothermic nature, which leads to the gas being able to generate heat by its own decomposition: heat thus generated would undoubtedly aid in causing explosion, and would thus extend the limits of explosive mixtures.

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4. *The Accurate Determination of Oxygen by Absorption with Alkaline Pyrogallol Solution. By* Professor FRANK CLOWES, *D.Sc.* (*Lond.*)

It was found repeatedly in my laboratory that during the absorption of oxygen from the Brin gas a considerable volume of carbon monoxide was evolved, although this did not occur in absorbing oxygen from air. If the evolution of the gas was known to take place, and the carbon monoxide was subsequently absorbed by cuprous chloride solution before reading off the residual nitrogen, the estimation of the volume of oxygen was correct; if this precaution was not taken the estimation was open to serious error. Repeated trials with varying proportions of pyrogallol and potassium hydrate showed that the evolution of carbon monoxide might be entirely prevented by using a sufficiently large excess of potassium hydrate. With the following proportions no fear of this source of error need be felt, even when pure oxygen is being absorbed:—160 grams of potassium hydrate and 10 grams of pyrogallol in 200 cubic centimetres of solution.

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5. *On the Amides of the Alkali Metals and some of their Derivatives*
By A. W. TITHERLEY, *M.Sc., Ph.D.*

Ammonia, by the substitution of one atom of hydrogen by the alkali metals, gives rise to a series of amides of interesting properties. The following were prepared: sodamide, $NaNH_2$; potassamide, KNH_2; lithamide, $LiNH_2$; and rubidamide, $RbNH_2$. The metals, on heating in ammonia, rapidly decompose it, forming the respective amides, especially lithium, whose action is very energetic. The amides are white crystalline substances, easily decomposed by water. On heating they distil or sublime without decomposition, except at high temperatures, when they split partially into their elements. No nitrides result, although these were stated by Davy to be formed by heating the impure sodamide and potassamide he obtained—his results having been vitiated by the glass vessels employed. The melting-points of the amides are very different, and bear no connection apparently with the atomic weights of the metals. Several substitution derivatives were exhibited, obtained by replacing the H atom of the NH_2 group by alkyl and other groups.

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6. *Interim Report on the Bibliography of Spectroscopy.*
See Reports, p. 243.

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7. *Report on the Action of Light on Dyed Colours.*—See Reports, p. 347.

FRIDAY, SEPTEMBER 18.

The following Reports and Papers were read:—

1. *Report on the Carbohydrates of Barley Straw.*—See Reports, p. 262.

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2. *The Retardation of Chemical Reaction from Diminution of Space.*
By Professor OSCAR LIEBREICH.

This subject may be regarded from the point of view either of Chemistry or of Physics, as it occupies a position on the borderland between those sciences.

We know that some of the phenomena of motion in capillary tubes differ from those in larger vessels filled with liquid. The melting-point is higher, the freezing-point is lower, the boiling-point is retarded. Of the phenomena of motion which go by the name of chemical reaction we know as yet nothing, for the condensation of gases in finely pulverised substances also belongs to purely physical phenomena.

This investigation arose out of a previous examination of chloral hydrate, the decomposition of which into chloroform takes place according to a well-known formula.

Under certain conditions this substance undergoes a molecular change. If the melted crystals—in appearance a matted mass of needles—are placed in benzene, isolated glassy-hard needles are obtained. The most varied experiments, made for the purpose of discovering whether a different chemical substance had been formed, proved unavailing; but there was certainly a change as far as physical qualities were concerned. The matted needle-mass dissolved in water without increase of volume; while in the case of the isolated needles an increase of volume was proved. No chemical difference being observed, the author endeavoured to find out whether both substances were alike in the velocity of reaction.

When soda solutions are mixed with solutions of chloral hydrate, the chloroform does not separate out in oily drops, but forms a nebula of chloroform in the liquid. The microscope, too, shows only a mass of minute spots. If the liquid is sufficiently diluted, the nebula does not form till after some minutes. The shape of this nebula induced the author to study that part in the fluid, where chemical reaction is considerably retarded, which he calls the 'dead space.'

If the solution be poured into a test tube, a space below the surface remains clear and transparent. The first thought cannot fail to be, that this phenomenon is caused either by sedimentation of the nebula, or by evaporation of the chloroform, or indeed by both. But the shape of the nebula reveals to the observer that these cannot be the true causes. If sedimentation were the cause, the nebula would be lowest in the middle; in evaporation, on the other hand, the same quantity of vapour would rise from every part of the surface, and thus the shape would be different from the one actually seen. For in reality the nebula shows the shape of an arch convex to the surface.

In order to observe this phenomenon more closely, a glass prism with an acute angle was used. Here the appearance was remarkable. Under the surface there was a clear space deflected in the direction of the acute angle and corresponding to the depth of the meniscus downwards, a space which even inside the angle was perfectly clear.

The 'dead space' can be seen in the synthesis of indigo from orthonitrobenzaldehyde, but the reaction is a very rapid one, and for this reason the experiments were made with iodic acid and sulphurous acid; 25 grammes iodic acid per litre and 0·88 gramme sulphurous acid per litre—the latter being the solution used by Landolt for his time-reactions. A starch-solution demonstrates the presence of free iodine. Both in the test tube and in the prism the same phenomena of 'dead space' can be observed as in the case of the chloral-hydrate reaction. This mixture is suited to vessels of the most varied shapes, as shown by experiments of a decisive nature. For instance, a tumbler is filled with the reacting mixture, and some of the liquid aspirated into a glass tube. The reaction first commences in the tumbler, and afterwards in the glass tube, and in its central line only. The column of coloured fluid reaches below the meniscus. As in this case the space free from reaction cannot be explained either by evaporation or by sedimentation, it follows that the glass wall and the surface of the fluid may cause the 'dead space.' The experiments may be modified by using a tube composed of hollow glass bulbs connected by capillary tubes. The reaction is then visible in the centre of the bulbs, while the liquid in the connecting capillary tubes remains perfectly clear. The following experiment was made to prove the retardation of reaction in capillary tubes. A tumbler and a capillary tube were filled with colourless reacting-fluid, and the latter was introduced into the tumbler-fluid. After the blue reaction had taken place in the tumbler the capillary tube was taken out. Its contents were found to have remained colourless. But when a similar capillary tube was filled with the blue fluid, the blue colour could be distinctly seen. Tubes which had been blown into bulbs were also filled with the reacting fluid, and it was observed that the reaction began in the centre of the bulb.

An instructive demonstration of the 'dead space' and its formation is made by fixing a drop of the reacting fluid between the convex faces of two watch-glasses. If the reaction be then watched from above, there is nothing extraordinary in the fact that the blue colour grows fainter as it approaches the centre, until at last it disappears entirely. But if, by means of an apparatus similar to those attached to microscope tables, one of the watch-glasses be raised, a sharply defined, colourless, and transparent patch is visible in the centre. Moreover, there is a dead space, not only in the centre of the drop, but also at its circumference, along the stretched surface of the fluid.

These experiments were variously modified in order to leave no doubt that the phenomena were not produced either by evaporation, by sedimentation, or by the alkalinity of the glass.

An experiment was then devised in which these three factors were completely eliminated by means of the reaction occurring in the reduction of sesquichloride of gold with formate of soda. The formate of soda, again, was formed by decomposition of chloral hydrate with a solution of carbonate of soda. These solutions were used in the following proportions:—

50 c.cm. $\frac{n}{6}$ solution of chloral hydrate were mixed with

4 c.cm. $\frac{n}{3}$ solution of carbonate of soda,

and three drops of a solution of sesquichloride of gold (1·5 per cent.) added. At a temperature of about 22° the reaction takes place, the so-called liquid gold separates out in the form of a violet solution. With this solution, and with the apparatus described, it is not difficult to find reactions which form the 'dead space.' Care must be taken, however, to exclude direct solar rays.

The 'dead space' is probably caused by internal resistance of the fluid. In a liquid, inclosed by a hard wall, the motion of the liquid will be the more hindered by the friction produced by this motion itself the smaller the vessel is. Not that, of course, any change is assumed in the coefficient, but the conclusion seems inevitable that the smaller the space inclosing a fluid, the more nearly the fluid resembles a solid as regards its internal resistance.

The same must hold good in the case of an inclosed fluid, where the upper wall is bounded by the surface-tension of the fluid, and also in the case of a fluid bounded only by its own stretched circumference—*i.e.*, the case of the drop.

This view of the change in the physical qualities of fluids is illustrated by some friction-experiments.

If a small disk-shaped float, having the smallest possible upward pressure, be allowed to rise in a glass vessel, it will be seen to come to an apparent standstill half a millimetre below the surface, and then to rise to the surface with greatly diminished velocity; a proof that there is friction on the fluid side of the stretched surface.

The second experiment consists in allowing a concentrated coloured glycerine-solution to rise in a colourless glycerine-solution of slightly greater density. If a glass tube, fitted at its upper part with a prism filled with the heavier solution, be used, the current of the liquid shows the direction taken by the 'dead space,' and thus indicates the places at which the fluid-resistance is at its maximum.

Thus we are brought to the conclusion that liquid friction is of influence in the phenomenon of chemical reaction, and that in small inclosed spaces—spaces in which the fluid is, as it were, solidified—the reaction is retarded.

It is worthy of consideration whether these observations have not an important bearing also in relation to biological processes.

Attention has long since been directed by the chemist and physiologist alike to the question whether there are not modes of reaction in the limited spaces of organisms differing from those observed hitherto in the larger vessels of the chemical laboratory.

The results given tend to show that the small space of the cells is not accidental, but that it has a function either to moderate or to stimulate chemical reactions, or even to determine their direction otherwise than in larger vessels.

Chemical reaction, thus modified, may well play an important *rôle* in cells, and it is hoped that not only in pure chemistry, but also in the chemistry of vital phenomena, further investigations on the lines suggested may lead to important results.

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3. *Excrescent Resins.* *By* Professor M. Bamberger.

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4. *Report on the Proximate Chemical Constituents of the various kinds of Coal.*—See Reports, p. 340.

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5. *On the Velocity of Reaction before Perfect Equilibrium takes place.* By MEYER WILDERMANN.

As we know, there are two kinds of equilibrium: perfect and imperfect. Gibbs gives us the rule for distinguishing the two kinds: when n kinds of molecules constitute $n+1$ phases or parts of a system, the equilibrium is a perfect one; and when n kinds of molecules constitute a system of less than $n+1$ phases, the equilibrium is an imperfect one. To perfect equilibrium belong first the so-called 'physical' reactions, where one and the same substance is in different states of aggregation, thus forming different parts or phases of the heterogeneous system—*e.g.*, where solid and liquid or gas, liquid and solid or gas, &c., are in equilibrium. To perfect equilibrium belongs also the great range of 'chemical' reactions, which have the common feature with the physical, that to a given temperature only a certain pressure corresponds at which the system can be in equilibrium, and the phases may change in their mass but not in their constitution—*e.g.*, the system $CaCO_3$ and CaO, CO_2, &c. The velocity of reaction before imperfect equilibrium takes place (in homogeneous systems) was thoroughly investigated by Wilhelmy, Harcourt and Esson, Gouldberg and Waage, van 't Hoff, and others. But as the velocity of reaction before perfect equilibrium takes place has remained to the present time a large and scarcely known field, and the few investigations which have been carried out have not led to any simple results or quantitative conclusion, the author has been induced to make the following investigation.

1. Velocity of solidification of liquids and solutions (phenol and solutions of water in phenol). The author has investigated the velocity of solidification of phenol and of solutions of water in phenol in a U-tube, one part of which was replaced by a narrow tube of very thin platinum; the U-tube was immersed in baths of different temperatures below the melting-point. By good arrangement for stirring, the temperature of the bath was kept constant within the limits of 0°·05 C. The time was observed to a $\frac{1}{5}$ second. A fine, very sensitive thermometer was placed in the platinum tube to measure the rise of temperature of the liquid while the reaction takes place (the rise equals more than 40 per cent. of the total value of overcooling $t_o - t_{ov}$). If abscissæ represent the amount of overcooling below the melting-point, and ordinates, the velocities of reaction, or the time required for the passage of the solidified mass from one end of the platinum tube to the other, we obtain straight lines, cutting the melting-point (instead of the irregular curves of Gernez or Moore, which cut the abscissæ considerably below the melting-point)—*i.e.*, the equation $\frac{dt}{dz} = c(t_o - t)$, (1.), where z is the time, t_o is the temperature of equilibrium, holds good. The surface of the solid in contact with the liquid remaining the same, the velocity of reaction is directly proportional to the remoteness from the melting-point.

2. Velocity of reaction before equilibrium between liquid and solid solutions takes place (solidification of phenol and meta-cresol). It was found that phenol and *m*-cresol form solid solutions. The *m*-cresol is partly dissolved in the liquid phenol, partly in the separated solid phenol, following the laws of van 't Hoff. The velocities in a U-tube have been investigated, and the author finds that the equation (1.) holds good.

3. Velocity of crystallisation of overcooled liquids and solutions (the solid solvent is in equilibrium with the liquid solvent or solution). In the case of crystallisation only a part of the liquid becomes solid as far as necessary to bring it to the freezing temperature. The method used is based on the principle that the heat freed during the reaction is as completely as possible absorbed by the liquid. Good arrangements for stirring are required. The cooling of the liquid stirred by the surrounding medium must be so small that it may be neglected or only a small correction required (1,250 c.c. liquid is used, $t_g - t$ is kept small). A very sensitive 1/100° thermometer is of first importance (with a long thin bulb as thin as possible). The time was observed to $\frac{1}{5}$ second. From the results obtained the equation, $lgn(t_2 - t_{ov}) - lgn(t_1 - t_{ov}) + lgn(t_o - t_1) - lg(t_o - t_2) = C(Z_2 - Z_1)(t_o - t_{ov})$

holds good; therefore the equation $\frac{dt}{dz} = c(t - t_{ov})\ (t_o - t)$, (2.), where t_{ov} is the temperature to which the liquid was overcooled, t_o is the freezing-point, holds good, *i.e.*, the velocity of reaction is directly proportional to the surface of the solid in contact with the liquid, and to the remoteness from the freezing temperature. The condition is $t - t_{ov} > 0$, *i.e.*, the solid solvent is present in the liquid, and the system is heterogeneous.

4. Velocity of melting of solid solvents in liquid solvents or solutions (*e.g.*, of ice in water or aqueous solutions). The velocity of ice melting cannot be measured with the same accuracy as the velocity of ice separation. The author has carried out experimental verification of the equation $\frac{dt}{dz} = c(t_o - t)$, where c is directly proportional to the surface of the solid in contact with the liquid, by using cubes of ice, whose surface could be directly measured at the beginning and at the end of the reaction, and during the reaction it could be calculated from the fall of temperature of the investigated liquid.

5. Velocity of crystallisation of oversaturated solution (equilibrium between separated salt and salt solution). The equation (2.) holds good—*i.e.*, the velocity of reaction is directly proportional to the surface of the salt in contact with the liquid and to the amount of oversaturation (not to the total quantity of the salt dissolved). This very remarkable fact throws light on the meaning of the velocity of reaction before perfect equilibrium. Let us assume that the total quantity of the salt dissolved takes place in the reaction, then our equation will be $\frac{dt}{dz} = c(t_1 - t)A$, where $t_1 - t$ is directly proportional to the surface of the separated crystals, A is the concentration of the liquid part of the time z. This equation can be written in the form $\frac{dt}{dz} = c(t_1 - t)\ (A' + a)$, where A' is the concentration at equilibrium and a is the amount of oversaturation at the time z. Now $c(t_1 - t)A' = 0$ independently of the value $t_1 - t$, since the concentration A' is in equilibrium with any quantity of the salt present in the liquid. The only equation for the reaction is therefore $\frac{dt}{dz} = c(t_1 - t)a$—*i.e.*, the equation given above.

Since in the case of perfect equilibrium one of the parts of the heterogeneous system can *completely* disappear (with the change of the temperature or of the pressure of equilibrium), it follows that above or below the point of equilibrium *no opposite* reaction occurs, and because of this when $\frac{dt}{dz}$ becomes zero, the equilibrium is a *static* one (and not a dynamic one, as assumed).

We thus find that one and the same equation represents the relations of all investigated reactions before perfect equilibrium. The equation is therefore *general*, and must be put at the basis of all other reactions of more complicated form (which will form the subject of further investigation).

Static equilibrium because of the interference of other factors is never in reality reached in nature. The equilibrium is never real or perfect, but only apparent. A detailed investigation of this in the case of equilibrium between ice and water or solution is given in the author's paper 'On the real and apparent freezing-point and the freezing-point methods.' This gives us the possibility of explaining some of the most important phenomena in nature, &c., as the formation of glaciers, icebergs, snow, the melting processes, &c. All these phenomena never completely reach the dead-point of perfect equilibrium, but a continuous change or reaction takes place in nature.

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6. *The Behaviour of Litmus in Amphoteric Solutions.* *By* Thomas R. Bradshaw, *B.A.*, *M.D.*

Solutions which redden blue litmus, and at the same time turn red litmus blue, are said to have an amphoteric (ἄμφω τέρας) reaction. This reaction is always given by human urine when its acidity is low, and is in this case due to the existence together of the dihydric and monohydric phosphates, $MH_2 PO_4$ and $M_2 HPO_4$, of which the former acts as an acid and the latter as an alkali towards litmus. The actual colour resulting is violet. No satisfactory explanation has been offered of the nature of the change in the litmus when the violet is produced. Heintz [1] supposed that litmus was of the nature of a diabasic acid, the red pigment containing two atoms of displaceable hydrogen, which in the blue litmus were replaced by a metal. He supposed that the monohydric and dihydric phosphates displaced only one atom of hydrogen or of metal, forming a body analogous to an acid salt—the violet litmus. He seems to have overlooked the fact that the violet litmus is only produced when both phosphates act together—alone they produce red and blue litmus.

The object of the present communication is to show that the violet litmus is a mechanical mixture of the red and the blue. It can be shown on theoretical grounds that when both phosphates are present in nearly equal proportions they must each affect the litmus in their own special way, the exact amount of blue and red produced being determined by the mass action of the phosphates. If red litmus is provisionally represented by the formula LH the reactions may be represented as follows:—

$$n\ M_2H\ PO_4 + n\ M\ H_2\ PO_4 + 2L = (n-1)\ M_2HPO_4 + (n+1)\ MH_2PO_4 + LH + LM.$$
$$n\ M_2H\ PO_4 + nMH_2\ PO_4 + 2\ LM = (n+1)\ M_2HPO_4 + (n-1)\ MH_2\ PO_4 + LM + LH.$$

The violet litmus is shown to be a mixture of the red and the blue by observing the light transmitted through its solution by the eye and by the spectroscope. This light is, in all respects identical with that transmitted through the red and the blue successively. Cochineal behaves in an analogous manner.

It can be shown that acetic acid behaves in a manner analogous to litmus in presence of the two phosphates. A small quantity of sodium acetate is added to a strong solution of $NaH_2\ PO_4$ and $Na_2H\ PO_4$. On distilling the solution free acetic acid comes over. The solution is then taken to dryness, the residue dissolved in water and acidulated with a few drops of dilute sulphuric acid. On distilling a further quantity of acetic acid comes over. Thus it appears that sodium acetate behaves in a manner analogous to blue litmus in the amphoteric solutions. To sum up:—

1. There is no evidence to show that any special modification of litmus is produced by amphoteric solutions.
2. The violet litmus is a mixture of the red and the blue.
3. The amount of the two forms of litmus in the amphoteric solution is determined by the mass action of the two kinds of phosphate.

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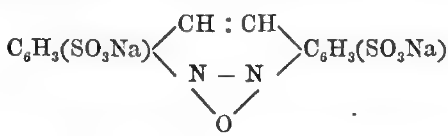
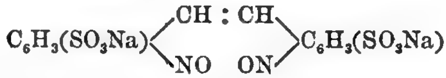
7. *Constitution of Sun Yellow or Curcumine, and Allied Colouring Matters.* *By* ARTHUR G. GREEN *and* ANDRÉ WAHL.

When caustic soda or caustic potash is added to a hot concentrated solution of paranitrotoluene-ortho-sulphonate of soda the liquid becomes at first bluish red, then changes to orange and deposits a thick orange-yellow precipitate (Walter, 'Bull. Soc. Mulhouse,' 1887, 99). The yellow colouring-matter thus formed, which is known in commerce as curcumine, sun yellow, &c., and dyes unmordanted cotton orange-yellow shades of considerable fastness to light and other agents, appears to consist for the most part of a body to which the constitution of an azoxy-stilbenedisulphonic acid



[1] Heintz, *Würzburger med. Zeitschr.*, 2, 230, 1861; *Journ. für prakt. Chem.*, 85, 24, 1862.

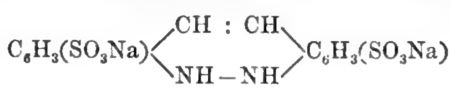
has been ascribed by Bender and Schultz ('Ber.,' **19**, 3234; **28**, 422), and that of a dinitrososostilbene disulphonic acid



by Fischer and Hepp ('Ber.,' **26**, 2231; **28**, 2281). It had long been known that by the action of caustic alkalies upon an alcoholic solution of paranitrotoluene a sparingly soluble red condensation product was formed, to which no satisfactory formula could be assigned (Klinger, 'Ber.,' **15**, 866; **16**, 941). It was shown by Bender and Schultz that this condensation product on reduction gave diamidostilbene whilst curcumine on reduction gave diamidostilbenedisulphonic acid, and that hence both products are probably stilbene derivatives.

In 1888 it was discovered by Bender that by condensing paranitrotoluene sulphonic acid with caustic soda in presence of weak reducing agents such as alcohol, glycerol, glucose, &c., colouring-matters were obtained possessing similar properties to curcumine, but dyeing redder shades of orange and dissolving in concentrated sulphuric acid with a violet or blue colour instead of a red (Eng. Pat. 2664 of 1888). It was subsequently found that these colouring-matters (so-called Mikado oranges) were also formed by the action of mild reducing agents, such as ferrous hydrate upon the primary condensation product (curcumine).

Neither of the two formulæ which have been proposed for curcumine gives a satisfactory explanation of its properties and reactions. They afford, for instance, no explanation of the dye-stuff character, the great stability towards oxidising agents, or of the difficulty of reduction to diamido-stilbene disulphonic acid. Both formulæ are based upon determinations of the quantity of hydrogen required to reduce the colour to its leuco compound, to which an hydrazo constitution

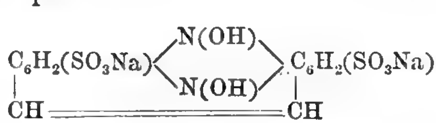


is attributed. According to Bender 4 atoms of hydrogen are required, whilst Fischer and Hepp find 6 atoms. In order to clear up this discrepancy Bender's experiments were repeated exactly according to his directions, but using the free acid of curcumine instead of the sodium salt. In agreement with Bender 4 atoms of hydrogen were found to be required. Since, however, the properties of the substance in no way correspond with those of an azoxy compound, and the equation

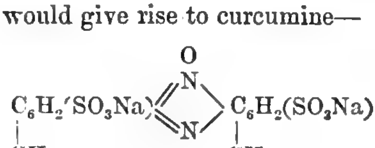
$$2C_6H_3(CH_3)(NO_2)(SO_3Na) = C_{14}H_6N_2O(SO_3Na)_2 + 3H_2O$$

would indicate the formation of a body having 2 atoms of hydrogen less than Bender's formula, we have been led to seek another formula more in accordance with the facts.

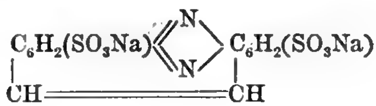
It may be supposed that the first action of caustic soda upon paranitrotoluene sulphonic acid consists in an intramolecular oxidation giving rise to dinitrosostilbene disulphonic acid. The two nitrogen atoms may now enter the opposite rings, forming an unstable compound—



which, by loss of water, would give rise to curcumine—

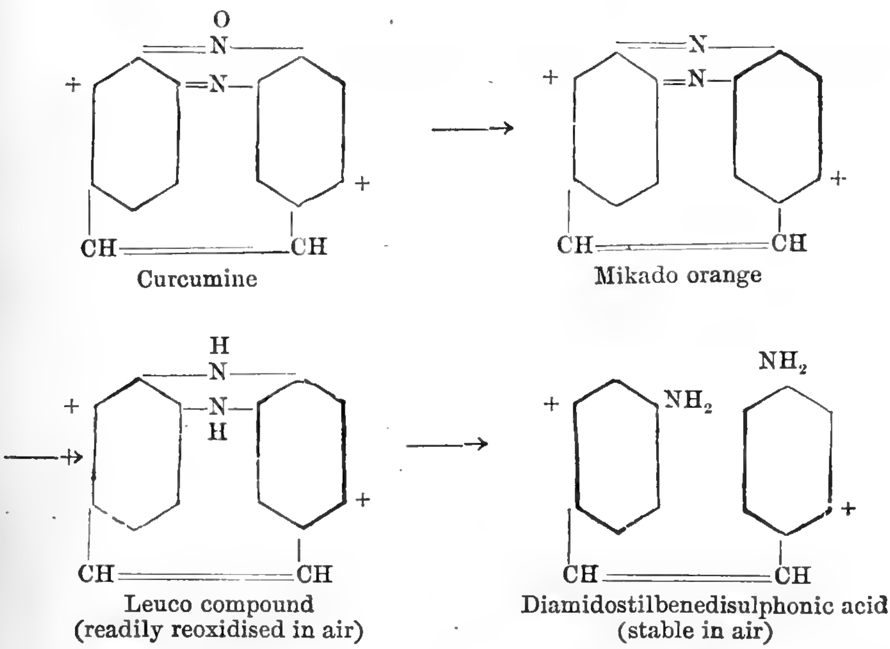


According to this formula curcumine should require 4H for reduction to its leuco compound and 2H for conversion to the azine—



This latter formula would therefore represent the constitution of the pure Mikado orange, which dissolves in concentrated sulphuric acid with a blue colour; and, in agreement with this view, it has been found that 2H are required by this colour for reduction to the leuco compound.

The progressive reduction is accordingly shown by the following formulæ:—



[N.B.—The crosses indicate the position of the HSO_3 groups.]

The above formulæ would explain the difficulty found in reducing curcumine to diamidostilbene disulphonic acid, also the extreme oxidisability of the leuco compound in air, a property characteristic of all azines, oxazines, thiazines, &c.; and, moreover, by representing these compounds as derivatives of an ortho-quinone, would account for their dye-stuff properties.

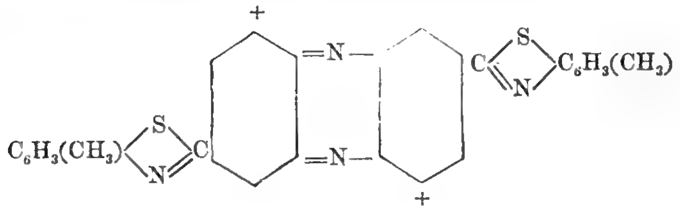
It is probable that a similar constitution must be assigned to chloramine orange, which is formed by oxidation of diamidostilbene disulphonic acid with sodium hypochlorite, and to Chicago orange obtained by caustic soda condensation of paranitrotoluene sulphonic acid with benzidine.

An analogous constitution is also suggested in the case of another class of colours—namely, the yellow, direct-dyeing, cotton-colouring matters which are obtained by the oxidation of amidothiazols such as primuline and dehydrothiotoluidine sulphonic acid. These colouring-matters, known in commerce as oxyphenine, chloramine yellow, chlorophenine, &c., present great analogy with the curcumine colours in their fastness to light, acids, and alkalies and in their chemical properties.

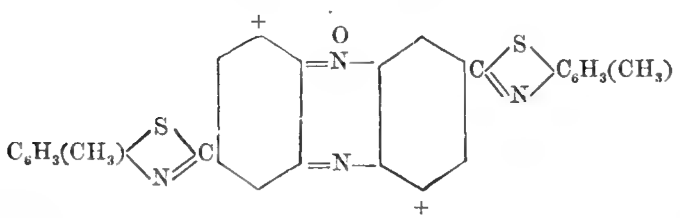
In order to determine the amount of oxygen required for their formation pure dehydrothiotoluidine sulphonic acid was oxidised with a known quantity of sodium hypochlorite both in the cold and at 80° C. The excess of hypochlorite was determined after filtering off the colouring-matter, by titration with arsenious acid. For 2 molecules of dehydrothiotoluidine sulphonic acid there were required—

In the cold —3 atoms of oxygen
Hot —4 atoms of oxygen

which corresponds to the following formulæ for the products:—



First Product.



Final Product.

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8. *Abnormalities in the Behaviour of Ortho-derivatives of* o-*Amido and Nitro-benzylamine. By* Dr. F. E. Francis.

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9. *Nitrates: Their Occurrence and Manufacture. By* William Newton.

The world's chief supply of nitrate is that of the northern provinces of Chili. The nitrate here occurs in a narrow band, following the eastern foot of the coast-line of hills at an elevation of 3,000 to 4,000 feet, and at a distance in a direct line from the sea varying from fifteen to thirty-five miles, extending from Pisagua in the north, to Antofagasta in the south, about 250 miles.

Owing to its rainless condition, this plain is almost absolutely devoid of growing vegetation. Previous vegetation there has been in abundance, as shown by the remains of forests, a few inches below the surface, in addition to which large quantities of organic matter are carried down by mountain floods. The decomposition of this organic matter forms nitrate in the ordinary way, but the nitrate has no growing vegetation to absorb it, and is therefore carried in solution by the drainage waters of the west side of the Andes, which are always percolating under the surface of the plain, and, at periods of about eight or nine years, even completely flood it. These waters collect at the lower side of the plain against the coast-hills, and there evaporate under the hot, dry atmosphere.

The crude nitrate is found under a layer of a few inches of blown dust. The first layer of nitrate-bearing strata is extremely hard rock, containing from 10 to 20 per cent. of nitrates; this rock varies from a few inches in thickness to 16 and 18 feet, and is bored through to reach the richer material called caliche, which contains sometimes as much as 70 to 80 per cent. of nitrate. This layer also varies in thickness up to 7 feet. In the extraction the boring is continued through this, and the whole mass is upheaved by blasting powder made on the spot.

The rock nitrate is neglected, and the caliche carted away to the crushers, thence to large iron boiling-tanks, a favourite shape of which is 32 feet by 6 feet broad, and 9 feet deep. In these are five coils of steam pipes, and the boiling is done by steam at about 50 lb. pressure. The boiling tanks are connected in series of six, so as to allow of proper lixiviation. The liquor of the tanks is run off at 112° Tw. It then contains about 80 lb. of nitrate to the cubic foot, of which it deposits 40 lb. at 25° C. The mother liquor, containing sometimes over 2 grammes of iodine to the litre, is pumped up to the iodine house, where it is treated with bisulphate of soda, and, after the deposition of the iodine, is, of course, used over again in the solution of the nitrate.

The total production of nitrate from June 1885 to June 1886 in Chili was 1,218,000 tons.

MONDAY, SEPTEMBER 21.

The following Papers and Report were read:—

1. *On Helium. By* Professor W. Ramsay, *F.R.S.*

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2. *On the Discovery of Argon in the Water of an Austrian Well. By* Professor Max Bamberger.

In the year 1853 Ragsky examined the gas of a spring in Peschtoldsdorf, near Vienna, and obtained the following results:—

	Volume per cent.
Oxygen	3·0
Carbonic acid	1·7
Marsh gas	1·5
Nitrogen	93·8
	100·0

Last year the author made a new analysis of this gas, which showed figures but little deviating from the above-mentioned analysis

After argon had been discovered by Rayleigh and Ramsay, it was probable that this gas, consisting almost entirely of nitrogen, also contained argon.

To determine this, a larger quantity of the gas (about 12 litres) was collected and, for further examination, was dried by sulphuric acid and chloride of calcium. The gas was passed through a glowing tube, which was half filled with copper netting, half with oxide of copper.

Leaving this tube, the gas had to pass through two soda lime and two calcium chloride conductors, in order to absorb the water formed, and was afterwards passed over quicksilver into a gasometer of Ehrenberg.

In order to remove the nitrogen, glowing magnesium was used in an apparatus, which in principle is similar to that of Schlösing fils.

It was found of considerable advantage to use three glowing tubes with magnesium. Under these circumstances an experiment which was carried out with about two litres of the gas took seven hours before the whole of the nitrogen was absorbed, and for a long time a high pressure on the manometer was to be observed. Consequently the gas in the apparatus was led off into an eudiometer. Now the gas containing the supposed argon, with traces of nitrogen and hydrogen, was freed from these gases by known methods.

After an experiment, it was found that the gas thus obtained was mixed with a large quanity of hydrogen. The original gas having been absolutely dry, the hydrogen could have had its origin in the magnesium only, as this material was cleaned by distillation in a stream of hydrogen, at which operation considerable quantities of this gas are absorbed (after Dumas).

In another experiment a dry tube filled with pentoxide of phosphorus was introduced into the hot conductor, to remove the hydrogen formed in the magnesium tube by oxidising it with copper oxide and absorbing the water formed.

In these two experiments the following figures were found for the quantity of gas not absorbed by magnesium:—

	I c.c.	II c.c.
Volume of the nitrogen before the absorption by magnesium	1172	1918
Volume of the collected gas (hydrogen, traces of nitrogen and argon)	95·6	28·2
Volume of the dry cleaned gas (argon)	13·0	23·9
Volume per cent. of gas not absorbed compared with the original quantity of nitrogen	1·11	1·24
Volume per cent. compared with the original volume of gas	1·04	1·16

The gas thus cleaned was put into Plücker's tubes at the glass technical Institute of Menes Goetze in Leipzig.

The examination of the gas by spectral analysis was made by Professors Eder and Valenta with their concave grating.

The result of this examination was an absolute conformity of the spectrum of the gas isolated by the author with Lord Rayleigh's normal spectrum of argon determined by Eder.

The author concluded by expressing the great pleasure he had in making this communication upon argon in the land of its birth, and in the presence of one of its distinguished discoverers.

3. *The Manufacture of Chlorine by means of Nitric Acid. By* Dr. F. Hurter.

4. *Low Temperature Research. By* Professor J. Dewar, *F.R.S.*

5. *Report on Electrolytic Analysis.*—See Reports, p. 244.

6. *A Modified Form of Schrötter's Apparatus for the Determination of Carbonic Anhydride. By* Charles A. Kohn, *Ph.D., B.Sc.*

Of the many forms of apparatus for the estimation of carbonic anhydride by loss, that devised by Schrötter is probably most widely in use. Compared with other forms, it is certainly more handy than Bunsen's apparatus, although the latter is more accurate, since it contains an absorption tube charged with dehydrated copper sulphate on pumice in addition to calcium chloride. In a modified Bunsen apparatus described by A. Christomanos ('Ber.,' 1894, 27, 2748), the drying tube is replaced by a small wash bottle containing concentrated sulphuric acid; the advantages of the latter over calcium chloride as a drying agent are pointed out. But this modified form suffers from the same disadvantage as the ordinary Schrötter apparatus in not making any special provision for the absorption of hydrochloric acid gas which is evolved whenever hydrochloric acid is employed in the decomposition of a carbonate. This is a well-recognised source of error, and it is customary to attach a tube charged with dehydrated copper sulphate on pumice to the sulphuric acid bulb of the ordinary Schrötter apparatus in order to effect the complete absorption of the hydrochloric acid gas. With this addition, very reliable results can be obtained, but the method of attachment of the additional tube is always more or less clumsy. The object of the present modification is to overcome this, and the new form has two additional advantages. The apparatus is more stable, and the copper sulphate tube can be easily turned through any angle, so as to attach the indiarubber tubing for drawing air through the apparatus, after heating to drive out the carbonic anhydride and allowing to cool. The pumice containing the dehydrated copper sulphate is held in place by a plug of glass wool, and the ground glass stopper below it keeps well in its place if properly greased. If necessary it can be made perfectly secure by means of platinum wire. The total weight of the apparatus when fully charged is 58 to 60 grms.

Mr. J. Towers, of Widnes, has undertaken to supply the apparatus.

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7. *A new Form of Aspirator.* *By* Charles A. Kohn, *Ph.D.*, *B.Sc.*, *and* T. Lewis Bailey, *Ph.D.*

The aspirator consists of a reversed gas meter worked by a small electric motor, and is specially adapted for aspirating large quantities of gas, such as are required for the determination of sulphur dioxide in air. A series of three cog-wheels are fixed to the axle of the drum of a wet gas meter, to which a 'Porter' motor is attached, which is run by a single secondary cell with a capacity of 25 ampere hours. The drum revolves twice per minute, the gearing being so arranged that about 15 cubic feet of air or other gas can be drawn through the absorbing tower or other apparatus per hour. The advantage of this form of aspirator is its evenness and continuity. The single cell is sufficient to run the meter for thirty hours.

TUESDAY, SEPTEMBER 22.

The following Papers and Report were read :—

1. *The Detection and Estimation of Carbon Monoxide in Air.* *By* Dr. J. Haldane.

This method for the determination of small percentages of carbonic oxide in air depends on the following facts :—

Hæmoglobin, the colouring matter of blood, readily combines to form similar compounds with both oxygen and carbonic oxide. Both compounds are dissociated in a vacuum, but the carbonic oxide compound (or carboxyhæmoglobin) is much more stable than the oxygen compound (or oxyhæmoglobin). In presence of a gas mixture containing both oxygen and carbonic oxide a mixture of carboxyhæmoglobin and oxyhæmoglobin is formed; and the proportions in which the hæmoglobin divides itself between the oxygen and carbonic oxide depends on the ratios of the percentage of oxygen to that of carbonic oxide multiplied by a constant. Hence if the percentage of oxygen in the gas mixture be known, as in the case of ordinary air, the percentage of carbonic oxide can be inferred if the proportions be known in which hæmoglobin brought into contact with the mixture divides itself between the two gases. Now, it is extremely easy to determine these proportions colorimetrically by taking advantage of the fact that in dilute solution carboxyhæmoglobin has a pink colour, while oxyhæmoglobin is yellow. By adding a certain amount of dilute carmine solution to oxyhæmoglobin solution, the tint of carboxyhæmoglobin solution can be exactly reproduced. In the case of a mixture of oxyhæmoglobin and carboxyhæmoglobin, the less the proportion of the latter present the less will be the amount of carmine required; and from the amount of carmine needed the proportion of carboxyhæmoglobin can easily be estimated.

The author then described the process in its simplest form. A solution of blood is first prepared of such strength as to show the difference of tint between oxyhæmoglobin and carboxyhæmoglobin; a suitable dilution can easily be guessed from the depth of colour. About 1 in 100 is very good. A solution of carmine of a corresponding or slightly greater depth of colour (about ·01 per cent.) is also prepared. The carmine is dissolved in a minimum of ammonia, and then diluted down.

The sample of air to be examined should be collected in a small, dry, and clean bottle of 100 or 200 c.c. capacity, and closed with a cork soaked in paraffin wax. This bottle is opened under the blood solution in a basin, and about 5 c.c. of air allowed to bubble out, so as to introduce a corresponding quantity of hæmoglobin solution into the bottle. The bottle is then recorked, removed from the basin, and shaken for ten minutes, so that a maximum saturation with carbonic oxide may be attained. During the shaking the bottle must be covered, as bright daylight alters the result very markedly. The blood solution in the bottle is then poured out into one of three narrow test-tubes of equal diameter. Into another of these test-tubes 5 c.c. of the original solution of blood are measured out with a pipette. The third is filled with the same blood solution after the hæmoglobin has been completely converted into carboxyhæmoglobin by shaking for about a minute with coal gas.

Carmine is now added from a burette to the 5 c.c. of oxyhæmoglobin until first the tint of the solution from the bottle of air, and afterwards the tint of the solution saturated with coal gas attained. Water may also be added if the carmine solution alters the *depth* of colour of the liquid. From the readings of the burette the proportion of carboxyhæmoglobin to oxyhæmoglobin may easily be calculated. In practice the estimation may be 2 per cent. too low or too high, but this is about the limit of error.

When 0·09 per cent. of carbonic oxide is present in the air the hæmoglobin is shared equally between the oxygen and carbonic oxide. The affinity of carbonic oxide for hæmoglobin is thus about 230 times as great as that of oxygen when twice 0·09 or 0·18 per cent. of carbonic oxide is present; two-thirds of the hæmoglobin go to the carbon oxide and one-third to the oxygen, and so on. Roughly speaking, the percentage of carbonic oxide in the air can be calculated by multiplying the number of parts of carboxyhæmoglobin to one part of oxyhæmoglobin by 0·09. Thus, if the hæmoglobin were found to be 10 per cent. saturated with carbonic oxide, then, as there would be to each part of oxyhæmoglobin one-ninth of carboxyhæmoglobin, one-ninth of 0·09 or 0·01 per cent. of carbonic oxide would be present in the air.

It is evident that the method cannot be used directly when high percentages of carbonic oxide are present. The sample in such a case must be diluted. Coal gas, for instance, requires dilution to about $\frac{1}{100}$th with air when this method is employed. When the oxygen percentage in the air is much diminished the sample must also be largely diluted with air, or a correction made in calculating the result.

Blood solution was originally suggested by Vogel as a qualitative test for CO in air. He used the spectroscopic test, and found he could detect 0·2 per cent. of the gas.

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2. *The Detection and Estimation of Carbon Monoxide in the Air by the Flame-cap Test.* *By* Professor FRANK CLOWES, *D.Sc.*

The detection of carbon monoxide in the air is mainly of importance on account of its poisonous nature when inhaled. It would rarely happen that serious explosions arise from its being fired in admixture with air, since a carbon monoxide explosion is of a comparatively mild character, and further air only commences to be feebly explosive when the carbon monoxide is present in the proportion of at least 13 per cent.; this is an amount which would render the air rapidly fatal to life.

The introduction of carbon monoxide into the air may arise from leakage of many forms of gaseous fuel, such as coal-gas, producer-gas, Dowson-gas, water-gas, and flue-gas from smelting works, whether the metal is smelted by the old reducing methods, or by the newer method more recently applied by Mr. Mond to the smelting of nickel ores. This gas is also produced by the detonation of the nitro-cotton explosives, and by the imperfect combustion of any ordinary fuel which may occur either slowly or explosively. Hence cases of poisoning by this gas have mainly arisen from the 'gas' taken from the iron blast-furnace, from water-gas either used alone or in the enrichment of coal-gas, from coal-gas leakage, and from the 'after-damp' of the colliery explosion or 'gob-fire.' It will be seen that this insidious poison is, therefore, of not infrequent occurrence in the air. The author finds that 0·25 per cent. of the gas can be detected in the air by a 'cap' 0·5 inch in height over the standard hydrogen flame. This test is, therefore, sufficiently sensitive for practical application, and furnishes the most rapid means of detecting the gas. It further serves to measure the percentage of carbon monoxide present in the air, since the height of the cap regularly increases as the amount of gas increases. It is applied either by carrying an ordinary miner's safety-lamp provided with a hydrogen flame into the atmosphere to be tested; or, since this would probably be attended with danger from carbon monoxide, the atmosphere can be made to pass over the flame by means of a pump. This test, however, fails to distinguish carbonic oxide from other combustible gases, and therefore recourse must be had to the ordinary process of absorption with cuprous chloride solution when the distinction, as well as the estimation of this gas, is necessary. The cuprous chloride method does not readily measure less than 0·5 per. cent. of the gas in the air, and this is a seriously poisonous proportion.

Dr. Haldane's method of detection and estimation, by means of suitably diluted blood, possesses the advantage of being delicate and distinctive, but requires good daylight, and cannot be carried out so rapidly as the flame-cap test can. It is, however, undoubtedly the most satisfactory method yet known of detecting and estimating minute proportions of carbon monoxide in the air, and should take its place amongst acknowledged methods in the chemical laboratory.

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3. *Chemical Education in England and Germany.* *By* Sir H. E. Roscoe, *F.R.S.*

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4. *Report on the Teaching of Science in Elementary Schools.*

See Reports, p. 268.

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5. *The Teaching of Science in Girls' Schools.* *By* L. Edna Walter, *B.Sc.*, *A.C.G.I.*

The object of teaching girls science at all is not to make them botanists, doctors, chemists, or engineers—at least below the age of fifteen—but to train their intelligence. There are two reasons why most schools fail so lamentably in the results achieved by what is intended to be science training; the first is that only the faculty of observation is as a rule cultivated, the second that the work is not commenced low enough down in the school. Botany, though so generally adopted, has a very limited educative value; physiology, though called a science, is scarcely ever taught as a science at all; and domestic economy is quite pernicious. Physical geography has an educative function of its own, but, though of immense value, its strength does not lie in the direction of scientific training. What is wanted to obtain this pre-eminently important effect is a gently graduated scientific course beginning with the simplest experiments for quite young children, and gradually increasing in complexity till the girls reach the age of about sixteen. It should be recognised that from beginning to end the course should be practical in character and quantitative as far as possible. Such a course as this can be followed if practical arithmetic be made the starting-point. This leads naturally to elementary physics, chiefly hydrostatics, and finally to a course of elementary chemistry. For this latter no finer scheme could be suggested than that outlined in Dr. Armstrong's contribution to the Report of the British Association Committee (Newcastle-on-Tyne meeting, 1889), which is of inestimable value to all who are interested in the teaching of chemistry. It is an important feature of the course I suggest that the children should use no text-books; their own notes written in their own words should form their books of reference. In this way their literary powers are also cultivated; but, above all, the children learn to rely on themselves. The aim of science training is to teach the girls to think for themselves, rely on themselves, and work for themselves. They must learn to *do* something, and this will never happen while science work is confined to mere lesson learning.

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION—J. E. MARR, Esq., M.A., F.R.S., Sec. G.S.

THURSDAY, SEPTEMBER 17.

The President delivered the following Address:—

THE feelings of one who, being but little versed in the economic applications of his science, is called upon to address a meeting of the Association held in a large industrial centre might, under ordinary circumstances, be of no very pleasant character; but I take courage when I remember that those connected with my native county, in which we are now gathered, have taken prominent part in advancing branches of our science which are not directly concerned with industrial affairs. I am reminded, for instance, that one amongst you, himself a busy professional man, has in his book on 'The Origin of Mountain Ranges' given to the world a theoretical work of the highest value; that, on the opposite side of the county, those who are responsible for the formation and management of that excellent educational institution, the Ancoats Museum, have wisely recognised the value of some knowledge of geology as a means of quickening our appreciation of the beauties of Nature; and that one who has done solid service to geology by his teachings, who has kept before us the relationship of our science to that which is beautiful—I refer to the distinguished author of 'Modern Painters'—has chosen the northern part of the county for his home, and has illustrated his teaching afresh by reference to the rocks of the lovely district around him. Nor can I help referring to one who has recently passed away—the late Sir Joseph Prestwich—the last link between the pioneers of our science and the geologists of the present day, who, though born in London, was of Lancashire family, and whom we may surely therefore claim as one of Lancashire's worthies. With these evidences of the catholicity of taste on the part of geologists connected with the county, I feel free to choose my own subject for this address, and, my time being occupied to a large extent with academic work, I may be pardoned for treating that subject in academic fashion. As I have paid considerable attention to the branch of the science which bears the somewhat uncouth designation of stratigraphical geology, I propose to take the present state of our knowledge of this branch as my theme.

Of the four great divisions of geology, petrology may be claimed as being largely of German origin, the great impetus to its study having been given by Werner and his teachings. Palæontology may be as justly claimed by the French nation, Cuvier having been to so great an extent responsible for placing it upon a scientific basis. Physical geology we may partly regard as our own, the principles laid down by Hutton and supported by Playfair having received illustration from a host of British writers, amongst whom may be mentioned Jukes, Ramsay, and the brothers Geikie; but the grand principles of physical geology have been so largely illustrated by the magnificent and simple features displayed on the other side of the Atlantic that we may well refer to our American brethren as leaders in this branch of study. The fourth branch, stratigraphical geology, is essentially British as regards origin, and, as everyone is aware, its scientific principles were established by William Smith, who was not only the father of English geology, but of stratigraphical geology in general.

Few will deny that stratigraphical geology is the highest branch of the science, for, as has been well said, it 'gathers up the sum of all that is made known by the other departments of the science, and makes it subservient to the interpretation of the geological history of the earth.' The object of the stratigraphical geologist is to obtain information concerning all physical, climatic, and biological events which have occurred during each period of the past, and to arrange them in chronological order, so as to write a connected history of the earth. If all of this information were at our disposal, we could write a complete earth-history, and the task of the geologist would be ended. As it is, we have barely crossed the threshold of discovery, and the 'imperfection of the geological record,' like the 'glorious uncertainty' of our national game, gives geology one of its great charms. Before passing on to consider more particularly the present state of the subject of our study, a few remarks upon this imperfection of the geological record may not be out of place, seeing that the term has been used by so many modern writers, and its exact signification occasionally misunderstood. The imperfection of the palæontological record is usually understood by the term when used, and it will be considered here as an illustration of the incompleteness of our knowledge of earth-history; but it must be remembered that the imperfection of the physical record is equally striking, as will be insisted on more fully in the sequel.

Specially prominent amongst the points upon which we are ignorant stands the nature of the Precambrian faunas. The extraordinary complexity of the earliest known Cambrian fauna has long been a matter for surprise, and the recent discoveries in connection with the *Olenellus* fauna do not diminish the feeling.[1] After commenting upon the varied nature of the earliest known fauna, the late Professor Huxley, in his Address to the Geological Society in 1862, stated that 'any admissible hypothesis of progressive modification must be compatible with persistence without progression, through indefinite periods. . . . Should such an hypothesis eventually be proved to be true, . . . the conclusion will inevitably present itself, that the Palæozoic, Mesozoic, and Cainozoic faunæ and floræ, taken together, bear somewhat the same proportion to the whole series of living beings which have occupied this globe, as the existing fauna and flora do to them.' Whether or not this estimate is correct, all geologists will agree that a vast period of time must have elapsed before the Cambrian period, and yet our ignorance of faunas existing prior to the time when the *Olenellus* fauna occupied the Cambrian seas is almost complete. True, many pre-Cambrian fossils have been described at various times, but, in the opinion of many competent judges, the organic nature of each one of these requires confirmation. I need not, however, enlarge upon this matter, for I am glad to say we have amongst us a geologist who will at a later stage read a paper before this Section upon the subject of pre-Cambrian fossils, and there is no one better able, owing to his intimate acquaintance with the actual relics, to present fairly and impartially the arguments which have been advanced in favour of the organic origin of the objects which have been appealed to as evidences of organisms of pre-Cambrian age than our revered co-worker from Canada, Sir J. William Dawson. We may look forward with confidence to the future discovery of many faunas older than those of which we now possess certain

[1] Dr. C. D. Walcott, in his monograph on 'The Fauna of the Lower Cambrian or Olenellus Zone' (Washington, 1890), records the following great groups as represented in the Olenellus beds of America:—Spongiæ, Hydrozoa, Actinozoa, Echinodermata, Annelida? (trails, burrows, and tracks), Brachiopoda, Lamellibranchiata, Gasteropoda, Pteropoda, Crustacea, and Trilobita. Others are known as occurring in beds of the same age in the Old World.

knowledge, but until these are discovered the palæontological record must be admitted to be in a remarkably incomplete condition. In the meantime a study of the recent advance of our knowledge of early life is significant of the mode in which still earlier faunas will probably be brought to light. In 1845 Dr. E. Emmons described a fossil, now known to be an *Olenellus*, though at that time the earliest fauna was supposed to be one containing a much later group of organisms, and it was not until Nathorst and Brögger established the position of the *Olenellus* zone that the existence of a fauna earlier than that of which *Paradoxides* was a member was admitted; and, indeed, the *Paradoxides* fauna itself was proved to be earlier than that containing *Olenus*, long after these two genera had been made familiar to palæontologists, the Swedish palæontologist, Augelin, having referred the *Paradoxides* fauna to a period earlier than that of the one with *Olenus*. It is quite possible, therefore, that fossils are actually preserved in our museums at the present moment which have been extracted from rocks deposited before the period of formation of the *Olenellus* beds, though their age has not been determined. The *Olenellus* horizon now furnishes us with a datum-line from which we can work backwards, and it is quite possible that the *Neobolus* beds of the Salt Range,[1] which underlie beds holding *Olenellus*, really do contain, as has been maintained, a fauna of date anterior to the formation of the *Olenellus* beds; and the same may be the case with the beds containing the *Protolenus* fauna in Canada,[2] for this fauna is very different from any known in the *Olenellus* beds, or at a higher horizon, though Mr. G. F. Matthew, to whom geologists owe a great debt for his admirable descriptions of the early fossils of the Canadian rocks, speaks very cautiously of the age of the beds containing *Protolenus* and its associates. Notwithstanding our ignorance of pre-Cambrian faunas, valuable work has recently been done in proving the existence of important groups of stratified rocks deposited previously to the formation of the beds containing the earliest known Cambrian fossils; I may refer especially to the proofs of the pre-Cambrian age of the Torridon sandstone of North-west Scotland, lately furnished by the officers of the Geological Survey, and their discovery that the maximum thickness of these strata is over 10,000 feet.[3] Amongst the sediments of this important system, more than one fauna may be discovered, even if most of the strata were accumulated with rapidity, and all geologists must hope that the officers of the Survey—who, following Nicol, Lapworth, and others, have done so much to elucidate the geological structure of the Scottish Highlands—may obtain the legitimate reward of their labours, and definitely prove the occurrence of rich faunas of pre-Cambrian age in the rocks of that region.

But, although we may look forward hopefully to the time when we may lessen the imperfection of the records of early life upon the globe, even the most hopeful cannot expect that record to be rendered perfect, or that it will make any near approach to perfection. The posterior segments of the remarkable trilobite *Mesonacis vermontana* are of a much more delicate character than the anterior ones, and the resemblance of the spine on the fifteenth 'body-segment' of this species to the terminal spine of *Olenellus* proper suggests that in the latter subgenus posterior segments of a purely membranous character may have existed, devoid of hard parts. If this be so, the entire outer covering of the trilobites, at a period not very remote from the end of pre-Cambrian times, may have been membranous, and the same thing may have occurred with the structures analogous to the hard parts of organisms of other groups. Indeed, with our present views as to development, we can scarcely suppose that organisms acquired hard parts at a very early period of their existence, and fauna after fauna may have occupied the globe, and disappeared, leaving no trace of its existence, in which case we are not likely ever to obtain definite knowledge of the characters of our earliest faunas,

[1] See F. Noetling, 'On the Cambrian Formation of the Eastern Salt Range,' *Records Geol. Survey India*, vol. xxvii. p. 71.

[2] G. F. Matthew, 'The Protolenus Fauna,' *Trans. New York Acad. of Science*, vol. xiv. 1895, p. 101.

[3] Sir A. Geikie, 'Annual Report of the Geological Survey [United Kingdom] . . . for the year ending December 31, 1893.' London, 1894.

and the biologist must not look to the geologist for direct information concerning the dawn of life upon the earth.

Proceeding now to a consideration of the faunas of the rocks formed after pre-Cambrian times, a rough test of the imperfection of the record may be made by examining the gaps which occur in the vertical distribution of forms of life. If our knowledge of ancient faunas were very incomplete, we ought to meet with many cases of recurrence of forms after their apparent disappearance from intervening strata of considerable thickness, and many such cases have actually been described by that eminent palæontologist, M. Barrande, amongst the Palæozoic rocks of Bohemia, though even these are gradually being reduced in number owing to recent discoveries; indeed, in the case of the marine faunas, marked cases of recurrence are comparatively rare, and the occurrence of each form is generally fairly unbroken from its first appearance to its final extinction, thus showing that the imperfection of the record is by no means so marked as might be supposed. Freshwater and terrestrial forms naturally furnish a large percentage of cases of recurrence, owing to the comparative rarity with which deposits containing such organisms are preserved amongst the strata.

A brief consideration of the main reasons for the present imperfection of our knowledge of the faunas of rocks formed subsequently to pre-Cambrian times may be useful, and suggestive of lines along which future work may be carried out. That detailed work in tracts of country which are yet unexplored, or have been but imperfectly examined by the geologist, will add largely to our stock of information needs only to be mentioned; the probable importance of work of this kind in the future may be inferred from a consideration of the great increase of our knowledge of the Permo-Carboniferous faunas, as the result of recent labours in remote regions. It is specially desirable that the ancient faunas and floras of tropical regions should be more fully made known, as a study of these will probably throw considerable light upon the influence of climate upon the geographical distribution of organisms in past times. The old floras and faunas of Arctic regions are becoming fairly well known, thanks to the zeal with which the Arctic regions have been explored. But, confining our attention to the geology of our own country, much remains to be done even here, and local observers especially have opportunities of adding largely to our stock of knowledge, a task they have performed so well in the past. To give examples of the value of such work, our knowledge of the fauna of the Cambrian rocks of Britain is largely due to the present President of the Geological Society, when resident at St. David's; whilst the magnificent fauna of the Wenlock limestone would have been far less perfectly known than it is, if it were not for the collections of men like the late Colonel Fletcher and the late Dr. Grindrod. Again, the existence of the rich fauna of the Cambridge Greensand would have been unsuspected, had not the bed known by that name been worked for the phosphatic nodules which it contains.

It is very desirable that large collections of varieties of species should be made, for in this matter the record is very imperfect. There has been, and, I fear, is still, a tendency to reject specimens when their characters do not conform with those given in specific descriptions, and thus much valuable material is lost. Local observers should be specially careful to search for varieties, which may be very abundant in places where the conditions were favourable for their production, though rare or unknown elsewhere. Thus, I find the late Mr. W. Keeping remarking that 'it is noteworthy that at Upware, and indeed all other places known to me, the species of *Brachiopoda* [of the *Neocomian* beds] maintain much more distinctness and isolation from one another than at Brickhill.'[1] The latter place appears to be one where conditions were exceptionally favourable in *Neocomian* times for the production of intermediate forms.

A mere knowledge of varieties is, however, of no great use to the collector without a general acquaintance with the morphology of the organisms whose remains he extracts from the earth's strata, and one who has this can do signal

[1] W. Keeping, Sedgwick Essay: *The Fossils and Palæontological Affinities of the Neocomian Deposits of Upware and Brickhill.* Cambridge, 1883.

service to the science. It is specially important that local observers should be willing to devote themselves to the study of particular groups of organisms, and to collect large suites of specimens of the group they have chosen for study. With a group like the graptolites, for instance, the specimens which are apparently best preserved are often of little value from a morphological point of view, and fragments frequently furnish more information than more complete specimens. These fragments seldom find their way to our museums, and accordingly we may examine a large suite of graptolites in those museums without finding any examples showing particular structures of importance, such as the sac-like bodies carried by many of these creatures. As an illustration of the value of work done by one who has made a special study of a particular group of organisms, I may refer to the remarkable success achieved by the late Mr. Norman Glass in developing the calcareous supports of the brachial processes of Brachiopods. Work of this character will greatly reduce the imperfection of the record from the biologist's point of view.

The importance of detailed work leads one to comment upon the general methods of research which have been largely adopted in the case of the stratified rocks. The principle that strata are identifiable by their included organisms is the basis of modern work, as it was of that which was achieved by the father of English Geology, and the identification of strata in this manner has of recent years been carried out in very great detail, notwithstanding the attempt on the part of some well-known writers to show that correlation of strata in great detail is impossible. The objection to this detailed work is mainly founded upon the fact that it must take time for an organism or group of organisms to migrate from one area to another, and therefore it was stated that they cannot have lived contemporaneously in two remote areas. But the force of this objection is practically done away with if it can be shown that the time taken for migration is exceedingly short as compared with the time of duration of an organism or group of organisms upon the earth, and this has been shown in the only possible way—namely, by accumulating a very great amount of evidence as the result of observation. The eminent writers referred to above, who were not trained geologists, never properly grasped the vast periods of time which must have elapsed during the occurrence of the events which it is the geologist's province to study. An historian would speak of events which began at noon on a certain day and ended at midnight at the close of that day as contemporaneous with events which commenced and ended five minutes later, and this is quite on a par with what the geologist does when correlating strata. Nevertheless, there are many people who still view the task of correlating minute subdivisions of stratified systems with one another with a certain amount of suspicion, if not with positive antipathy; but the work must be done for all that. Brilliant generalisations are attractive as well as valuable, but the steady accumulation of facts is as necessary for the advancement of the science as it was in the days when the Geological Society was founded, and its members applied themselves 'to multiply and record observations, and patiently to await the result at some future period.' I have already suggested a resemblance between geology and cricket, and I may be permitted to point out that just as in the game the free-hitter wins the applause, though the patient 'stone-waller' often wins the match, so, in the science, the man apt at brilliant generalisations gains the approval of the general public, but the patient recorder of apparently insignificant details adds matter of permanent value to the stores of our knowledge. In the case of stratigraphical geology, if we were compelled to be content with correlation of systems only, and were unable to ascertain which of the smaller series and stages were contemporaneous, but could only speak of these as 'homotaxial,' we should be in much the same position as the would-be antiquary who was content to consider objects fashioned by the Romans as contemporaneous with those of mediæval times. Under such circumstances geology would indeed be an uncertain science, and we should labour in the field, knowing that a satisfactory earth-history would never be written. Let us hope that a brighter future is in store for us, and let me urge my countrymen to continue to study the minute subdivisions of the strata, lest they be left behind by the geologists of other countries, to whom the necessity for this kind of study is apparent, and who are carrying it on with great success.

The value of detailed work on the part of the stratigraphical geologist is best grasped if we consider the recent advance that has been made in our science owing to the more or less exhaustive survey of the strata of various areas, and the application of the results obtained to the elucidation of earth's history. A review of this nature will enable us not only to see what has been done, but also to detect lines of inquiry which it will be useful to pursue in the future; but it is obvious that the subject is so wide that little more can be attempted than to touch lightly upon some of the more prominent questions. A work might well be written treating of the matters which I propose to notice. We have all read our 'Principles of Geology,' or 'The Modern Changes of the Earth and its Inhabitants considered as illustrative of Geology,' to quote the alternative title; some day we may have a book written about the ancient changes of the earth and its inhabitants considered as illustrative of geography.

Commencing with a glance at the light thrown on inorganic changes by a detailed examination of the strata, I may briefly allude to advances which have recently been made in the study of denudation. The minor faults, which can only be detected when the small subdivisions of rock-groups are followed out carefully on the ground, have been shown to be of great importance in defining the direction in which the agents of denudation have operated, as demonstrated by Professor W. C. Brögger, for instance, in the case of the Christiania Fjord;[1] and I have recently endeavoured to prove that certain valleys in the English Lake District have been determined by shattered belts of country, the existence of which is shown by following thin bands of strata along their outcrop. The importance of the study of the strata in connection with the genesis and subsequent changes of river-systems is admirably brought out in Professor W. M. Davis's paper on 'The Development of certain English Rivers,[2] a paper which should be read by all physical geologists; it is, indeed, a starting-point for kindred work which remains especially for local observers to accomplish. Study of this kind not only adds to our knowledge of the work of geological agencies, but helps to diminish the imperfection of the record, for the nature of river-systems, when rightly understood, enables us to detect the former presence of deposits over areas from which they have long since been removed by denudation.

An intimate acquaintance with the lithological characters of the strata of a district affords valuable information in connection with the subject of glacial denudation. The direction of glacial transport over the British Isles has been largely inferred from a study of the distribution of boulders of igneous rock, whilst those of sedimentary rock have been less carefully observed. The importance of the latter is well shown by the work which has been done in Northern Europe in tracing the Scandinavian boulders to their sources, a task which could not have been performed successfully if the Scandinavian strata had not been studied in great detail.[3] I shall presently have more to say with regard to work connected with the lithological characters of the sediments. Whilst mentioning glacial denudation, let me allude to a piece of work which should be done in great detail, though it is not, strictly speaking, connected with stratigraphy, namely, the mapping of the rocks around asserted 'rock-basins.' I can find no actual proof of the occurrence of such basins in Britain, and it is very desirable that the solid rocks and the drift should be carefully inserted on large-scale maps, not only all around the shores of several lakes, but also between the lakes and the sea, in order to ascertain whether the lakes are really held in rock-basins. Until this work

[1] W. C. Brögger, *Nyt. Mag. for Naturvidensk*, vol. xxx. 1886, p. 79.

[2] W. M. Davis, *Geograph. Journ.*, vol. v. 1895, p. 127.

[3] It is desirable that the boulders of sedimentary rock imbedded in the drifts of East Anglia should be carefully examined and fossils collected from them. The calcareous strata associated with the Alum Shales of Scandinavia and the strata of the Orthoceras-Limestone of that region may be expected to be represented amongst the boulders.

is done, however probable the occurrence of rock-basins in Britain may be considered to be, their actual existence cannot be accepted as proved.

When referring to the subject of denudation, mention was made a moment ago of the study of the lithological character of the sediments. Admirable work in this direction was carried out years ago by one who may be said to have largely changed the direction of advance of geology in this country owing to his researches 'On the Microscopical Structure of Crystals, indicating the Origin of Minerals and Rocks.' I refer, of course, to Dr. H. C. Sorby. But since our attention has been so largely directed to petrology, the study of the igneous and metamorphic rocks has been most zealously pursued, whilst that of the sediments has been singularly little heeded, with few exceptions, prominent amongst which is the work of Mr. Maynard Hutchings, the results of which have been recently published in the 'Geological Magazine,' though we must all hope that the details which have hitherto been supplied to us, valuable as they are, are only a foretaste of what is to follow from the pen of this able observer. Descriptions of the lithological changes which occur in a vertical series of sediments, as well as of those which are observed when any particular band is traced laterally, will no doubt throw light upon a number of interesting questions.

Careful work amongst the ancient sediments, especially those which are of organic origin, has strikingly illustrated the general identity of characters, and therefore of methods of formation, of deposits laid down on the sea-floors of past times and those which are at present in course of construction. Globigerine-oozes have been detected at various horizons and in many countries. Professor H. Alleyne Nicholson[1] has described a pteropod-ooze of Devonian age in the Hamilton Limestone of Canada, which is largely composed of the tests of *Styliola*; and to Dr. G. J. Hinde we owe the discovery of a large number of radiolarian cherts of Palæozoic and Neozoic ages in various parts of the globe. The extreme thinness of many argillaceous deposits, which are represented elsewhere by hundreds of feet of strata, suggests that some of them, at any rate, may be analogous to the deep-sea clays of modern oceans, though in the case of deposits of this nature we must depend to a large extent upon negative evidence. The uniformity of character of thin marine deposits over wide areas is in itself evidence of their formation at some distance from the land; but although the proofs of origin of ancient sediments far from coast-lines may be looked upon as permanently established, the evidence for their deposition at great depths below the ocean's surface might be advantageously increased in the case of many of them. The fairly modern sediments, containing genera which are still in existence, are more likely to furnish satisfactory proofs of a deep-sea origin than are more ancient deposits. Thus the existence of *Archæopneustes* and *Cystechinus* in the oceanic series of Barbadoes, as described by Dr. J. G. Gregory, furnishes strong proofs of the deep-sea character of the deposits, whilst the only actual argument in favour of the deep-sea character of certain Palæozoic sediments has been put forward by Professor Suess, who notes the similarity of certain structures of creatures in ancient rocks to those possessed by modern deep-sea crustacea, especially the co-existence of trilobites which are blind with those which have enormously developed eyes.

A question which has been very prominently brought to the fore in recent years is that of the mode of formation of certain coral-reefs. The theory of Charles Darwin, lately so widely accepted as an explanation of the mode of formation of barrier-reefs and atolls, has been, as is well known, criticised by Dr. Murray, with the result that a large number of valuable observations have been recently made on modern reefs, especially by biologists, as a contribution to the study of reef formation. Nor have geologists been inactive. Dr. E. Mojsisovics and Professor Dupont, to mention two prominent observers, have described knoll-like masses of limestone more or less analogous, as regards structure, to modern coral-reefs. They consider that these have been formed by corals, and indeed Dupont maintains that the atoll-shape is still recognisable in ancient Devonian

[1] Nicholson and Lydekker, *Manual of Palæontology*, chap. ii.

coral-reefs in Belgium.[1] I would observe that all cases of 'knoll-reefs' of this character have been described in districts which furnish proofs of having been subjected to considerable orogenic disturbance, subsequent to the formation of the rocks composing the knoll-shaped masses, whilst in areas which have not been affected by violent earth-foldings, the reef-building corals, so far as I have been able to ascertain, give rise to sheet-like masses, such as should be produced according to Dr. Murray's theory. I would mention especially the reefs of the Corallian Rocks of England, and also some admirable examples seen amongst the Carboniferous Limestone strata of the great western escarpment of the Pennine Chain which faces the Eden Valley in the neighbourhood of Melmerby in Cumberland. Considering the number of dissected coral-reefs which exist amongst the strata of the earth's crust, and the striking way in which their structure is often displayed, it is rather remarkable that comparatively little attention has been paid to them by geologists in general, when the subject has been so prominently brought before the scientific world, for we must surely admit that we are much more likely to gain important information, shedding light upon the methods of reef-formation, by a study of such dissected reefs, than by making a few bore-holes on some special coral island. I would specially recommend geologists to make a detailed study of the British coral-reefs of Silurian, Devonian, Carboniferous, and Jurassic ages.

Turning now to organic deposits of vegetable origin, we must, as the result of detailed work, be prepared to admit the inapplicability of any one theory of the formation of coal seams. The 'growth-in-place' theory may be considered fairly well established for some coals, such as the spore-coals, whilst the 'drift' theory furnishes an equally satisfactory explanation of the formation of cannel-coal. It is now clear that the application of the general term *coal* to a number of materials of diverse nature, and probably of diverse origin, was largely responsible for the dragging-out of a controversy, in which the champions of either side endeavoured to explain the origin of all coal in one particular way.

The stratigraphical geologist, attempting to restore the physical geography of former periods, naturally pays much attention to the positions of ancient coast-lines; indeed, all teachers find it impossible to give an intelligible account of the stratified rocks without some reference to the distribution of land and sea at the time of their formation. The general position of land-masses at various times has been ascertained in several parts of the world, but much more information must be gathered together before our restorations of ancient sea-margins approximate to the truth. The Carboniferous rocks of Britain have been specially studied with reference to the distribution of land and water during the period of their accumulation, and yet we find that owing to the erroneous identification of certain rocks of Devonshire as grits or sandstones, which Dr. Hinde has shown to be radiolarian cherts, land was supposed to lie at no great distance south of this region in Lower Carboniferous times, whereas the probabilities are in favour of the existence of an open ocean at a considerable distance from any land in that direction. This case furnishes us with an excellent warning against generalisation upon insufficient data.

As a result of detailed study of the strata, the effects of earth-movements have been largely made known to us, especially of those comparatively local disturbances spoken of as orogenic, which are mainly connected with mountain-building, whilst information concerning the more widely spread epeirogenic movements is also furnished by a study of the stratified rocks. The structure of the Alps, of the North-West Highlands of Scotland, and of the uplifted tracts of North America is now familiar to geologists, whilst the study of comparatively recent sediments has proved the existence of widespread and extensive movements in times which are geologically modern; for instance, the deep-water deposits of late Tertiary age found in the West Indies indicate the occurrence of considerable uplift in that region. But a great amount of

[1] Similar knoll-like masses have been described in this country by Mr. R. H. Tiddeman as occurring in the Craven district of Yorkshire, but he does not attribute their formation to coral-growth to any great extent.

work yet remains to be done in this connection, especially concerning horizontal distortion of masses of the earth's crust, owing to more rapid horizontal advance of one portion than of another, during periods of movement. Not until we gather together a large amount of information derived from actual inspection of the rocks shall we be able to frame satisfactory theories of earth-movement, and in the meantime we are largely dependent upon the speculations of the physicist, often founded upon very imperfect data, on which is built an imposing superstructure of mathematical reasoning. We have been told that our continents and ocean-basins have been to a great extent permanent as regards position through long geological ages; we now reply by pointing to deep-sea sediments of nearly all geological periods, which have been uplifted from the ocean-abysses to form portions of our continents; and as the result of study of the distribution of fossil organisms, we can point almost as confidently to the sites of old continents now sunk down into the ocean depths. It seems clear that our knowledge of the causes of earth-movements is still in its infancy, and that we must be content to wait awhile, until we have further information at our disposal.

Recent work has proved the intimate connection betwixt earth-movement and the emission and intrusion of igneous rocks, and the study of igneous rocks has advanced beyond the petrographical stage; the rocks are now made to contribute their share towards the history of different geological periods. The part which volcanic action has played in the actual formation of the earth's crust is well exemplified in Sir Archibald Geikie's Presidential Addresses to the Geological Society, wherein he treats of the former volcanic history of the British Isles.[1] The way in which extruded material contributes to the formation of sedimentary masses has, perhaps, not been fully grasped by many writers, who frequently seem to assume that deposition is a measure of denudation, and *vice versâ*, whereas deposition is only a measure of denudation, and of the material which has been ejected in a fragmental condition from the earth's interior, which in some places forms a very considerable percentage of the total amount of sediment.

The intruded rocks also throw much light on past earth-history, and I cannot give a better illustration of the valuable information which they may furnish to the stratigraphical geologist, when rightly studied, than by referring to the excellent and suggestive work by my colleague, Mr. Alfred Harker, on the Bala Volcanic Rocks of Carnarvonshire.[2]

Perhaps the most striking instance of the effect which detailed stratigraphical work has produced on geological thought is supplied by the study of the crystalline schists. Our knowledge of the great bulk of the rocks which enter into the formation of a schistose complex is not very great, but the mode of production of many of them is now well known, and the crude speculations of some of the early geologists are now making way for theories founded on careful and minute observations in the field as well as in the laboratory. Recent work amongst the crystalline schists shows, furthermore, how careful we should be not to assume that because we have got at the truth, we have therefore ascertained the whole truth. We all remember how potent a factor dynamic metamorphism was supposed to be, owing to discoveries made in the greatly disturbed rocks of Scotland and Switzerland; and the action of heat was almost ignored by some writers, except as a minor factor, in the production of metamorphic change. The latest studies amongst the foliated rocks tend to show that heat does play a most important part in the manufacture of schists. The detailed work of Mr. George Barrow, in North-east Forfarshire,[3] has already thrown a flood of light upon the origin of certain schists, and their connection with igneous rocks, and geologists will look forward with eagerness to further studies of the puzzling Highland rocks by this keen observer.

The subject of former climatic conditions is one in which the geologist has very largely depended upon followers of other branches of science for light, and yet it is one peculiarly within the domain of the stratigraphical geologist; and

[1] Sir A. Geikie, *Quart. Journ. Geol. Soc.*, vols. xlvii. and xlviii.
[2] Alf. Harker, *Sedgwick Essay* for 1888 (Camb. Univ. Press, 1889).
[3] G. Barrow, *Quart. Journ. Geol. Soc.*, vol. xlix. 1893, p. 330.

information which has already been furnished concerning former climatic conditions, as the result of careful study of the strata, is probably only an earnest of what is to follow when the specialist in climatology pays attention to the records of the rocks, and avoids the theories elaborated in the student's sanctum. The recognition of an Ice Age in Pleistocene times at once proved the fallacy of the supposition that there has been a gradual fall in temperature throughout geological ages without any subsequent rise, and accordingly most theories which have been put forward to account for former climatic change have been advanced with special reference to the Glacial period or periods, although there are many other interesting matters connected with climate with which the geologist has to deal. Nevertheless, the occurrence of glacial periods is a matter of very great interest, and one which has deservedly received much attention, though the extremely plausible hypothesis of Croll, and the clear manner in which it has been presented to general readers, tended to throw other views into the shade, until quite recently, when this hypothesis has been controverted from the point of view of the physicist. In the meantime considerable advance has been made in our actual knowledge, and this year, probably for the first time, and as the result of the masterly *résumé* of Professor Edgworth David,[1] the bulk of British geologists are prepared to admit that there has been more than one glacial period, and that the evidence of glacial conditions in the southern hemisphere in Permo-Carboniferous times is established. Croll's hypothesis of course requires the recurrence of glacial periods, but leaving out of account arguments not of a geological character, which have been advanced against this hypothesis, the objection raised by Messrs. Gray and Kendall,[2] that in the case of the Pleistocene Ice Age 'the cold conditions came on with extreme slowness, the refrigerations being progressive from the Eocene period to the climax,' seems to me to be a fatal one. At the same time, rather than asking with the above writers 'the aid of astronomers and physicists in the solution of' this problem, I would direct the attention of stratigraphical geologists to it, believing that, by steady accumulation of facts, they are more likely than any one else to furnish the true clue to the solution of the glacial problem.

I have elsewhere called attention to marked changes in the faunas of the sedimentary rocks when passing from lower to higher levels, without the evidence of any apparent physical break, or any apparent change in the physical conditions, so far as can be judged from the lithological characters of the strata, and have suggested that such sudden faunistic variations may be due to climate. I refer to the matter as one which may well occupy the attention of local observers.

One of the most interesting points connected with climatic conditions is that of the former general lateral distribution of organisms, and its dependence upon the distribution of climatic zones. The well-known work of the late Dr. Neumayr[3] has, in the opinion of many geologists, established the existence of climatic zones whose boundaries ran practically parallel with the equator in Jurassic and Cretaceous times, and the possible existence of similar climatic zones in Palæozoic times has been elsewhere suggested; but it is very desirable that much more work should be done upon this subject, and it can only be carried out by paying close attention to the vertical and lateral distribution of organisms in the stratified rocks.

So far we have chiefly considered the importance of stratigraphical geology in connection with the inorganic side of nature. We now come to the bearing of detailed stratigraphical work upon questions concerning the life of the globe, and here the evidence furnished by the geologist particularly appeals to the general educated public as well as to students of other sciences.

[1] T. W. E. David, 'Evidences of Glacial Action in Australia in Permo-Carboniferous Time,' *Quart. Journ. Geol. Soc.*, vol. lii. p. 289.

[2] J. W. Gray and P. F. Kendall, 'The Cause of an Ice Age,' *Brit. Assoc. Rep.* (1892), p. 708.

[3] M. Neumayr, 'Ueber klimatische Zonen während der Jura- und Kreidezeit,' *Denkschr. der math.-naturwissen. Classe der k. k. Akad. der Wissenschaften*, vol. xlvii. Vienna, 1883.

Attention has just been directed to the probable importance of former climatic changes in determining the distribution of organisms, but the whole subject of the geographical distribution of organisms during former geological periods, though it has already received a considerable amount of attention, will doubtless have much further light thrown upon it as the result of careful observations carried out amongst the stratified rocks.

So long ago as 1853, Pictet laid it down as a palæontological law that 'the geographical distribution of species found in the strata was more extended than the range of species of existing faunas.' One would naturally expect that at a time when the diversity of animal organisation was not so great as it now is, the species, having fewer enemies with which to cope, and on the whole not too complex organisations to be affected by outward circumstances, would spread further laterally than they now do; but as we know that in earliest Cambrian times the diversity of organisation was very considerable, it is doubtful whether any appreciable difference would be exerted upon lateral distribution then and now, owing to this cause. At the time at which Pictet wrote, the rich fauna of the deeper parts of the oceans, with its many widely distributed forms of life, was unknown, and the range in space of early organisms must have then struck every one who thought upon the subject as being greater than that of the shallow-water organisms of existing seas, which were alone known. It is by no means clear, however, with our present knowledge, that Pictet's supposed law holds good, and it will require a considerable amount of work before it can be shown to be even apparently true. Our lists of the fossils of different areas are not sufficiently complete to allow us to generalise with safety, but a comparison of the faunas of Australia and Britain indicates a larger percentage of forms common to the two areas, as we examine higher groups of the geological column. If this indication be fully borne out by further work, it will not prove the actual truth of the law, for the apparent wider distribution of ancient forms of life might be due to the greater probability of elevation of ancient deep-sea sediments than of more modern ones which have not been subjected to so many elevatory movements. Still, if the law be apparently true, it is a matter of some importance to geologists; and I have touched upon the matter here in order once again to emphasise the possibility of correlating comparatively small thicknesses of strata in distant regions by their included organisms.

Mention of Pictet's laws, one of which states that fossil animals were constructed upon the same plan as existing ones, leads me to remark upon the frequent assumption that certain fossils are closely related to living groups, when the resemblances between the hard parts of the living and extinct forms are only of the most general character. There is a natural tendency to compare a fossil with its nearest living ally, but the comparison has probably been often pushed too far, with the result that biologists have frequently been led to look for the ancestors of one living group exclusively amongst forms of life which are closely related to those of another living group. The result of detailed work is to bring out more and more prominently the very important differences between some ancient forms and any living creature, and to throw doubts on certain comparisons; thus I find several of the well-known fossils of the Old Red Sandstone, formerly referred without hesitation to the fishes, are now doubtfully placed in that class.

The importance of detailed observation in the field is becoming every day more apparent, and the specialist who remains in his museum examining the collections amassed by the labours of others, and never notes the mode of occurrence of fossils in the strata, will perhaps soon be extinct, himself an illustration of the principle of the survival of the fittest. In the first place such a worker can never grasp the true significance of the changes wrought on fossil relics after they have become entombed in the strata, especially amongst those rocks which have been subjected to profound earth-movements; and it is to be feared that many 'species' are still retained in our fossil lists, whose supposed specific characters are due to distortion by pressure. But a point of greater importance is, that one who confines his attention to museums cannot, unless the information supplied to him be very full, distinguish the differences between fossils which are variations from a contemporaneous dominant form, such as 'sports,' and those which have been termed 'mutations,' which existed at a later period than the forms which they resemble. The value of the latter to those who are attempting to work out phylogenies is obvious, and their nature can only be determined as the result of very laborious and accurate field-work; but such labour in such a cause is well worth performing. The student of phylogeny has had sufficient warning of the dangers which beset his path from an inspection of the various phylogenetic trees, constructed mainly after study of existing beings only, so

'. . . like the borealis race,
That flit ere you can point their place;'

but recent researches amongst various groups of fossil organisms have further illustrated the danger of theorising upon insufficient data, especially suggestive being the discovery of closely similar forms which were formerly considered to be much more nearly related than now proves to be the case; thus Dr. Mojsisovics[1] has shown that Ammonites once referred to the same species are specifically distinct, though their hard parts have acquired similar structures, sometimes contemporaneously, sometimes at different times, and Mr. S. S. Buckman[2] has observed the same thing, which he speaks of as 'heterogenetic homœomorphy' in the case of certain brachiopods, whilst Prof. H. A. Nicholson and I[3] have given reasons for supposing that such heterogenetic homœomorphy, in the case of the graptolites, has sometimes caused the inclusion in one genus of forms which have arisen from two distinct genera. As the result of careful work, dangers of the nature here suggested will be avoided, and our chances of indicating lines of descent correctly will be much increased. It must be remembered that, however plausible the lines of descent indicated by students of recent forms may be, the actual links in the chains can only be discovered by examination of the rocks; and it is greatly to be desired that more of our geologists who have had a thorough training in the field should receive in addition one as thorough in the zoological laboratory. Shall I be forgiven if I venture on the opinion that a certain suspicion which some of my zoological fellow countrymen have of geological methods is due to their comparative ignorance of palæontology, and that it is as important for them to obtain some knowledge of the principles of geology as it is for the stratigraphical palæontologist to study the soft parts of creatures whose relatives he finds in the stratified rocks?

The main lines along which the organisms of some of the larger groups have been developed have already been indicated by several palæontologists, and detailed work has been carried out in several cases. As examples, let me allude to the trilobites, of which a satisfactory natural classification was outlined by the great Barrande in those volumes of his monumental work which deal with the fossils of this order, whilst further indication of their natural inter-relationships has been furnished by Messrs. C. D. Walcott, G. F. Matthew, and others; to the graptolites, whose relationships have been largely worked out by Professor C. Lapworth, *facile princeps* amongst students of the *Graptolitoidea*, to whom we look for a full account of the phylogeny of the group; to the brachiopods, which have been so ably treated by Dr. C. E. Beecher,[4] largely from a study of recent forms, but also after careful study of those preserved in the fossil state; and to the echinids and lamellibranchs, whose history is being extensively elucidated by Dr. R. T. Jackson[5] by methods somewhat similar to those pursued by Dr. Beecher.

[1] E. Mojsisovics, *Abhandl. der k. k. geol. Reichsanst.*, vol. vi. 1893.

[2] S. S. Buckman, *Quart. Journ. Geol. Soc.*, vol. li. 1895, p. 456.

[3] H. A. Nicholson and J. E. Marr, *Geol. Mag.*, Dec. 4, vol. ii. 1895, p. 531.

[4] C. E. Beecher, 'Development of the Brachiopoda,' *Amer. Journ. Sci.*, ser. iii. vol. xli. 1891, p. 343, and vol. xliv. 1892, p. 133.

[5] R. T. Jackson, 'Phylogeny of the Pelecypoda,' *Mem. Boston Soc. Nat. Hist.*, vol. iv. 1890, p. 277; and 'Studies of Palæechinoidea,' *Bull. Geol. Soc. Amer.*, vol. vii. 1896, p. 171.

I might give other instances,[1] but have chosen some striking ones, four of which especially illustrate the great advances which are being made in the study of the palæontology of the invertebrates by our American brethren.

I have occupied the main part of my address with reasons for the need of conducting stratigraphical work with minute accuracy. Many of you may suppose that the necessity for working in this way is so obvious that it is a work of supererogation to insist upon it at great length; but experience has taught me that many geologists consider that close attention to details is apt to deter workers from arriving at important generalisations in the present state of our science. A review of the past history of the science shows that William Smith, and those who followed after him, obtained their most important results by steady application to details, and subsequent generalisation, whilst the work of those who theorise on insufficient data is apt to be of little avail, though often demanding attention on account of its very daring, and because of the power of some writers to place erroneous views in an attractive light, just as

'. . . the sun can fling
Colours as bright on exhalations bred
By weedy pool or pestilential swamp,
As on the rivulet, sparkling where it runs,
Or the pellucid lake.'

Nor is there any reason to suppose that it will be otherwise in the future; and I am not one of those who consider that the brilliant discoveries were the exclusive reward of the pioneers in our science, and that labourers of the present day must be contented with the gleanings of their harvest; on the contrary, the discoveries which await the geologist will probably be as striking as are those which he has made in the past. The onward march of science is a rhythmic movement, with now a period of steady labour, anon a more rapid advance in our knowledge. It would perhaps be going too far to say that, so far as our science is concerned, we are living in a period rather of the former than of the latter character, though no great geological discovery has recently affected human thought in the way in which it was affected by the proofs of the antiquity of man, and by the publication of 'The Origin of Species.' If, however, we are to some extent gathering materials, rather than drawing far-reaching conclusions from them, I believe this is largely due to the great expansion which our science has undergone in recent years. It has been said that geology is 'not so much one science, as the application of all the physical sciences to the examination and description of the structure of the earth, the investigation of the agencies concerned in the production of that structure, and the history of their action'; and the application of other sciences to the elucidation of the history of our globe has been so greatly extended of recent years that we are apt to lose sight of the fact that geology is in itself a science, and that it is the special province of the geologist to get his facts at first hand from examination of the earth. The spectroscope and the telescope tell the geologist much; but his proper instrument is the hammer, and the motto of every geologist should be that which has been adopted for the Geological Congress, '*Mente et malleo.*'

At the risk of being compared to a child playing with edged tools, I cannot help referring to the bearing of modern stratigraphical research on the suggested replacement of a school of uniformitarianism by one of evolution. The distinguished advocate of evolutionism, who addressed the Geological Society in 1869 upon the modern schools of geological thought, spoke of the school of evolution as though it were midway between those of uniformitarianism and catastrophism, as

[1] *E.g.*, the following papers treating of the Cephalopoda:—A. Hyatt, 'Genesis of the Arietidæ,' Smithsonian Contributions, vol. xxvi. 1889; M. Neumayr, Jura-Studien I., 'Ueber Phylloceraten,' *Jahrb. der k. k. Geol. Reichsanst.*, vol. xxi. 1871, p. 297; L. Würtenberger, 'Studien über die Stammesgeschichte der Ammoniten,' Leipzig, 1880; S. S. Buckman, 'A Monograph of the Inferior Oolite Ammonites of the British Islands,' 1887 (*Monogr. Palæontographical Soc.*).

indeed it is logically, though, considering the tenets of the upholders of catastrophism, as opposed to those of uniformitarianism, at the time of that address, there is no doubt that evolutionism was rather a modification of the uniformitarianism of the period than intermediate between it and catastrophism, which was then practically extinct, at any rate in Britain. One of my predecessors in this chair, speaking upon this subject, says that 'the good old British ship "Uniformity," built by Hutton and refitted by Lyell, has won so many glorious victories in the past, and appears still to be in such excellent fighting trim, that I see no reason why she should haul down her colours, either to "Catastrophe" or "Evolution."' It may be so; but I doubt the expediency of nailing those colours to the mast. That Lyell, in his great work, proved that the agents now in operation, working with the same activity as that which they exhibit at the present day, *might* produce the phenomena exhibited by the stratified rocks seems to be generally admitted, but that is not the same thing as proving that they *did* so produce them. Such proof can only be acquired by that detailed examination of the strata which I have advocated in this address, and at the time that the last edition of the 'Principles' appeared, our knowledge of the strata was far less complete than it has subsequently become. It appears to me that we should keep our eyes open to the possibility of many phenomena presented by rocks, even newer than the Archæan rocks, having been produced under different conditions from those now prevalent. The depths and salinity of the oceans, the heights and extent of continents, the conditions of volcanic action, and many other things may have been markedly different from what they are at present, and it is surely unphilosophical to assume conditions to have been generally similar to those of the present day on the slender data at our disposal. Lastly, uniformitarianism, in its strictest sense, is opposed to rhythmic recurrence of events. 'Rhythm is the rule with nature; she abhors uniformity more than she does a vacuum,' wrote Professor Tyndall, many years ago, and the remark is worth noting by geologists. Why have we no undoubted signs of glacial epochs amongst the strata from early Cambrian times to the Great Ice Period, except in Permo-Carboniferous times? Is there not an apparent if not a real absence of manifestation of volcanic activity over wide areas of the earth in Mesozoic times? Were not Devonian, Permo-Triassic, and Miocene times periods of mountain-building over exceptionally wide areas, whilst the intervening periods were rather marked by quiet depression and sedimentation? A study of the evidence available in connection with questions like these suggests rhythmic recurrence. Without any desire to advocate hasty departure from our present methods of research, I think it should be clearly recognised that evolution may have been an important factor in changing the conditions even of those times of which the geologist has more direct knowledge. In this, as in many other questions, it is best to preserve an open mind; indeed, I think that geologists will do well to rest satisfied without an explanation to many problems, amongst them the one just referred to; and that working hypotheses, though useful, are better retained in the manuscript notebooks of the workers than published in the Transactions of learned societies, whence they filter out into popular works, to the great delight of a sceptical public should they happen to be overthrown.

May I trespass upon your patience for one moment longer? As a teacher of geology, with many years' experience in and out of a large university, I have come to the conclusion that geology is becoming more generally recognised as a valuable instrument of education. The memory, the reasoning faculties, and the powers of observation are alike quickened. The work in the open air, which is inseparable from a right understanding of the science, keeps the body in healthy condition. But over and above these benefits, the communing with Nature, often in her most impressive moods, and the insignificance of events in a man's lifetime, as compared with the ceaseless changes through the long æons which have gone before, so influence man's moral nature that they drive out his meaner thoughts and make him 'live in charity with all men.'

The following Papers were read:—

On the Geology of the Isle of Man.
By Professor W. Boyd Dawkins, M.A., F.R.S.

The geology of the Isle of Man presents many points worthy of the attention of the Geological Section. The following notes are based on my survey, during the last ten years, on the 6-inch scale, and on borings carried out under my advice through the thick covering of drift in the north of the island.

The Ordovician Massif.

The *massif* of the island consists of Ordovician clay-slates, phyllites, and quartzites, locally much folded and contorted, traversed by numerous volcanic dykes, and penetrated at Foxdale, the Dhoon, and Santon by three bosses of granite. They are for the most part unfossiliferous, the only three fossils as yet found being *Palæochorda*, *Dictyonema*, and a trilobite,[1] sufficiently perfect to be identified with one or other of the Ordovician genera. They are probably the south-western prolongation of the Skiddaw slates of the Lake Country beneath the Irish Sea. They are of unknown thickness, and have a general dip seawards, from an axis running from N.E. to S.W., the slates and shales forming the central nucleus of hills—Snaefel, North and South Barule, Cronk-na-Trelay, &c.—and the quartzites for the most part occurring in the littoral areas, and more particularly along the south-eastern seaboard, from Ramsey to Langness. These rocks have been locally very much altered by the heat caused by crushing. Where the slates, for example, have been traversed by white quartz veins, the friction, caused by the smashing of the quartz into the softer slates, has caused the development of mica-schist at the point of contact, and more rarely also of hornblende.

The crush-conglomerates (of Ballanayre and Sulby Glen), mainly occurring in the north of the Massif, formed by the smashing of thinly bedded quartzites and harder slates, and their being driven into the softer slates, testify to the enormous subterranean forces which have been at work, as Mr. Lamplugh has conclusively shown.[2] The result is a conglomerate, composed of blocks great and small, mostly rounded, and some scored like those from the glacial drift, each being covered by a thin film of sericite.

The Carboniferous Limestone of the South.

The Carboniferous Limestone series is seen in the south of the island, in the area of Castletown, Langness, and Ballasalla, to rest on a sea-worn floor of the highly contorted Ordovician rocks. At the base is the Red Conglomerate, some 15 feet thick, out of which the arches at Langness have been cut by the sea. It is formed of pebbles, red and white vein-quartz and red quartzite, derived from the break-up of the strata below, the grey Ordovician quartzite, with iron pyrites, having been oxidised into the red quartzite of the pebble. On this rest the thinly bedded limestones and shales of Castletown Bay and Derbyhaven. The beds of limestone increase in thickness to the west of Castletown Bay and at Port St. Mary. To the upper portion of this series belong the black and white limestones and black Poseidonia shales of Pool Vaish, and the interbedded volcanic agglomerate, between that place and Scarlet Point. The latter is proved to have been the site of the eruption by the Augite Porphyrite of the Stack.

The dykes of Olivine-dolerite [3] which riddle the limestone on the shore between this point and Castletown and Kentraugh are post-Carboniferous, and are referred by Horne and A. Geikie to the Early Tertiary age. The most important of these is the Strandhall dyke, which cuts the lode in the Ballacorkish lead-mine, the fore-

[1] Bolton, *Geological Magazine*, Dec. iii. vol. x. p. 29.
[2] *Quarterly Journ. Geol. Soc.*, vol. li. 1895, p. 565.
[3] Hobson, *Quarterly Journ. Geol. Soc.*, vol. xlvii. p. 432.

shore at Strandhall, and then runs across the peninsula of Scarlet, appearing again on the foreshore at Knock-Rushen. It is probably continued through the Bay of Castletown, and is represented by the network of dykes on the foreshore close to the Langness copper-mine, and crossing the peninsula of Langness.

The Carboniferous Limestone is highly faulted and folded, has a westerly dip, and has been faulted down into the Ordovician strata by the Port St. Mary fault, extending from the sea near that place, across Bay ny Carrickey to Ballashimmin, the throw being to the east. In consequence of this the upper strata of the Carboniferous Limestone are unrepresented in the south of the island.

The Permian Strata of the North of the Island.

The series of Red Sandstones and Conglomerates, to the east of Peel, considered by some geologists to belong to the Old Red Sandstone, and by others to the basement beds of the Carboniferous, are of Permian age. They extend along the shore-line from the Cregmalin to Willstrand, being faulted at both these points against the Ordovician slates. Inland their boundary is concealed by the thick covering of drift. It probably does not extend further than about one hundred yards to the south of the main road from Peel to Kirk Michael, a boring at Ballagar having proved the slate. It consists of, A, the Peel Sandstones, and irregular conglomerates, red, and reddish-grey and buff, 913 feet in thickness, plunging seawards at an angle from 40° to 45°; and, B, the Stack conglomerates and breccias, more or less calcareous, red, sandy, and grey, 455 feet thick.[1] The true base of these strata is concealed by the glacial drift, unless it be represented by the Red Conglomerates of the small and obscure patches faulted into the shales near Glenfaba. The Peel Sandstones are the equivalent of the Rot-todt-liegende of the Continent, and the Lower Permian Sandstones of St. Bees Head and the Vale of Eden.

The Stack conglomerates and breccias represent the base of the Magnesian Limestone of the Upper Permian, of the North of England, described so well by Sedgwick and Binney. They are identical in physical characters with 'the brockram' of the Cumbrian area, and are proved to be post-Carboniferous by the presence of pebbles of Carboniferous Limestone.

The Strata underneath Drift-covered Northern Plain.

The glacial drift occupies by far the greater portion of the island, and forms a thick mantle over the plain, extending from the abrupt Ordovician escarpment, sweeping westwards from Ramsey towards Kirk Michael. The contrast between this plain and the hilly region to its south rendered it probable that the strata underneath the drift are not Ordovician; and the high northern dip of all the rocks, Ordovician and Permian, rendered it probable that Carboniferous Rocks, and possibly Coal Measures, occurred below. Under these circumstances four borings were put down in 1891–96 by Messrs. Craine, Mr. Todd being the engineer in charge, with the following results.

The boring at Lhen Moar[2] proved the existence of the Carboniferous Limestone underneath the sands, clays, and gravels of the Drift at a depth of 167 feet 6 inches from the surface. The limestone dips at an angle of 40°, and is massive. It was penetrated to a depth of 66 feet.

The next borehole at Ballawhane, near Blue Point, about 4,050 feet to the north-east of that at Lhen Moar, gave a most interesting section.

	Feet	Inches
Boulder Drift sands, gravels, and clays	171	0
Triassic Sandstone, red and grey	373	2
Permian Marls and Sandstones of the Stack series . .	136	2
Carboniferous Limestone, grey and red, with crinoids .	37	10

[1] For details see *Manchester Geol. Soc.*, 1894, vol. xxii.; Dawkins, on the *Geology of the Isle of Man*, Part I.

[2] For details see Dawkins, *Trans. Manchester Geol. Soc.*, vols. xxii. and xxiii.; *Geology of the Isle of Man*, Parts I. and II.

In this section the Triassic Sandstone cores prove a dip of 10°, while the Stack series below have a dip of from 30° to 40°. The absence of the Peel Sandstones proves that the Permians are faulted against the Carboniferous Limestone. The Triassic Sandstone probably belongs to the Lower or Bunter series.

A third boring at Knock-y-Dooney, near Rue Point, at a distance of 1,670 yards to the north-east of Ballawhane, recently completed, has added another group of rocks to Manx geology. The section is as follows:—

	Feet	Inches
Glacial drift	173	0
Triassic Sandstone	463	4
Permian rocks of the Stack series	28	3
Yoredale sandstones and shales	283	0
Carboniferous Limestone	14	4
	961	11

This, the deepest boring in the island, proves the existence of the Yoredales, dipping at an angle of 30°, and passing into the Carboniferous Limestone, here, as before, full of crinoids.[1]

The fourth boring, close to the Lighthouse at the Point of Ayre, has completed the catalogue of the Manx rocks. Here the rocks are as follows:—

	Feet
Boulder drift	298
Marls, red, brown, and grey, with gypsum and rock salt . .	392
	690

The salt sets in at 500 feet below the surface, and the total thickness of the rock salt is 33 feet 6 inches, the two thickest beds being 20 feet and 9 feet 6 inches. Besides these a brine run, 2 feet 6 inches in depth, occurs at a depth of 615 feet 5 inches from the surface. The depth of the salt-field remains unproved.

The discovery of this salt-field is of considerable value, because it links on the salt-field at Carrickfergus with those of Barrow and of Cheshire, and shows that the Irish Sea is a basin in which the salt-bearing Triassic Marls were deposited. They have since been broken up and denuded, and it remains to be proved how far they are continuous under the sea, eastwards to Barrow and to the north-west in the direction of Carrickfergus.

General Conclusions as to Solid Geology.

It remains now to sum up the general results of the study of the Manx Palæozoic and Mesozoic strata. The Ordovician Massif is practically identical with the Skiddaw series of the Lake Country, the volcanic ash being left out. In Man and in the Lake Country there is the same relation between the Ordovician Massif and the Carboniferous Limestone, the Yoredale and the Permian strata, and the same unconformity between the Palæozoic strata below and the Triassic strata above. The Triassic Sandstone is probably the same as that of Aldingham and Barrow, which is sandwiched in between the Magnesian Limestone (Sheet 91, N.W. Geological Survey) and the Saliferous Marls of Barrow. We may also conclude, from this identity of structure between the districts of Barrow and Black Combe in the Lake district and of the rocks of the north of Man, that there is little hope of the south-western extension of the Whitehaven coalfield, so gallantly sought for by Messrs. Craine in their borings. The discovery of a salt-field is a most valuable addition to the mineral wealth of the island.

Broken rings of Permian and Triassic rocks similar to those encircling the Cumbrian Massif probably surround that of Man, being mostly covered by the sea or by thick masses of drift. In the north of the island they probably dip northwards, and occupy a position approximately represented by the map on the wall, in which the uncoloured part of the northern plain is a *terra incognita,* only to be explored by further borings.

[1] For details of this section see report of Mr. Todd, published in the *Journal of the Isle of Man Natural History and Antiquarian Society*, vol. iii. p. 65.

The Boulder-drift of the North.

The Boulder-drift of the northern plain is deposited on a floor of solid rocks, which sinks rapidly from 160 feet on the south-west at Ballawhane to 298 feet below high-water mark on the north-east at the Point of Ayre. It is no less than 450 feet in thickness, when the cliffs and hills of the plain are taken into account. It contains the usual marine shells. Inland the drift occurs to a height of more than 600 feet above the sea. The distribution of the Foxdale granite boulders proves that the glaciation was from north to south.

The Prehistoric Strata.

With regard to the prehistoric river terraces, and alluvia, and the peat-beds which are considerable in the north, I will only add that the discovery of the great Irish Elk in the peat near St. John's, and in the forest on the shore-line near Strandhall, proves that the island was united to Ireland or Britain in the prehistoric age.

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2. *Observations on some of the Footprints from the Trias in the Neighbourhood of Liverpool. By* H. C. Beasley.

The footprints generally known as those of the Cheirotherium or Cheirosaurus have been the subject of much speculation and some study for a long time past, but unfortunately without any very certain result; their general character is, however, so well known that I hardly need refer to them. Besides this large and rather singular form we have a great number and variety of smaller footprints.

A number of quite distinct forms may be traced, indicating that the fauna was rich both in individuals and in species. A slab in University College, on which about ninety-five footprints are shown on an area of about three square feet, illustrates this. The footprints are generally found in relief as natural casts in sandstone of prints made in the underlying marl or clay where the wet mud has taken the impression and afterwards been covered with sand. They occur most plentifully along certain beds, but this is because only at those places were the conditions favourable for their presentation. The author particularly draws attention to the fact that the prints indicate animals of terrestrial and not marine habits; for, although in older accounts webbed feet are described and figured, his own observations point to these being of very rare occurrence. This would necessitate the existence of dry land in the neighbourhood, and must be taken into account in any attempt to understand the formation of the Keuper. They are found at intervals from just above the conglomerates at the base to the lower part of the Keuper marls, the highest beds of the Keuper exposed. They have not been found in the *Bunter* in this district. The Liverpool Free Museum has lately acquired a slab from Storeton which shows some interesting forms; one, the largest about two inches long, is possibly of a chelonian. In the less perfect examples it is represented by an oval pad and four projecting points slightly removed from it on one side, but in more perfect examples it is seen that these are connected by toes with the pad, and that the projecting points are portions of strong curved claws. On the slab it is difficult to trace a regular series, but from measurements taken at the quarry from portions of the same bed the author found that the feet had a stride of about nine inches, whilst the width of the track—that is, between the line of impressions of the right foot and those of the left—was eight inches, indicating a broad-bodied animal. Another footprint well shown on the slab is much smaller, being about three-quarters of an inch long, and consists of three toes of nearly equal length—the middle one being the longest—and a very small toe on one side projecting from what appears to be the palmar portion of the foot. The three longer toes lie very closely together, and quite parallel, and often the print shows no division between them, and each terminates in a short sharp claw. This is the form described to the Geological Section by Mr. O. W. Jeffs at the Oxford meeting.[1] They are, perhaps, better shown on a slab from the same bed of

[1] *Brit. Assoc. Report*, 1894, p. 658.

rock in the museum of University College. The slab also has a profusion of the prints attributed to the Rhynchosaurus. The author has lately been endeavouring to classify under certain types the more common forms for the sake of facilitating reference; the results are given in his paper lately published.[1] Any one interested in the subject can see numerous examples in Liverpool Museum or at University College. But perhaps the most interesting collection is that at the Bootle Free Museum, where what are probably the type specimens described some sixty years ago are carefully preserved and well exhibited.

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3. *Recent Borings in the Red Marl, near Liverpool.* *By* G. H. Morton, *F.G.S.*

Boring in the Red Marl near Altcar, North of Liverpool.

During the years 1890–92 an important boring was made in the Red Marl, rather under a mile N.N.E. of Altcar, and nearly two miles east from Formby Station. Previous to 1890 the formation was supposed not to exceed 400 feet in thickness, the amount proved at Birkdale many years ago. The following is a section of the strata passed through, condensed from details for which I am indebted to Mr. E. Fidler, who was connected with the undertaking.

	Feet	Inches
Peat	5	0
Loam and sand	28	6
Boulder clay	16	0
Sand and marl	8	6
Red Marl	971	0
Keuper Sandstone	62	0
	1,091	0

The diamond boring machine was used, and the diameter of the bore-hole was 13 inches near the surface, 7 and 6 inches through most of the Red Marl, and 5 inches in the Keuper Sandstone. The dip of the strata was supposed to be a few degrees to the north-east, as determined by the cores brought up. The marl separated with thin laminæ, and the surfaces were often covered with pseudomorphic crystals of chloride of sodium from an eighth to an inch across, and they were most numerous in the middle and lowest beds. There were many seams of gypsum, which varied in thickness from a quarter of an inch to 3 or 4 inches, and a few diagonal cracks filled with the same mineral traversed the beds, and often contained fragments of marl and presented a brecciated appearance. The surfaces of the cores of gypsum exhibited pseudomorphs like those on the marl. Most of the marl was red, but sometimes a greenish grey, and the lower beds contained the tracks of annelids, which have been found on the same horizon in several other places in Lancashire and Cheshire. The Keuper Sandstone below the Red Marl was red and grey in colour, and there was an abrupt change from one formation to the other without any transitional strata between.

The object of the boring was to find brine or rock-salt, but it was unsuccessful, and the attempt was made in consequence of a tradition that prevails in the neighbourhood that salt water occurs below the surface. Mr. J. Dickinson, F.G.S., in his Parliamentary Report on 'The Salt Districts,' refers to a brine spring mentioned by Dr. Browning, and Baines, in his 'History of Lancashire,' states that it 'contained as much salt as that at Northwich.' Mr. Fidler informed me that, though salt water has been frequently found near the surface in various places in the district, fresh water was found on penetrating to a greater depth.

I am inclined to think that the salt water found about the surface of the country is in consequence of frequent floods from the sea in former years and the deposit of spray during storms. The wind carries the fine spray for many

[1] *Proc. Liv. Geol. Soc.*, 1896.

miles inland, and a film of salt has been found coating windows at a distance of twenty or thirty miles from the sea after storms, so that it is certain to impart a saltness to the soil over the land along the coast.

Boring in the Red Marl at Ford, on the West of Bidston Hill.

Another boring in the Red Marl has been in progress during the last two years on the east bank of the Fender, a brook running from south to north into the Birkett and finally into Wallasey Pool. The object of the boring was to obtain an additional supply of water for Birkenhead, and I am indebted to Mr. W. A. Richardson, C.E., for the following section of the strata passed through.

	Feet
Surface soil	1
Boulder clay	45
Sand and gravel	16
Red Marl	454
Keuper Sandstone	244
Fault rock	7
Upper Soft Sandstone of the Bunter	133
	900

The boring was made with a revolving iron disc with steel chisels, two feet in diameter, suspended by a flat rope; but the cores brought up were only 4 inches across, most of the rock having been broken into fragments, sand and clay. The cores showed that the strata were horizontal. The Red Marl was found to be much harder than usual, and principally composed of tough argillaceous sandstones and shales, nearly all of a red colour. Very little gypsum was found, and the entire absence of pseudomorphic crystals remarkable. It seems probable that the deposit was formed in deeper water than the Red Marl at Altcar.

At Greasby, a village two miles west of the boring, there are some beds, about two inches thick, containing small ramifying tube-like cavities from $\frac{1}{40}$ to $\frac{1}{60}$ inch in diameter. They have been supposed to be at the base of the Red Marl, but were found at several horizons in the boring, and evidently do not indicate the base, so that the beds at Greasby may be considerably above it. The Red Marl ended at the depth of 516 feet below the surface, so that deducting 62 feet for the superficial deposits the thickness is 454 feet, being about double the amount it was expected to be. There was an abrupt change from the Red Marl into the underlying Keuper Sandstone, which was penetrated to the depth of 244 feet, when a fault was crossed and the Upper Soft Sandstone of the Bunter proved to the depth of 133 feet.

The Geological Survey Map of the district (Sheet 79, N.E.) distinguishes the Red Marl from the 'Waterstones' at the base over the centre of Wirral, but it does not seem possible to have made such a distinction in South-west Lancashire, where both are included in the Red Marl. At Ford most of the marl is of an arenaceous character, while on the east of Liverpool the beds are softer and include more shale and clay. It seems, however, that the Keuper Sandstone in Wirral is of less thickness than it is under Liverpool, and that the upper beds there are represented by the 'Waterstones.'

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4. *Erosion of the Sea Coast of Wirral.* *By* G. H. Morton, *F.G.S.*

The oldest maps of the coast of Wirral, the north-western extremity of Cheshire, afford very little information on the exact outline of the coast in former years. It was not until the publication of the 6-inch map of the Ordnance Survey in 1880 that it became possible to make exact observations on the erosion of the coast. The late Sir James Picton, F.S.A., in 1846, was the first to direct attention to the waste of the land, but he had not made any personal investigation, and more recent writers on the subject have confined themselves to showing the incorrectness of some of his statements, rather than making original observations. The object of this paper is to record the result of close attention given to the subject for many years.

Half a mile south-west of the Leasowe Embankment, and about 100 yards from Seabank Cottages, there is an old weather-beaten brick and stone house, known as the 'Warren,' and evidently the oldest in the neighbourhood. According to the 6-inch Ordnance Map, the distance between the house and the sea was about 130 yards, when the country was surveyed in 1871, but I found it to be 70 yards in 1890, 55 yards in March 1894, and only 45 yards in May 1896, and the residents have shown me the position of several high sand-hills that once formed part of the lost land.

In an affidavit, filed in a recent case concerning the extension of the Embankment, George Banks states that he had been born and had lived in the house ever since. It was only 60 yards from high-water mark at spring tides in 1892, 'whereas when he first remembered it the house stood at least 350 yards from high-water mark at spring tides, and the land washed away included some sand-hills 30 and 40 feet, and one 50 or 60 feet in height.'

The greatest erosion by the sea along the coast has taken place at Dove Point, about 350 yards to the south-west of the house. In 1862 there were two 'perches' constructed of timber, one being 10 yards from the edge of the sand-hills, which were then about 12 feet high, and the other 150 yards behind, near the boundary of the inclosed land. The seaward Perch is shown in the frontispiece of the 'Geology around Liverpool.' On January 20, 1863, this Perch had become close to the edge of the cliff and fell down on the shore, its original position being indicated by several masses of masonry and large stones which had formed the foundation of the structure. The Perch was re-erected on the sand-hills, and is shown on the 6-inch map, but it was afterwards removed, with the one behind, to the north-east of the 'Warren,' so that neither of them is now in the place shown on the map. The foundation stones still lie on the shore in their original position. In consequence of the continual erosion by the sea the stones have gradually become further from the coast line, and in September 1894 the distance was 144 yards, showing the erosion of the coast from 1863 to 1894 to have been between 4 and 5 yards per annum. In May 1896 the distance had been increased to 152 yards, proving an erosion of 8 yards in 20 months, but as they included two winters the loss would be 4 yards per annum.

South of Dove Point the erosion gradually decreases, but 50 yards of the sand-hills have been washed away on the north-east of Sandhey, though not in recent years, as there is now a fringe of grass growing in the denuded bay for about 100 yards, when it gradually dies away. The grounds along the sea-front at Sandhey are protected by an embankment and groins, which arrest the encroachment of the sea. Beyond, in front of Hoylake, there is no erosion, and the Red Stones at Hilbre Point protect the land from the sea.

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5. *Oscillations in the Level of the Land as shown by the Buried River Valleys and later Deposits in the Neighbourhood of Liverpool.* By T. Mellard Reade, *F.G.S.*

The author, after describing the extensive post-Glacial deposits on the coasts of Lancashire and Cheshire, consisting of blown sand resting upon a peat- and forest-bed, which again rests upon scrobicularian clays and silts—the tree remains, consisting of stools of oak, Scotch fir, and birch rooted into the estuarine deposits—shows that the whole series rest upon an eroded surface of the low-level marine Boulder-clays and Sands, which again repose upon the Triassic rocks. The surface of the Trias, whether Bunter or Keuper, is worn into a system of hills and valleys which are largely obscured and filled up with Boulder-clay.

After a discussion of these facts the author concludes that they point to the existence of three land surfaces—the first in time being pre-Glacial or at least pre-Boulder-clay; the second, post-Glacial, represented by the buried eroded surface of the Boulder-clay, and the third by the peat- and forest-beds which run down to below low-water mark.

All these land surfaces represent periods when the land was higher relatively to the sea-level than at present, the deposits resting severally upon them representing each a period of depression when the land was relatively lower, as respects the sea, than at present.

It was pointed out that these indubitable earth-movements could not be accounted for on the principle of isostasy, or loading and unloading, nor could they be explained away by alterations of the sea-level, nor by subterranean denudation, and that we must therefore look for their explanation, not to external causes, but to forces acting over large areas and hidden deep down in the interior of the earth.

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6. *Tertiary Deposits in North Manxland.* *By* Alfred Bell.

After suggesting that local agencies were sufficient to account for the glacial phenomena in the centre and south of the island, the writer proceeds to give reasons in support of his proposition that the deposits in the north, instead of being, as usually supposed, of glacial origin, are really pre-Glacial, as he finds that there are no traces of till or a ground moraine, and that the clays throughout are to a large extent free from stony matter, except such as may have been due to floating ice, brought in after the shingle beach with Pliocene shells had been formed.

The shells he does not consider 'remanie,' but contemporaneous with the beach they occur in, and to belong to the same series of pre-Glacial deposits containing similar shells at Wexford, Aberdeen, and Iceland, of Weybourn Crag age, possibly an unopened chapter in Pliocene geology.

Not finding any shingle in the cliffs, he concludes that the rolled stones on the beach are far travelled, having no connection with the island deposits.

The list of shells is the first localised one of any of the deposits in the island, and is supplemented by notices of such species as were not personally collected by him at Shellag.

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7. *On the Occurrence of Sillimanite Gneisses in Central Anglesey.* *By* Edward Greenly, *F.G.S.*

The author records the occurrence of the mineral Sillimanite in certain gneisses and schists of Central Anglesey, which are traversed by great numbers of sills and thin bands of growth, often injected 'lit par lit.' There is an absence of chilled edges, the granite being quite coarse at the points of contact which have been observed. The whole series closely resembles that recently described in eastern Sutherland by Mr. J. Horne and the author, but it is also associated with the hornblendic gneisses, whose Hebridean or Lewisian aspect has been noted by Sir A. Geikie.

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8. *On Quartzite Lenticles in the Schists of South-eastern Anglesey.* *By* Edward Greenly, *F.G.S.*

The author describes the occurrence of numerous lenticles of quartzite in the chloritic schists of Beaumaris. They are generally from quarter of an inch to a foot in length, but four large masses also occur, of which the largest, the quartz-rock of Pen-y-parc, is a lenticle some 700 feet in length. These quartzite lenticles are ascribed to a cataclastic origin, the structures resembling on a large scale (except that the matrix is crystalline) those of the mylonites of the N.W. Highlands of Scotland. The author also compares them to the 'crush-conglomerates' of the Isle of Man. The whole series is probably due to the breaking down of a group of alternating shales and thin grits, containing also a few thick beds of quartzite. Their present condition furnishes evidence of the intensity of the earth-movements which have affected the schistose rocks of Anglesey.

FRIDAY, SEPTEMBER 18.

The following Papers and Report were read :—

1. *Pre-Cambrian Fossils.* *By* Sir WILLIAM DAWSON, *LL.D., F.R.S.*

The author stated that it was his object merely to introduce the specimens he proposed to exhibit by a few remarks rendered necessary by the present confusion in the classification of pre-Cambrian rocks. He would take those of Canada and Newfoundland as at present best known, and locally connected with the specimens in question.

He referred first to the 'Olenellus Zone,' and its equivalent in New Brunswick, the 'Protolenus Fauna' of Matthew, as at present constituting the base of the Cambrian and terminating downward in barren sandstone. This Lower Cambrian had in North America, according to Walcott, afforded 165 species, including all the leading types of the marine invertebrates.

Below the Olenellus Zone, Matthew had found in New Brunswick a thick series of red and greenish slates, with conglomerate at the base. It has afforded no Trilobites, but contains a few fossils referable with some doubts to Worms, Mollusks, Ostracods, Brachiopods, Cytideans, and Protozoa. It is regarded as equivalent to the Signal Hill and Random Sound Series of Murray and Howley in Newfoundland, and to the Kewenian, and the Chuar and Colorado Cañon Series of Walcott in the west. The latter contains laminated forms apparently similar to Cryptozoon of the Cambrian and Archæozoon of the Upper Laurentian.

The Etcheminian rests unconformably on the Huronian, a system for the most part of coarse clastic rocks with some igneous beds, but including slates, iron ores, and limestones, which contain worm-burrows, sponge-spicules, and laminated forms comparable with Cryptozoon and Eozoon. The Huronian, first defined by Logan and Murray in the Georgian Bay of Lake Huron, has been recognised in many other localities, both in the west and east of Canada and the United States; but has been designated by many other local names, and has been by some writers included, with the Etcheminian and sometimes with part of the Laurentian, in the scarcely defined 'Algonkian' group of the United States Geological Survey.

Below the Huronian is the Upper Laurentian or Grenville system, consisting of gneisses and schists (some of which, as Adams has shown, have the chemical composition of Palæozoic slates), along with iron ore, graphite, and apatite, and great bands of limestone, the whole evidently representing a long period of marine deposition, in an ocean whose bed was broken up and in part elevated before the production of the littoral clastics of the Huronian age. It is in one of the limestones of this system that, along with other possible fossils, the forms known as *Eozoon Canadense* have been found. The author did not propose to describe these remains, but merely to exhibit some microphotographs and slices illustrating their structure, referring to previous publications for details as to their characters and mode of occurrence.

Below the Grenvillian is the great thickness of Orthoclase gneiss of various textures, and alternating with bands of hornblende schist, constituting the Ottawa gneiss or Lower Laurentian of the Geological Survey. No limestones or indications of fossil remains have yet been found in this fundamental gneiss, which may be a truly primitive rock produced by aqueo-igneous or 'crenitic' action, before the commencement of regular sedimentation.

The author proposed, with Matthew, to regard the Etcheminian series and its equivalents as pre-Cambrian, but still Palæozoic; and, as suggested by himself many years ago, to classify the Huronian and Grenvillian as *Eozoic*, leaving the term Archæan to be applied to the Lower Laurentian gneiss, until it also shall have afforded some indications of the presence of life.

He insisted on the duty of palæontologists to give more attention to the pre-Cambrian rocks, in the hope of discovering connecting links with the Cambrian, and of finding the oceanic members of the Huronian, and less metamorphosed equivalents of the Upper Laurentian, and so of reaching backward to the actual beginning of life on our planet, should this prove to be attainable.

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2. *Some Features of the Early Cambrian Faunas.* *By* G. F. MATTHEW, *D.Sc., F.R.S.C.*

Trilobites.

The larval features of the early Cambrian Trilobites are chiefly referred to in this paper because in them we may look for points of structure which will appear in the adult condition of their predecessors.

The early Cambrian Brachiopoda and Ostrocoda are also briefly considered.

Except in Olenellus and its allies the larval forms of the earliest trilobites are little known; but in those of the Paradoxides beds a number of them belonging to different genera are known, so that in these we have fuller data for comparison.

The abundance and variety of trilobites in the Cambrian rocks are truly remarkable; and the flexibility of the type is indicated by the numerous genera that appeared successively in that early age. They thus become valuable in marking the divisions of these rocks, as the vertebrates do those of the Tertiary; and their remains enable us to recognise different parts of the Cambrian system with ease and certainty in all the regions around the Atlantic ocean.

This being the case, it may be profitable to examine the forms of the earliest Cambrian trilobites, and note how they compare with the larvæ of the trilobites of the Paradoxides beds. The law of development would lead us to expect that in the pre-Paradoxides faunas of the Cambrian certain features of the larval forms of the trilobites of the Paradoxides beds should appear as permanent adult features in their predecessors. And such is the case.

In 1892 Dr. J. Bergeron summed up the evidence on this point, derivable from the trilobites of the Paradoxides and Olenellus faunas, in his article, "Is the fauna called primordial the most ancient fauna?"[1] He utilised the studies of Barrande, Walcott, Ford, and others for this purpose, and his conclusion was that there must have been a more ancient fauna.

Discoveries of other faunas beside that of Olenellus, older than the Paradoxides beds, have been made since Bergeron wrote upon this subject, and we may now place his theory against some additional facts which bear upon it.

To make the application clearer, the author briefly presented some of the characteristics of the earliest larval stages of the trilobites of the Paradoxides beds, as shown in the young of Paradoxides, Ptychoparia, Conccoryphe, Microdiscus, and Agnostus. Among them are the following:—

1. Predominance of the cephalic over the caudal shield.
2. A long narrow glabella, with nearly parallel sides. In these early moults the posterior lobes of the axial rachis (which includes the glabella) are short and weak, as compared with the anterior, and especially the first.[2]
3. The eyes are absent; when they first appear they are near the lateral margin, and in several genera are elongated.
4. There are no movable cheeks; when these first appear they are narrow and marginal.
5. There is no thorax; this region begins with one segment, and in some genera never exceeds the number of 2 to 4. The pleuræ at first are short.
6. The pygidium at first is quite short and of one segment.

[1] *Revue générale des Sciences*, Paris, 1892.

[2] *Paradoxides* is apparently an exception to this rule, but we do not know its earliest stages.

Three local faunas, all older than Paradoxides, have been made known since Bergeron's paper was written. They all show more or less the increasing prevalence of larval features in the trilobites as we go back in time. J. C. Moberg has described a number of species from Sweden, including two species of Olenellus, in which some of the above larval characters are shown.

J. F. Pompeckj has just described a pre-Paradoxides fauna from Bohemia in which are a few trilobites that possess larval characters. Thus his Ptychoparia is referred to sub-genus Conocephalites, probably because it has a long eyelobe.[1] It is a primitive form with short pleuræ, if we may judge from the short posterior extension of the dorsal suture. His Solenopleura also differs from that genus in its long eyelobe and long glabella, but these also are larval features. Another species of Solenopleura, however, cited by Pompeckj, has shorter eyelobes.

It is the Protolenus fauna of the St. John group (Cambrian), however, which shows most decidedly larval traits in its adult trilobites.

Among these trilobites all (so far as their remains show it) have prolonged eyelobes, a peculiarity which marks the early Olenidæ. Many of them have long cylindrical glabellas, also a larval character. Many have a short posterior extension of the dorsal suture, indicating the primitive feature of short pleuræ. Many have small and weak pygidia; this is inferred from the rarity of this part of the organism in the collections preserved.

Protolenus (typical), which has a general resemblance to Paradoxides, differs from it in the absence of a clavate glabella, and the small anterior lobe of this part of the head-shield; but these are characters found in the larval stages of Paradoxides.

A genus of this fauna, although not as common as Protolenus, is Ellipsocephalus: this genus also abounds with Protaspian peculiarities.

Lastly, one may refer to the genus Micmacca, which has the following larval features, long cylindrical glabella, long eyelobes, short posterior extension of the dorsal suture. If Zacanthoides, of the middle Cambrian, were shorn of its long posterior extension of this suture and its long pleuræ, it would not differ greatly from Micmacca.

In the Olenellus fauna, also, are genera such as Olenellus, Protypus, Avalonia, and Olenelloides, which retain marked larval characters.

Brachiopoda.

If we turn our attention to the Brachiopoda, we note that they show a special development in the early Cambrian, different from that of the Paradoxides beds, and the later members of the Cambrian system.

The most notable feature is the large percentage of Obolidæ (including Siphonotretinæ). The older Cambrian holds in common with the Paradoxides beds, the small shells of Acrothele, Acrotreta, and Linnarssonia; but it also has a series of larger forms peculiar to it: such are Obolus, Botsfordia, Trematobolus and Siphonotreta of the Protolenus fauna, and Schizambon and Michwitzia of the Olenellus fauna. This great development of oboloid shells is not repeated until Ordovician time.

Not only are these old Cambrian faunas remarkable for the peculiar types of Brachiopods which they possess, but they are also notable for those they lack. A true Lingula has not been found, though Lingulella is a common genus.

The larval growths of Ordovician and Silurian Lingulæ carry us back to a form which is Oboloid. Thus in *L. quadrata*, *L. Howleyi*, &c., the cell is first circular as in Obolus, then oval as in *L. Quebecensis*, &c., and finally takes on the sub-quadrate form of the adult shell. But there is a more elementary form of the Brachiopod shell than the circular shell of Obolus: this is seen in Paterina and the young shell of Botsfordia, which is nearly semicircular. Both these shells come from beds that are older than Paradoxides.

[1] In the larval forms of Ptychoparia and Solenopleura of the Paradoxides beds, however, the eyelobe is short.

Ostracoda.

The Ostracoda also give us definite forms peculiar to the early Cambrian beds. Such are the types represented in Beyrichona and Hipponicharion; such also are those with flexible tests represented by Aluta. Other Ostracoda are present in more varied forms than in the Paradoxides beds.

To sum up these distinctive features of the animals of the earliest Cambrian faunas, we may say—

1. That the Trilobites retain larval characteristics to an unusual degree.
2. The Brachiopoda have a large percentage of Obolidæ.
3. The Ostracoda are plentiful and varied, and present some peculiar types.

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3. *Report on Life Zones in British Carboniferous Rocks.*
See Reports, p. 415.

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4. *The Range of Species in the Carboniferous Limestone of North Wales.* *By* G. H. Morton, *F.G.S.*

Attention having recently been directed to this subject, I have been induced to present the results of many years' collecting in the Carboniferous Limestone of North Wales. The formation there presents four well-defined subdivisions, each of them, with the exception of the highest, having distinct lithological characters, viz.—Lower Brown Limestone, Middle White Limestone, Upper Grey Limestone, and the Upper Black Limestone. Lists of the fossils have been made, collected more or less continuously along the country from each subdivision.

In North Wales the occurrence and succession of the species in the subdivisions vary in different areas, and the larger the area examined the more difficult it becomes to find species peculiar to certain horizons. In order to obtain a definite result, I have compiled three separate lists of the species obtained in that number of distinct areas. There are the Llangollen, the Flintshire, and the Vale of Clwyd Lists. Each of the lists shows the relative scarcity and abundance, and the range of the species in the subdivisions; and although future search will doubtless add to the rare and occasional species, the number and range of the common and very common must be very nearly correct. Neither the rare nor the occasional species are of much use in defining distinct horizons in consequence of their rarity, and it is only the common and very common species that can be expected to indicate a definite horizon or zone. In North Wales a great difficulty arises from the occurrence of all the common and very common species in the Upper Grey Limestone, with the exception of *Productus comoides*, and although all pass downwards, they become scarce in consequence of the general paucity of fossils in the inferior subdivisions.

In the Llangollen List there are 69 rare, 28 occasional, 16 common, and 27 very common species. Deducting Foraminifera, which are not in the other lists, there are 36 species that are common and very common, and they all occur in the Upper Grey Limestone, with the exception of *Posidonomya Gibsoni* from higher strata, and *Productus comoides* in the Lower Brown Limestone, all the other species in the list being rare and occasional forms.

In the Flintshire List there are 92 rare, 35 occasional, 30 common, and 11 very common species, and of the 41 common and very common, 37 species occur in the Upper Grey Limestone, 4 of the remaining species, *Posidonomya Becheri*, *Aviculopecten granosus*, and *A. papyraceus* occurring in the Upper Black Limestone, and *Productus comoides* in the Lower Brown Limestone.

In the Vale of Clwyd List, which includes the Great Orme's Head, there are 16 rare, 22 occasional, 12 common, and 10 very common species; and of the 22 common and very common, 21 species occur in the Upper Grey Limestone, the exceptional species being *Productus comoides*. None of the 21 species are peculiar to the subdivision, for they all occur in the underlying Middle White Limestone. The number in the list is less than in the others, on account of the Upper Grey Limestone having been considerably denuded in the Vale of Clwyd.

Nearly the whole of the common and very common fossils occur in each of the three lists, for there are few that are not found in all the areas.

Of the numerous common and very common species found in the Carboniferous Limestone of North Wales, it is impossible to find any that are restricted to horizons of less importance than the subdivisions into which the formation is naturally divided. An examination of the first appearance and continuity of the species seems to indicate that they were introduced from some pre-existing area, and that the upper beds of the formation are more recent than in Derbyshire and Yorkshire, where the thickness of the Limestone is very much greater.

The sudden appearance of species in restricted areas, like those found in the Upper Grey Limestone at Axton, in Flintshire, where 20 species occur, and at Graig-fawr, in the Middle White Limestone, where 6 species occur, not found elsewhere in North Wales; and the early appearance of 3 species in beds of black limestone and shale at the base of the Middle White Limestone at the Great Orme's Head seem to indicate migration from some other area. The latter species are *Orthis Michelina*, *Spirifera humerosa*, and *S. rotundata*. *Spirifera humerosa* had only been previously found at Llangollen and in Flintshire, while *S. rotundata* is rare in North Wales; but none of the 3 species had been previously found at a lower horizon than the Upper Grey Limestone. *Productus giganteus* first appears in the Lower Brown Limestone, and very large specimens occur within 50 feet from the base at Moel Hiraddug, a few miles from Rhyl. The species occur all through the Carboniferous Limestone, and thousands may be seen in the Upper Grey Limestone.

In this paper the range of the species found is confined to North Wales, but when the subdivisions of the Carboniferous Limestone in other parts of the country are worked out, and the species from each tabulated, it will be interesting to compare the result with that obtained in North Wales.

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5. *On the Source of Lava.* *By* J. LOGAN LOBLEY, *F.G.S., Professor of Astronomy and Physiography, City of London College.*

The object of this paper, which was illustrated by diagrams, was to show that small columns of lava cannot pass through thirty miles of earth crust, and that therefore the source of lava cannot be at that distance from the surface, as is so often assumed.

The reasons adduced were:

First, that from the pressure of overlying rocks there can be no fissures giving a passage to lava below ten miles from the surface, since this pressure, much greater than the crushing weight of rocks, would cause lateral extension where possible.

Secondly, if even a way were open, lava rising from a source thirty miles deep, would by contact with cooler rock masses lose its fluidity at twenty miles from the surface. The temperature of lava at its source cannot be very much greater than that of the contiguous solid rocks, and lava would lose heat continuously and increasingly as it ascended the volcanic conduit. The temperature at twenty miles below the surface is much under rock-fusion temperature, and the lava-columns giving small or even moderate emissions are so insignificant in volume that they would there be so cooled as to solidify. Estimates of the volume of lava-columns were given in illustration; and it was further shown that a column of lava 300 feet in diameter and thirty miles high would require a dynamic force of 820,800,000 tons to sustain it even without ejection.

The author's conclusion is that lava is not derived from[1] a central source, but

[1] *Brit. Assoc. Report*, 1888, p. 670.

that, in accordance with his previously stated hypothesis, by combined physical and chemical action rocks are fused and lava produced within the outer rind of the globe of ten miles in thickness.

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6. *On the Post-Cambrian Shrinkage of the Globe.* *By* J. LOGAN LOBLEY, *F.G.S., Professor of Astronomy and Physiography, City of London College.*

The author, having previously shown that a shrinkage of the globe sufficient to produce the rock-foldings of post-Cambrian times would require an interior temperature previous to the shrinkage 5,000° F. higher than now,[1] in the present paper gave his reasons for concluding that such a temperature of the interior mass of the globe would give a surface temperature that would render impossible those geological agencies of erosion and sedimentation which the Cambrian strata show to have been in full operation when those rocks were formed.

Calculations founded on the British Association rate of increase of underground temperature, both on the supposition of a solid globe and of one with a fused interior, showed that with an increase of 5,000° F. the surface temperature would be very much above the critical point of water, the existence of which on the surface would be thereby rendered impossible.

It was further shown that if the author's estimate of the increase of internal temperature required is too high, and only 1,000° F. increase be allowed for the interior heat in Cambrian times, the surface temperature would even then be quite incompatible with known Cambrian conditions.

The author's conclusion is that since Cambrian times there has been no appreciable loss of planetary heat, and consequently no appreciable shrinkage of the globe; and that therefore another explanation must be found for rock-crushing, rock-folding, elevations, and subsidences of land areas, the uprise and issue of lava and of seismic phenomena.

A table was appended showing the temperature of isogeotherms for every mile of thickness of an earth-crust of thirty miles, with a base temperature of 3,700° F.

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7. *On the Cause of the Bathymetric Limit of Pteropod Ooze.* *By* PERCY F. KENDALL, *F.G.S.*

Preliminary.—Two forms of carbonate of lime are known to the mineralogist, viz., Aragonite, rhombic, sp. gr. 2·93, H. = 3·5 – 4, and Calcite, hexagonal (rhombohedral), sp. gr. 2·72, H. = 2·5 – 3·5. The former can be prepared artificially by precipitation from a *hot* solution (90° C.), while the latter is precipitated at all lower temperatures. Both forms occur in organic structures, and it is found that Aragonite structures when deprived of animal matter are opaque, while Calcite structures are translucent. There is no perceptible difference in solubility between the two mineral species when dealt with in powder or when of inorganic origin; but in porous formations of every geological age it is found that Aragonite shells, of whatever thickness, disappear by solution before thin and delicate Calcite shells of Foraminifera and Polyzoa are even sensibly affected. It is probable that Aragonite is penetrated by extremely slender fibrillæ of organic matter, whose removal produces the characteristic opacity.

Solvent action of sea-water.—Sea-water exercises a solvent action upon calcareous bodies, especially upon and about coral reefs and in the profound depths. The solvent is almost certainly carbonic acid disengaged from decomposing organic matter. The 'Challenger' observations show that carbonic acid is present in great abundance in the bottom water at great depths; it is further known that solution is rendered much more rapid by the immense pressures prevailing in deep water.

[1] *Report of the British Association for the Advancement of Science*, Oxford Meeting, 1894, p. 649.

It follows from this that the calcareous parts of the inhabitants of the '*benthos*' would be liable to solution during life, unless (*a*) they were protected by the flesh of the animal or by epidermis, or (*b*) they consisted of Calcite.

The deep-sea mollusca are mainly composed of Aragonite, but they generally have an extremely thick epidermis. The deep-sea calcareous corals are almost exclusively simple forms, and the lower portion of stony structure is gradually left bare as the creature grows. All the forms examined by the author, *e.g.*, Caryophyllia, Parasmilia, Cyclocyathus, Stephanophyllia,[1] are of Calcite, whereas nearly all reef-building Actinozoa produce Aragonite structures.

The effects of solution upon the nature and distribution of deep-sea deposits.—Deep-sea deposits are mainly derived from two sources: (*a*) land detritus and volcanic ejecta carried seaward by currents; (*b*) remains of free-swimming pelagic organisms. Inshore the deposits usually contain a large percentage of detrital materials, while towards the deep the organic remains tend to preponderate. As the water deepens another factor, solution, comes into play, and the calcareous elements of the deposits are progressively removed by solution. The solution is, according to Murray, Agassiz, and others, effected in part during the slow sinking of surface organisms, and in part while lying upon the floor of the ocean. Agassiz assigns the greater importance to solution during descent, but the fact recorded by him, that 'the more numerous the shells are in the surface waters, the greater is the depth at which they will accumulate at the bottom,' seems to show that solution at the bottom is very considerable. In the profoundest depths the deposits consist almost wholly of non-calcareous materials. Two principal calcareous deposits occur below 500 fathoms, viz., *Globigerina ooze*, which covers 49½ million square miles of the ocean floor and has a bathymetric range from 400 to 2,925 fathoms, and *Pteropod ooze*, which is a Globigerina ooze characterised by the presence of a large number of shells of Pteropods and Heteropods. It occurs only where the surface waters are warm, and hence is limited to tropical and subtropical regions. It covers an area of 400,000 square miles, and ranges in depth from 395 fathoms to 1,525 fathoms, below which the Pteropod shells disappear, leaving a normal Globigerina ooze. It is generally agreed that the limitation in depth of the Pteropod remains is due to solution, for the living Pteropods swarm over the surface in prodigious numbers, whatever be the depths below.

Agassiz succinctly states the facts as follows: 'The Pteropod and Heteropod shells are the first to disappear from deposits, then the more delicate surface Foraminifera, and finally the larger and heavier ones.' The fact that these relatively large shells wholly disappear by solution under conditions that the minute Foraminifera survive is beyond doubt, and demands explanation. Several explanations have been proposed. Fuchs in 1877 suggested that Globigerina might be composed of Calcite and the Pteropods of Aragonite, and the author independently made the same suggestion. Dr. Murray and the Abbé Renard, however, rejected that hypothesis, and considered that the Globigerina survived by reason of their greater thickness.

The author, with the assistance of Mr. Albert Jowett, a student in the Geological Laboratory of the Yorkshire College, has made a number of determinations of the relative thickness of Globigerina and Orbulina, the most characteristic Foraminifera of the deep-sea oozes and of Styliola and Cavolinia as representing the Pteropods. He failed to find any such difference of thickness as would account for the much greater durability of the Foraminifera, the range of thickness of the two classes being practically identical. It may be represented by the numbers 2–6·5 in each case.

The mineral constitution was also successfully determined. Prof. W. J. Sollas determined the sp. gr. of Globigerina by an extremely ingenious adaptation of heavy solutions to be approximately that of Calcite. This has been confirmed by the author, who has also obtained a uniaxial optical figure from specimens of Orbulina, showing that the low sp. gr. is due to Calcite constitution, and not to the presence of animal matter.

[1] These are corals of deep-sea types from the Cretaceous rocks.

Similar tests were applied to the Pteropods *Cavolinia* and *Stiliola*. No completely satisfactory optical figure could be obtained, though the optical test seemed to indicate a biaxial substance (Aragonite); but the sp. gr. determinations many times repeated were conclusive that those Pteropod-genera are Aragonite.

Conclusions:—1. The effect of difference of thickness of calcareous shells upon their rate of solution is quite insignificant in comparison with that of difference of mineral constitution; thus in the Coralline Crag shells of *Voluta* and *Cyprina* (Aragonite), a third of an inch thick, have been quite removed, while the delicate Polyzoa (Calcite) which encrusted them are perfectly preserved, together with remains of Vitreous Foraminifera (Calcite).

2. There is no noteworthy difference in thickness between the Pteropods and Globigerinæ.

3. Pteropod-shells consist of Aragonite, while Globigerina and all other Vitreous Foraminifera examined are composed of Calcite.

4. The disappearance of Pteropods at 1,500 fathoms, while the Globigerinæ extend to 2,925 fathoms, is due to the mineral character of the shells, and not to their thickness.

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8. *On the Conditions under which the Upper Chalk was deposited.* *By* PERCY F. KENDALL, *F.G.S.*

Attempts to determine the approximate depth of the Chalk sea from the comparison of the Cretaceous fauna with the Molluscan inhabitants of the existing seas are unsatisfactory, because there are no grounds for the belief that the low temperatures at present found in the ocean depths prevailed in Cretaceous times; hence temperature did not limit distribution to the extent that it does now.

Solution dependent upon the depth of water would, however, act as it does in existing seas, and the author has applied certain principles stated in another paper read before the Section to the case of the Upper Chalk.

Calcareous organisms consist in some cases of aragonite, and in others of calcite. Aragonite in organic structures is so much more soluble than calcite (though of identical chemical composition) that gigantic aragonite shells may be completely dissolved, while calcite Foraminifera exposed to exactly the same conditions remain perfectly preserved.

The distribution in depth of the Pteropod Ooze of the tropical seas indicates the depth at which slender aragonite shells are dissolved. Pteropods swarm in the surface waters in such numbers that the sea is literally thick with them, yet, being composed of aragonite, their remains practically disappear from the oozes in depths exceeding 1,500 fathoms, and only sporadic examples are met with. The remains of globigerinæ, which live side by side with the pteropods, survive by virtue of their calcite composition down to 2,925 fathoms, nearly twice the depth. These facts seem to show that 1,500 fathoms is the depth at which the more delicate aragonite shells yield to solution.

Turning to the Upper Chalk, we find that all aragonite structures, large and small, have been wholly dissolved away, while calcite Foraminifera and Polyzoa are well preserved and retain their fine markings.

The question arises, When did the solution take place? To this we may answer with some confidence that it has been effected mainly prior to consolidation, for chalk is a rock which takes and preserves impressions remarkably well; yet casts of aragonite shells are extremely rare, and are almost invariably of large and robust shells. The Cephalopods furnish the best illustrations of these facts; the phragmocone of *Belemnitella mucronata*, an aragonite structure, has never been found in this country, though the guards (calcite) occur by thousands. If the solution of the phragmocones had taken place subsequently to deposition, empty alveoli would be found; but in no case has the author seen a Belemnitella in this condition, but always with the alveolus filled with chalk.

Casts of Ammonites (aragonite) are very rare in the Upper Chalk, such as occur being usually of very large size, but the Aptychi (calcite) of small species are occasionally found well preserved. Many considerations render it probable that the consolidation of the chalk took place concurrently with deposition; for example, bands of rolled nodules of chalk occur at varions horizons, and the same is probably the case with the Globigerina ooze of the existing oceans, for the 'Challenger' dredged nodules of hardened ooze from a depth of 1,700 fathoms.

The author concludes that the Upper Chalk was probably deposited in a depth of at least 1,500 fathoms, a conclusion which Dr. Hume and Mr. Jukes Browne appear to have reached by entirely different methods.

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9. *The Highwood Mountains of Montana and Magmatic Differentiation. A Criticism.* *By* H. J. Johnston-Lavis, *M.D., F.G.S., &c.*

The author brings forward a new interpretation of the facts described by Messrs. W. H. Weed and L. V. Pirrsson ('Bull. Geol. Soc.,' America, vol. vi. pp. 389–422, pts. 24–26) in their account of the remarkably interesting volcanic region of the Highwood mountains, with reference, more especially, to Square Butte.

This mountain they show to be a dismantled laccolite intrusion into Cretaceous sandstones. The peripheral part of this intrusion is composed of a dark basic rock, that they call shonkinite, containing about 47 per cent. of silica, poor in alumina and alkalies, but rich in iron, lime, and magnesia. The core is composed of a white syenite containing about 57 per cent. of silica, is rich in alumina and alkalies, but poor in iron and alkaline earths. The authors conclude, therefore, that this is a case of magmatic differentiation in which the bases have concentrated to the sides by a process of diffusion or liquation.

The author suggests that what really took place at Square Butte was as follows: In the first stage a conduit containing a paste sensibly approaching the syenite in composition was injected into the Jurassic and other basic sedimentary rocks subjacent to the Cretaceous sandstone, which forms a more superficial part of the original country. Here the upper intratelluric portion of the intrusion underwent basification by interosmotic action with the conduit walls. In the second stage this, now shonkinite, paste or magma was pushed on and formed a blister or laccolite in the sandstone smaller than the complete one of Square Butte. This, having undergone partial lapidification and becoming highly viscous, was in turn pushed up and aside by the intrusion of the syenite. This latter paste had probably remained a shorter time in the conduit, the walls of which had already been in part exhausted in osmotic interchange or diffusion by the earlier batch of paste that had remained in contact with them, and had been so basified to the composition of shonkinite. In consequence of this the second batch, which formed the syenite mass, was less or entirely unchanged in composition.

The peculiar plate-like structure of the peripheral portion, which is erroneously attributed by the authors to cracking, set up parallel to the isotherms of cooling, is, in fact, evidence of shearing planes or fluxion structure in a viscous mass the homogeneity of which was not perfect at the time of its being stretched over the uprising boss of syenite. The phenomenon is met with in domes of all viscid magmas, and is beautifully shown in the island of Basiluzzo; the writer suggests that the cleavage of gneiss, forming mantles to granite intrusions, may have also so arisen.

The partial fusion together of the shonkinite and syenite shows that the former was yet very hot, as indicated by the plasticity that must have existed to allow of the formation of the concentric shear-planes referred to. Had the shonkinite not been to some extent plastic it would have been more fractured, and fragments of it would have become enveloped in the syenite.

The shonkinite, however, was in that state of which the author first showed the important bearing in volcanic rocks, and which may conveniently be called *viscous inertia*, in which a viscous body responds instantaneously to a shock as if it were a solid. The shonkinite, although plastic, was at such a critical point that when it was suddenly stretched out over the back of the new syenite intrusion it cracked, and, syenite being injected, the white band described by the authors was produced in exactly the situation one would have expected to have found it.

The plate structure of this white band being continuous with that of the inclosing shonkinite is not an objection to its dyke-like nature, for there are several ways in which such cleavage may be developed.

At any rate the presence of this white band is quite inexplicable on the '*segregation*' or 'liquation' hypothesis, and is the insurmountable obstacle to the acceptance of Messrs. Weed's and Pirrsson's generalisations as to magmatic differentiation.

SATURDAY, SEPTEMBER 19.

The following Papers and Reports were read:—

1. *The Depths of the Sea in Past Epochs.* *By* E. B. WETHERED, *F.G.S.*

The author referred to the teachings of Hutton that the past history of our planet is to be explained by what we see going on at the present time. Till the reports of the 'Challenger' Expedition were published our knowledge of the 'depths of the sea' was very meagre, and the teachings of Hutton could not be applied for want of this knowledge. After reading the report on 'Deep Sea Deposits,' by Mr. Murray, it occurred to the author that it would be of interest to study in detail the 'Depths of the Sea in Past Epochs,' so far as possible, by a microscopic examination of limestones which contain what is preserved of the fauna of the sea in which these rocks were formed, and thus to further test the teachings of Hutton.

The author has, however, only accomplished a small part of the work indicated, and in this paper he only gives an outline of his investigations so far done.

Commencing with the Wenlock Limestone of the Silurian system, the author referred to the leading fossils, and remarked on the very fragmentary condition of the calcareous remains which have contributed to the building up of this limestone. Judging by the high percentage of detrital matter in the rock, in one bed amounting to 30·4 per cent., he thinks that land was not far off, and therefore the shells and skeletons of marine creatures may have been subjected to the action of waves, which would account for the fragmentary condition in which they were finally deposited on the floor of the sea.

Reference was next made to the work of encrusting organisms which had not been pointed out prior to the author's researches. In some beds of the Wenlock Limestone the majority of the organic calcareous fragments are partially or entirely inclosed by a crust which was the work of the little-understood genus *Girvanella.* This organism consists of a minute calcareous tube, as small as ·01 of a millim. in diameter, with well-defined walls. So important has been the work of this tubular form of life that the crusts produced by the growth and multiplication of the tubules have in some cases become the chief factor in building up beds of limestone.

Passing to the Carboniferous period, the author referred to the known fact that mollusca, corals, crinoids, polyzoa, &c., were very numerous in the sea of this epoch, and their shells and skeletons have contributed to the calcareous deposits which accumulated on the floor of the Carboniferous sea, which deposits are now known as the Carboniferous Limestone. It is, however, an error to suppose that the remains of these creatures were the chief constituents of the calcareous deposits in the depths of the Carboniferous sea. If the great central mass of the Carboniferous Limestone be examined microscopically, it will be found that the tests of microscopic life form the material with which this strata has been built up. Indeed, microscopic life must have been quite as abundant in Carboniferous waters as it was in the sea in which the chalk was formed, and not unlike what we find at the present time. We know that the chalk is largely built up of the remains of Foraminifera, and the calcareous ooze drawn up from the Atlantic has been proved to be full of the tests of Foraminifera associated with other organisms. This is deeply interesting, but it is at least equally so to know that in Palæozoic seas the condition of things was similar. The chalk has been spoken of as the Cretaceous equivalent of the calcareous ooze drawn up from the Atlantic of to-day, but the Carboniferous Limestone is very much older chalk.

Another microscopic form of life which existed in great profusion on the floor of the Carboniferous sea is the remarkable genus *Calcisphæra.* It consists of a hollow calcareous sphere averaging in diameter about ·004 of an inch, and when cut in section has the appearance of a ring. In such numbers did this spherical object exist that we could scarcely section a small piece of limestone from the middle series of the Carboniferous Limestone without finding several specimens or fragments of Calcisphæra.

The author next referred to the encrusting organisms which lived in the Carboniferous sea. The work was similar to that described in the Wenlock sea, and to such an extent had the encrusting been carried on that some beds of the Carboniferous Limestone are practically built up of the minute sphericles so produced. As, too, in the case of the Wenlock sea, the encrusting process was chiefly done by the genus *Girvanella,* but there was also another encrusting organism at this period, namely, the genus *Mitcheldeania,* which was a more complicated form of life compared with *Girvanella.*

Passing to the Oolitic system of the Jurassic period, the author pointed to the profusion of marine life which existed, but the point of interest to which he desired to especially refer was the formation of the oolitic granules, of which these rocks were chiefly constructed.

Up to the time of the author's investigations these granules were regarded as chemical concretions, but in the 'Geological Magazine' of 1889 he showed that the larger types of oolitic granules, known as Pisolite, were not concretions but the work of organisms. He has since been forced to the conclusion that this organic origin applies to all oolitic granules, large and small.

The author then referred back to the encrusting processes which took place on the floor of the Wenlock and Carboniferous seas for the purpose of pointing out that the granules so formed were really oolitic granules. In the Jurassic Oolite sea, however, the encrusting organisms had greatly increased, and they have been the chief builders of the oolitic rocks. The process was briefly this.

As the fragmental remains of calcareous organisms settled on the floor of the sea they were seized hold of, so to speak, by the encrusting organisms which gradually inclosed them. At times nearly every fragment was so captured, and became the nucleus for the encrusting growth; in this way the Jurassic freestones were constructed.

Further proof of the organic origin of oolitic granules has been produced by Rathplatz, who has shown that oolitic granules collected on the shores of the Red Sea and Great Salt Lake are the work of calcareous algæ. This again bears out the truth of Hutton's statements, that we are to understand the past by the present.

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2. *The Rippling of Sand.* By VAUGHAN CORNISH.

The author distinguishes three principal kinds of rippled sand, viz.—

1. The Ripple Mark of Sea.
2. The Ripple Mark of Streams.
3. The Ripple Mark of Dunes.

In (1) symmetrical, knife-edged ridges are built up, owing, as is well known, to the complete reversal of the current at short intervals, which results in an effective co-operation of the direct current with the vortex formed in the lee of projections of the rough surface of the sand. This mechanism in the vertical plane raises the ridges, and, in plan, extends them laterally, so that the mottled surface of the initial stage is changed into long lines of parallel ridge and furrow.

If the direction of the waves changes another set of ridges is formed, and this produces polygonal figures. These have an even number of sides, and the sides are arranged in opposing pairs. This serves to discriminate hexagonal forms due to fossil ripple mark from Hitchcock's supposed fossil tadpole-nests.

2. The symmetrical, rounded, ripple-mark of the sandy bottom of a stream is formed by the alternate acceleration and retardation of current which occurs wherever the surface of the water is corrugated by a train of standing waves. This form has been called Ripple Drift. The ridges only travel when the whole train of water-waves travels; when the train of waves arises from a *fixed* obstacle the sand ridges are stationary; where, however, there is much sedimentation of floating sand, the weather slope receives most of the sand shower, and the ridges travel *upstream*.

3. The Ripple Mark of Dunes is produced when sand grains roll before the wind. These ripples are not symmetrical, but they preserve their sectional shape during their growth, the height and length increasing in the same proportion. They grow laterally in the same way as (1). They are produced by the steadiest natural wind, and by a steady artificial blast even the resistance offered by the sand grains being sufficient to produce in yielding air a periodic motion such as must be independently produced in water for the formation of the regular ripple mark of sea or stream. Flying-sand falling upon the surface of a sand-dune blurs the pattern of the ripples; but if the shower be not too thick the grains are soon sorted into position as they roll.

3. *Are there Fossil Deserts?* *By* Professor Dr. JOHANNES WALTHER.

If we accept the postulate of Lyell, that the phenomena of former periods must be explained by the existing phenomena of our earth, we must look around to find the regions over which transported material is deposited. It is well known that on the bottom of the seas and lakes the transporting action comes to an end, and that no material is carried out of them. Therefore it is the opinion of most geologists that the greater part of our sedimentary rocks were deposited from water. The author has spent much time in travelling, for the sake of studying the areas occupied by deserts, and finds that, besides the old sea and lake bottoms, there is a large area of no drainage in the existing deserts.

On our globe there is a harmonious system of climatic zones. The largest of these is the tropical zone, which forms more than half the surface of the earth. The smallest area is the polar regions, which contain only one-eighth of the earth's surface. Between these are intercalated in each hemisphere a temperate zone, and a zone of desert, arranged quite symmetrically. By the postulate of Lyell we must believe that similar deserts must have existed in the past. The investigation of these ancient wastes is a problem not yet worked out.

4. *Notes on the Ancient Rocks of Charnwood Forest.* *By* W. W. WATTS, *M.A.*, *F.G.S.*

[Communicated by permission of the Director-General of the Geological Survey.]

In the course of the re-survey of sheet 155 for the Geological Survey, the author was instructed to examine the ancient rocks of Charnwood Forest. The boundaries dividing these rocks from the Carboniferous, Triassic, and Plutonic rocks had already been mapped by his colleague Mr. Fox Strangways, who had also determined with much accuracy the position and general character of all the exposures of the older rocks. It was merely left to the author to endeavour to get out the succession and structure of these older rocks.

The ancient rocks of Charnwood Forest appear in isolated spots, sometimes of considerable size, through the Trias of the Midland Plain. The oldest rock in contact with them is the Carboniferous Limestone of Grace Dieu, which is dolomitised. Evidence as to their exact age cannot, therefore, be obtained from superposition.

They clearly existed as islands in the Triassic and Carboniferous seas, and most probably stood up as mountains on the land in Old Red Sandstone times. The Trias runs up into the hollows and valleys of the old rocks, and from the small amount of débris which extends beyond the margins of the masses it is obvious that the smaller of these at any rate have been uncovered at a time geologically very recent. Their features are not those of the present day, but date dack partly to the subaërial denudation of Old Red Sandstone and probably earlier times, and partly to the aqueous denudation of Carboniferous and Triassic times. This is the reason for the peculiar character of the surface features presented by the old rock; escarpments are practically absent, hard beds are cut off abruptly, the rocks strike across the ridges, and the landscape generally is not of the usual subaërial character. Present-day denudation, by clearing out the Triassic débris, has done little more than expose to-day a pre-Triassic landscape.

The ancient rocks themselves may be classified as follows, in descending order:—

Swithland and Groby slates	The Brand series.
Conglomerate and Quartzite	
Purple and green beds	
The olive hornstones of Bradgate	The Maplewell series.
The Woodhouse beds	
Slate Agglomerate of Roecliffe	
Hornstones of Beacon Hill	
Felsitic Agglomerate	
Rocks of Blackbrook	The Blackbrook series.

This general succession corresponds with that made out by Messrs. Hill and Bonney, with whose observations the author is in substantial agreement.

These divisions sweep round the semidome, which is exposed; it is elongated from N.W. to S.E., and broken by several longitudinal faults in the same direction. Probably there are some cross faults as well.

The succession is most easily made out in the eastern side of the anticline, but even here the details are very much complicated, and it is not possible to trace some of the beds for any considerable distance, although the general succession seems quite clear. As Messrs. Bonney and Hill pointed out, the two agglomerates form a most useful index, and one which can be traced for a great part of the way round the Forest. The same may be said of the Beacon Hill beds and of the Brand series.

The bulk of the rocks are made of volcanic ingredients, even the fine hornstones and slates being made of volcanic dust, interleaved with tuffs and breccias. When the lower part of the Maplewell series is traced round to the north-west it becomes coarser, and eventually passes into a mass of very coarse agglomerates in which the succession is not easy to unravel, while it is much confused by faulting and the intrusion of igneous rocks, possibly also by the outflow of lava.

Bardon Hill presents exceptional difficulties. While the chief rocks are like those of Grace Dieu, Cademan, and Whitwick, it lies altogether out of the line of these rocks, and must owe its position to faulting. The agglomerates are also associated with a mass of porphyroid like that which occurs in a normal position at Peldar Tor and High Sharpley. At Bardon this rock appears to be intrusive into the agglomerates, and a similar explanation may have to be adopted for Sharpley, Peldar, and Ratchet. Many difficulties would still have to be met, not the least of which is the occurrence of boulders of Peldar rock in some of the agglomerates. A possible explanation of this is found at High Sharpley, where porphyroid, which is now acknowledged to be either an intrusion or a lava, is nodular in structure; it has been subsequently sheared so as to put on the aspect of an agglomerate.

The porphyroid would appear to have been the first rock intruded before much movement had taken place in the rocks; it is sheared, cleaved, and crushed along the N.W. and S.F. lines.

Syenite was next intruded, generally along the main movement planes such as faults, and the junction of the Brand series with the Maplewell series. It has been somewhat crushed by the movement, and its main divisional planes agree with the cleavage and faulting directions in the country.

A still later intrusion appears to be the Mount Sorrel granite, which does not penetrate into the Forest proper while it is in contact with rocks whose relation to the rest of the Forest has not been ascertained with certainty. It is the only igneous rock which effects any considerable amount of metamorphism in the clastic rocks with which it is in contact.

As to the age of the rocks we have little to guide us. They are unlikely to be later than Cambrian; they are not at all like the fossiliferous Cambrian rocks of Nuneaton; they do not contain Cambrian fossils, nor do the Nuneaton diorites penetrate them. On the other hand, the movement by which they were affected came from the direction S.W. to N.E., whilst Lower Silurian and Cambrian rocks are generally, except at Nuneaton, affected by forces which acted at right angles to this.

Professor Lapworth, when with the author in Charnwood, succeeded in finding a worm burrow in the slates low down in the Brand series, and Mr. Rhodes has since obtained one or two additional examples: these are the first undoubted fossils found in Charnwood.

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5. *The Geology of Skomer Island.*
By F. T. Howard, *M.A., F.G.S., and* E. W. Small, *M.A., B.Sc., F.G.S.*

I. *Previous Literature.*—De la Beche (in 'Trans. Geol. Soc.,' 2nd series, vol. ii.) mentions the presence of a 'quartzose and striped cornean,' of 'bedded greenstone,' and 'massive compact greenstone.' Murchison (Silurian system) gives a section across part of the island, and indicates the occurrence of Upper Cambrian rocks. Rutley and Teall have described the microscopic characters of some of the rocks, but none of these authorities gives exact localities, or describes the relationship of the different beds.

II. *General Character and Arrangement of the Sedimentary and Igneous Rocks.*—The general strike of the beds is more or less east and west, with a southerly dip. A well-marked ridge of felsitic conglomerate running from the west side of the Wick in an east by north direction to the north of Welsh Way serves as a convenient base line; beneath it are finer conglomerates, sandstones rich in felspar, and red shales; above it finer beds occur to the south, faulted against basalt in the Wick, conformably passing beneath the basalt at High Cliff. This basalt forms the southern promontory of the island except near the Mewstone, where quartz grits occur. Beneath the conglomerate, between the Wick and Tom's House, a very coarse breccia occurs, resting upon and derived from a highly siliceous banded and spherulitic felsite, which weathers white and shows spherules up to several inches in diameter. This appears to be the felsite described by Rutley, and is probably the striped quartzose cornean of De la Beche. In the cove west of Tom's House a basalt appears to pass quite regularly beneath the felsite. Massive and thinly bedded basalts follow to the north, but in Pigstone Bay thin felsites, grits, and shales are seen, and a conglomerate of basalt and felsite fragments resting upon an uneven floor of basalt. The section here shows clearly the interbedded character of the igneous rocks. North of Bull Hole we meet with felsite again, which occupies the northernmost part of the island, including the outlying Garland stone. Some bands of ash are seen in the basaltic cliffs between the north point of the island and North Castle. Sedimentary grits and shales occur in North and South Haven, and at the Rye Rocks; they pass beneath a basalt which apparently forms all the remaining portion of the Neck.

III. *Influence of the Geological Structure on the Physical Features.*—The two marked inlets of North and South Haven, as also the channel separating (at high water) the Mewstone from the main parts of the island, have been formed by the more rapid erosion of the sedimentary strata, and the Wick has been clearly eaten out along a line of fault between basalt and sedimentary beds. A curious series of ridges running across the island in a more or less east and west direction mark the outcrops of massive basalts, felsites, and hard felsitic conglomerates, the lower ground between them being formed of softer sedimentary strata, or of more thinly bedded rocks of basaltic character.

IV. *Age of the Rocks.*—No fossils have yet been found on Skomer, but along the south side of the promontory at Wooltack Park, on the mainland, some grits and shales occur, containing tentaculites, &c., which closely resemble those of Skomer, and have the same general dip. These beds are mapped by the Survey as Llandeilo, but are probably somewhat later in age. We are therefore inclined to regard the corresponding beds on Skomer, with their associated igneous rocks, as of Bala or Llandovery age.

V. *Microscopic Characters of the Rocks.* (*a*) SEDIMENTARY.—The grits consist of clear quartz grains, with the angles rounded off, a felspar weathered beyond recognition, and, rarely, some mica. A granite pebble from the conglomerate ridge comes from the same mass as the Brimaston granite. (*b*) FELSITES.—Several of the slides show good flow structure, with phenocrysts of felspar, sometimes largely kaolinised. A section cut from the more coarsely spherulitic part of the rock to the east of Tom's House shows five well-marked whitish spherules (of about $\frac{1}{6}$-inch diameter) in a greenish granular ground. The spherules are much cracked, and show dusty brown material in concentric bands towards the edges. Under crossed Nicols a well-marked fibrous radiating structure is apparent, but the crystallisation is somewhat confused, and the spherules do not show a clearly defined black cross. In two places the slide shows patches of crystalline character, which appear to be basaltic inclusions. (*c*) BASALTS AND PORPHYRITES.—The slides cut from specimens obtained from the west side of Tom's House, the cave at the bottom of the Wick, the west side of South Haven, and from North Castle, all show porphyritic felspars, often with good crystal outlines, granules of augite, and much ilmenite or magnetite. The rock from the Neck, opposite Midland Island, is a porphyrite, showing fine laths of plagioclase felspar, and much black granular material, probably ilmenite, with no phenocrysts. The Skomer Head rock is a basalt—ophitic in parts—with lath-shaped felspar crystals, much augite (some of which is quite fresh), magnetite or ilmenite, and greenish decomposition products. The basalt of the Pigstone Rock shows good phenocrysts of felspar in a fine-grained dusty ground-mass; the augite is small, and mostly altered. The rock seen at the Table is a porphyritic basalt, with large felspars showing very distinct crystal outlines, some olivine, a little augite, and numerous opaque granules of ilmenite. Some of the basalts (*e.g.*, that north of Bull Hole) show distinct flow structure, the small lath-shaped felspars being seen to bend round larger crystals.

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6. *Notes on Sections along the London Extension of the Manchester, Sheffield, and Lincoln Railway between Rugby and Aylesbury.* By HORACE B. WOODWARD, *F.R.S.*, *F.G.S.*

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Commencing at Willoughby, near Braunston, attention was drawn to cuttings in the Lower Lias, from the zone of *Ammonites armatus* to that of *A. capricornus* at Catesby. The Catesby tunnel was excavated partly in the higher beds of Lower Lias, and partly in the Middle Lias, zone of *A. margaritatus.* The Marlstone rock-bed occurred above the tunnel and was exposed at its southern entrance. At Charwelton a mass of Upper Lias was let down by a trough-fault between beds of Middle Lias. Gravel containing pebbles of chalk and derived Jurassic fossils occurred also at Charwelton. Sections of Upper Lias were noted at Woodford Halse and Banbury Lane, near Moreton Pinkney.

Boulder Clay was first encountered south of Woodford Halse, the vale of Lower Lias not exhibiting any section of it. It covers considerable tracts of the higher grounds onwards towards Steeple Claydon, and is an extension of the East Anglian Chalky Boulder Clay.

Cuttings near Sulgrave and onwards to Helmdon and Brackley showed fossiliferous marls and limestones of the Great Oolite with underlying Estuarine Beds.

At one point east of Hill Farm, south of Radstone, where the Boulder Clay rested on the marls and limestones of the Great Oolite, streaks of reddish brown clay were noticed at the base of the grey Glacial Clay. Elsewhere the Boulder Clay was seen resting on a piped surface of Great Oolite, the 'pipes' being filled with reddish-brown clay. In places the Great Oolite was somewhat disturbed and nipped up. Evidently the agent which produced the Boulder Clay was forced over an old land-surface formed of Great Oolite. That formation was disturbed in places, and portions of the old soil were stripped off and incorporated in the Boulder Clay. Further south the Boulder Clay was banked up against a bed of coarse boulder-gravel, such as is found near Buckingham, near the southern margin of this Glacial drift.

In places pebbles from overlying gravel were noticed to occur a foot or two down in Great Oolite Clay. In dry weather, when clays become deeply fissured, stones from overlying drift or soil may drop into crevices, and become embedded in a much older deposit to a depth of four or five feet.

No cornbrash was shown in any of the cuttings. South-west of Rosehill Farm, near Chetwode, the Oxford Clay appeared, and it was well seen north-east of Charndon Lodge Farm, where clays of the zone of *Ammonites ornatus* were exposed.

Near Steeple Claydon a specimen of *A. Sutherlandiæ* with *A. Lamberti* attached was picked up on the embankment. The fossils were identified by Mr. G. Sharman.

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7. *Report on the Stonesfield Slate.*—See Reports, p. 356.

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8. *Report on the Investigation of a Coral Reef.*—See Reports, p. 377.

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9. *Report on Geological Photographs.*—See Reports, p. 357.

MONDAY, SEPTEMBER 21.

The following Reports and Papers were read:—

1. *Report on the Hoxne Excavation.*—See Reports, p. 400.

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2. *On the Discovery of Marine Shells in the Drift Series at High Levels in Ayrshire, N.B. By* John Smith.

Where best developed the Ayrshire Drift Beds are arranged in the following order:—

1. Upper Boulder-clay, often with large blocks.
2. Stratified sand and gravel.
3. Boulder-clay, blocks generally small.
4. Gravel, sharp sand, hour-glass sand, and muddy sand.
5. Laminated mud or clay, sometimes with one or two beds of Boulder-clay.
6. Lower Boulder-clay, often with large blocks.
7. Mammoth and Reindeer bed at Kilmaurs.

In bed No. 1 marine shells occur at 40 and 1,061 ft. above sea-level, and at many intermediate heights.

In bed No. 2 I have got marine shells frequently up to a little above 200 ft. above sea-level, and in one instance at about 800 feet.

In bed No. 3 marine fossils are frequent up to at least 600 ft. above sea-level.

In bed No. 5 (laminated mud or clay) I have not yet found any fossils.

In the lower Boulder-clay (6) marine fossils are occasionally got, but it is, generally speaking, much obscured by talus along the river banks.

The Boulder-clays in fresh cuttings often look as if they were massive, but weathered exposures often show lines of stratification, and sometimes there are thin horizontal bands of sand or gravel through them.

Striated stones are got in them lying beside perfectly unscratched and angular stones, and far-travelled stones and boulders are got beside those of the district.

The Boulder-clays, generally speaking, take their colour from the formations on which they rest, or at least from one not far away.

About the middle of the county some stones and boulders from the north are mixed with those from the south.

At about 700 feet of altitude in certain districts there is no Boulder-clay *to be seen* on top of the sand and gravel, the latter being well bedded and the gravel well rounded.

Up to 800 feet in the open country there are many drums of drift, and in the narrow glens under certain conditions the drums are got up to a much higher altitude, the Boulder-clay reaching to over 1,700 feet, and the sands and gravel interbedded with it to over 1,000 feet.

In the sand and gravel beds there are occasionally large boulders, as well as in the laminated mud.

The interstratified beds are sometimes much contorted

Under the Boulder-clay the rock is sometimes crushed, the fragments being often mixed into the bottom of the clay.

The Boulder-clay appears sometimes to have been dragged a bit, and then the stones are more intensely striated and the shelly fragments scratched.

Sometimes the stones are standing on edge in the Boulder-clay.

The '25 foot' beach always rises on a *platform* cut out by the waves, but the '40-foot' one is sometimes seen resting on *drums* of Boulder-clay.

The great bulk of the marine shells occur as fragments, although there are some very good specimens.

The fragments are mostly sharp-edged, and many have the epidermis, a few being scratched and polished.

The fossils that turn up most frequently are: Astarte compressa, Astarte sulcata, Cyprina islandica, and Leda pernula.

The occasional being: Pecten islandicus, Cardium, Natica, Buccinum or Fusus, Littorina littorea (worn), Plates of Balani, and burrows of boring sponges. Many fragments cannot be determined.

What looks like Melobesia (sticking to stones) has turned up in three localities.

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3. *Notes on the Superficial Deposits of North Shropshire. By* C. CALLAWAY, *D.Sc., F.G.S.*

The author gives a sketch of observations on the sandy and shingly deposits that lie scattered over the plain of North Shropshire. They are found as high as 1,100 feet at Gloppa, while erratics occur on the Longmynd hills as high as 1,050 feet. That the gravels and sands are of marine origin is inferred from their arrangement, which is similar to that of ordinary littoral deposits, and from their abundant molluscan fauna, which is entirely marine. Under the former head attention is called to the frequent occurrence of ripple-marks in the sands, and under the latter it is remarked that the comminuted condition of many of the fossils is to be expected from littoral conditions. It is pointed out that, in the eastern part of the area, chalk flints are abundant, which is hardly consistent with a north-western derivation; while the discovery of a Cornbrash fossil in the sands at Wellington proves derivation from the east or south. In conclusion, the author insists upon the decisive fact that the hills and crags of the area do not present the rounded outlines to be expected in a glaciated district.

4. *The Glacial Phenomena of the Vale of Clwyd.* *By* J. Lomas *A.R.C.S., and* P. F. Kendall, *F.G.S.*

The Vale of Clwyd is a V-shaped valley running almost N. and S. The floor is composed of Triassic rocks, while the sides consist of Silurian slates and grits with faulted inliers of Carboniferous age at intervals along the inner edges.

The tract of land occupying the mouth of the Vale is low and marshy. As the solid rock is reached in this district only at a considerable depth below O. D., and there are evidences of a pre-Glacial line of cliffs along the neighbouring coasts, we must regard it as an arm of the sea which has been filled up with drift deposits.

About St. Asaph and southwards the ground rises into mounds which run nearly parallel to the axis of the Vale. Where gaps appear in the Moel Fammau range the drift mounds curve round so as to be parallel with the opening.

Further south, beyond Denbigh, the ground is again flat, and this character continues to the end of the open part of the Vale.

The deposits at the north consist of clays and sands with shell fragments similar to those spread over the plains of Lancashire and Cheshire, and contain erratics from the N.

At St. Asaph, Colwyn, and other places these northern drifts are seen to overlie an older deposit yielding Welsh erratics exclusively, and containing no shell fragments.

The northern drift extends as far as Tremeirchion on the east, and a boulder of Scotch granite has been found near Denbigh on the west.

Above Denbigh only Welsh drift is found.

Near Llanfair the Clwyd leaves the main valley and goes through a gorge continuing to near Corwen. At Pwll-glas, Derwen, Gwyddelwern, and other places the valley is blocked by mounds of gravel which run athwart the valley. They represent terminal moraines laid down by a glacier proceeding down the Vale from the Dee Valley.

Sequence of Events.—The Welsh hills nursed glaciers during the early part of the Glacial period. These increased and spread out from Arenig Mawr as a centre. So great was the ice-spread that boulders were carried over the highest points in the Moel Fammau and the Mynydd Hiraethog and Cyrn-y-Brain ranges.

The ice from Scotland, Lake District, and Ireland, creeping southwards and filling the shallow Irish Sea, cleaved on reaching the N. Wales massif about the Gt. Orme's Head.

So great was the pressure that the Welsh ice was also divided into two streams, one going west through the Menai Straits and over Anglesey, and the other going eastwards and joining with the great sheet which swept over Cheshire into the Midlands.

Evidence of this cleavage we have in the Glacial striæ which are divergent E. and W. of the Conway and in the character of the boulder transport. The E. side of the Vale of Clwyd is covered with great deposits of red drift derived from the floor of the Vale, while the W. side contains no Triassic rocks. Through the opening about Bodfari enormous masses of red sand were carried, and formed the well-known deposits of the Wheeler Valley.

On the dwindling of the ice the valleys still retained small glaciers, the deposits of one being found in the Upper Clwyd.

Conclusions.—The Drift lends no countenance to the theory that this portion of North Wales was submerged during the Glacial period. In fact the absence of northern Drift with shells in places at a level below the shell-bearing beds on each side directly contradicts the assumption.

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5. *On some Post-Pliocene Changes of Physical Geography in Yorkshire.* *By* Percy F. Kendall, *F.G.S.*

The drift deposits of Yorkshire are extensively developed over all the low grounds and in much of the hill country. They have been attributed by the officers of the Geological Survey, the late Professor Carvill Lewis, Mr. Lamplugh, and other geologists, to the action of glaciers descending all the principal valleys, from Teesdale on the north to Airedale on the south, with a great main stream occupying the Vale of York almost as far as the Humber, and a Scandinavian ice-sheet abutting against the whole coast-line.

Pre-Glacial valleys have been detected beneath the drift at depths exceeding 170 feet below O.D.

The irregular accumulation of the glacial deposits produced many changes in the courses of the rivers, and a great area was added to the coast-line.

The *Derwent* has been shown by Mr. Fox Strangways to have reversed its flow, and instead of discharging into Filey Bay, it now flows westward, passes through the Howardian Hills in a narrow gorge 150 feet deep, and ultimately joins the Ouse. The change of direction has been ascribed to the formation of a ridge of boulder-clay, which extends across the valley behind Filey, and has a minimum altitude of 130 feet, which is only 70 feet below the top of the notch in the Howardian Hills. The author considers it more probable that the diversion was effected by an ice-barrier. At one stage a lake would be formed occupying the whole Vale of Pickering, and lacustrine deposits are found, having a thickness of over 90 feet.

The river system of the Vale of York is very peculiar. The Tees crosses a very broad tract of soft rocks without receiving a single tributary from the south. The Wiske rises in the north-western corner of the Cleveland Hills, and approaches within two miles of the Tees, then turns south and joins the Swale.

The Drift is very deep along the line of the Tees, and thins to the south, so that the solid rocks are exposed at many places along a line running through Northallerton and Bedale. This was the pre-Glacial Watershed. Northward of it the Drift is mainly boulder-clay, while southward gravels largely predominate; exactly the same fact is observed south of the watershed between the Mersey and the Severn.

The *Swale* and *Wiske* were formerly tributaries of the Tees.

No study has yet been made of the Ure.

The *Nidd* furnishes an example of a diversion different from any yet noted. Down to Ripley it flows through a wide and open valley, but below that village it enters a narrow and deep gorge or ravine cut partly through grits and shales of the Millstone Grit series, and partly through Magnesian Limestone. For long distances its banks are extremely steep, and in places, as at Knaresborough and Plumpton, even vertical, producing scenery unrivalled in any part of Yorkshire. This is obviously so recent a channel that the author was impelled to seek an older one, and discover the cause of its abandonment. Such an old valley is clearly traceable from Ripley, past Nidd Hall and Brearton, out into the Vale of York. It is broad and well defined, and its sides have a very gentle slope, like those of the upper part of the valley, and there are extensive marshy patches in its course. Near Nidd Hall a large lateral moraine of a glacier, which came down Uredale, obstructs the old valley. Many excavations display the usual structure of moraines.

The *Wharfe* presents similar features to those of the Nidd. Its valley is wide and open until the town of Wetherby is reached; then the river, instead of pursuing a north-easterly course through a valley extending through the town, turns abruptly to the south-east, and runs through a gorge in the Magnesian Limestone down to Tadcaster. The valley across the site of Wetherby is filled with a great thickness of excessively coarse morainic gravel, thrown down by the side of the same glacier as that which deflected the Nidd, and it seems probable that this also is a case of diversion.

There are numerous small diversions of the Aire by terminal moraines—for example, near Keighley and Bingley—but its lower course appears quite normal.

Great changes have been wrought in the upper part of the Calderdale by the events of the Glacial period, but they and the remarkable vicissitudes of the Trent will be dealt with in a future communication.

6. *Report on Erratic Blocks.*—See Reports, p. 366.

7. *Another Possible Cause of the Glacial Epoch.* *By* Professor EDWARD HULL, *LL.D., F.R.S., F.G.S.*

The author gave an account of the results arrived at by Professor J. W. Spencer, Ph.D., in his memoir on 'The Reconstruction of the Antillæan Continent' ('Bull. Geol. Soc.,' America, January 1895) from observations laid down on the Admiralty charts of the east coast of North America and the shores of the West Indian Islands and Gulf of Mexico. He shows that the 'continental shelf' lying between the coast and the 100-fathom line is succeeded by a second and deeper plateau, called by Professor A. Agassiz 'the Blake plateau,' the average depth of which may be taken at 2,700 feet, separated from the continental shelf by a steep descent, and in its turn bounded by a second steep descent leading down to the abysmal depths of the Atlantic Ocean at 12,000 or 13,000 feet below the surface. A careful investigation of the soundings shows that these plateaus are traversed by channels, sometimes of great depth and with precipitous sides, leading down from the *embouchures* of the existing rivers which open out on the coast, and connected with the outer margins of the plateaus by wide embayments. The form of these channels would in some cases entitle them to be called 'cañons' or 'fjords'; and, as Professor Spencer truly considers that such channels could only be formed by river erosion, he concludes that the whole eastern coast and the West Indian Isles were elevated to the extent of the outer embayments where they open out on the floor of the ocean. Such an elevation of 12,000 feet or so would have connected North and South America along the line of the Antilles, constituting a single continent,[1] and are termed 'stupendous changes of level' of the Pleistocene epoch.

The author of this paper proceeds to discuss some of the climatic conditions which would result from such changes, and supposes that the elevation of the Antillæan continent would have shut out the northern branch of the great equatorial current known as the Gulf Stream from the Caribbean Sea and the Gulf of Mexico, causing it to enter the North Atlantic directly; and he comes to the conclusion that the Atlantic current would have crossed the 40th parallel with surface temperature of only 74° F., instead of 84° F., as is the case at the present day. The author then discusses the question to what extent such a lowering of the temperature of the present Gulf Stream would have affected the climate of the regions bordering the North Atlantic, and considers that this effect may be approximately arrived at by transferring the climatic conditions of the isotherm of annual mean temperature of 30° F. (the freezing point of water) to those of the 42° F. of the present day, resulting in sub-glacial conditions along the line of this isotherm.

Proceeding next to examine the effects of the elevation of the American continent to the extent required by Professor Spencer's conclusions, the author considers it as extremely probable that the cold produced by this physical change, added to that due to the lowering of the temperature of the Atlantic current, would result in bringing about the conditions of the Glacial epoch; and as similar elevation of land has been determined in the case of the platform of the British Isles and North-western Europe—though to a much smaller extent than in the case of the American continent—the increased cold due to this cause, added to that due to the diminished temperature of the Atlantic current, would have been, if not a *vera causa* of the Glacial epoch of Europe, a most material cause in bringing about the climatic conditions of that epoch.

8. *Final Report on the High-level Shell-bearing Deposits at Clava and Kintyre.*—See Reports, p. 378.

[1] For those who are unable to obtain Professor Spencer's original memoir, the review thereof by Mr. A. J. Jukes-Browne, F.G.S., in the *Geological Magazine* for April 1895, will probably suffice.

9. *Interim Report on the Singapore Caves.*—See Reports, p. 399.

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10. *Interim Report on the Calf Hole Exploration.*

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11. *Interim Report on the High-level Flint-drift at Ightham.*

TUESDAY, SEPTEMBER 22.

The following Reports and Papers were read :—

1. *Interim Report on the Investigation of the Locality where the Cetiosaurus Remains in the Oxford Museum were found.*

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2. *Interim Report on the Eurypterid-bearing Deposits of the Pentland Hills.*

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3. *Interim Report on the Palæozoic Phyllopoda.*

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4. *Interim Report on the Registration of Type Specimens.*

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5. *Fifth Contribution to Rhætic Literature.*
By MONTAGU BROWNE, *F.G.S., F.Z.S.*

The Rhætic Bone-bed of Aust Cliff, and the Rock-bed above it.

The Rhætic bone-bed of Aust Cliff seldom yields perfect examples of vertebrate remains, and still more rarely, if ever, objects in association. An examination of the rock shows the reason for this. It is made up largely of sub-angular fragments or rolled boulders of the Keuper sandstone to be found immediately below it, around which are sands, probably of Keuper age, so arranged, and so highly charged with fragmentary remains of Rhætic vertebrata and their excretæ, as to denote currents of considerable turbulence, such as now obtain in seas or estuaries of no great depth.

Of quite a different character are the black shales above, and the bed of stone resting thereupon. This band of stone, which has been described by Wright, and is known as the *Pullastra arenicola* bed, shows it to have been much more quietly deposited, and it is in this that bones are more likely to be found in association at Aust and Westbury-on-Severn. This band of stone is the so-called bone-bed of the 'Garden Cliff,' Westbury-on-Severn, of Penarth, Lavernock, and Watchet, the *true* bone-bed of Aust not being represented at those places, or if at Lavernock in a very attenuated form. Neither at Pylle Hill, Bristol, nor at the Spinney Hills, nor at Wigston, Leicester, nor at Walton, Leicestershire, nor in the Nottinghamshire Rhætics does a bone-bed exist of the same character as that at Aust; the bone-bed of the Spinney Hills, though not of like extent, is on the same horizon, and contains specimens in the same state of mineralisation as at Aust Cliff. Another point which lends colour to this theory of partial similitude is that in both Aust and the Spinney Hill bone-bed remains of *Ceratodus* have been found, which have not yet been obtained in the lower *Pullastra arenicola* or *Isodonta Ewaldi* beds.

It is therefore in the first band of stone containing these invertebrate fossils, and which *never lies* immediately upon the 'tea-green marls,' that the most perfect remains of the lesser Dinosauria, Labyrinthodontia, and of other vertebrata must be sought, and from this bed at Aust was procured the fine jaw with teeth of *Saurichthys* described by Mr. A. Smith Woodward, and several unusually perfect specimens obtained by the writer at Aust Cliff and Westbury-on-Severn.

The genus Sphenonchus, i.e., *Head-defences of certain* Hybodont Sharks. Sphenonchus hamatus, *Agassiz.*

This species, already recorded in Britain from the Lias, has now been discovered by the author in the Rhætic bone-bed of Aust Cliff. Other specimens examined by him were collected by Mr. Storrie from the Lavernock bone-bed, and by Mr. T. Burrows in the bone-bed of the Spinney Hills.

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6. *On the Skull of the South African Fossil Reptile Diademodon. By* H. G. Seeley, *F.R.S., Professor of Geology in King's College, London.*

Only two or three teeth have hitherto been known. The crowns are of mammalian type, and although referred to the Gomphodont division of the Theriodontia, no proof of the structure of the skull has been previously available. The skull now described was found at Wonderboom by Dr. Kannemeyer. It gives evidence of ten premolar and molar teeth, of which four are counted as premolars and six as molars. The molar teeth are transverse, with a type of crown which closely resembles Diademodon Brownii. The last molar is small, with a narrow posterior talon. The skull is fractured, so that the cerebral region is lost, and the snout is lost by a vertical fracture, which passes through the hemispherical pits upon the pre-orbital angle at the junction of the frontal nasal and maxillary bones; so that the canine teeth are not preserved. The author described the limits of the pre-frontal and post-frontal bones, and states that the post-frontal differs from that of Ornithorhynchus in its different relation to the small brain cavity, and in contributing to form the circular orbit of the eye.

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7. *Note on examples of Current Bedding in Clays. By* H. G. Seeley, *F.R.S., Professor of Geology in King's College, London.*

The author remarked that, although thin layers are defined by differences of colour in some slates, it is rare for bedding in the great clays to be marked unless by changes in mineral character. He has observed current bedding in the mottled clays of the Woolwich and Reading beds, and in Wealden purple clays near Tunbridge Wells.

About two years since current bedding was uncovered in Messrs. Poulton's pit in the Reading beds at Katesgrove, near Reading. Above the current bedded sand, with bands of pipe-clay and fossil leaves, which occur towards the base of the deposit, crimson and green clays occurred in regular alternations of about twenty thin beds, which thickened from the west to the east. They were laid down in the usual curved succession of thin layers horizontally truncated above by the rapidity of flow of the current. The layers thickened to the west, beyond the sheltering bank of the deposits. Each of these beds, which was only two to four inches thick in the western corner of the pit in which the current bedding is seen, spreads over the pit as one of the nearly horizontal layers of mottled clay, which form the part of the section between the yellow sands below and the brown clay above with marine fossils. There is no evidence of the laminated structure being due to sand, but a few small irregular calcareous concretions, about an inch or two in diameter, occur in the beds of green colour.

The second example was first observed by the Rev. T. R. R. Stebbing, F.R.S., at the new Recreation Ground, Tunbridge Wells, and at his request the author examined the section. The deposit is a purple clay of Wealden age, and either Weald Clay or a subordinate deposit in the Tunbridge Wells sand. It has at first the aspect of a boulder clay with bedding inclined to the east. Every layer, in the thickness exposed of 14 feet, is full of fragments of yellow sandstone, all apparently derived from one deposit, such as the Ashdown sand. They are all angular, and vary in size from one inch to two feet in length. There is no trace of smoothing or grooving on any of the large number of fragments examined, and therefore no ground for attributing their transport to ice. The volume of water which would effect transport of such a thickness of clay may have been merely the result of exceptionally heavy rain, for the large fragments appear to be torn away by their natural joints and bedding planes, and the small fragments are such as the action of varying temperature would produce in a terrestrial surface. The angle of dip was about 15°. Mr. F. G. Smart, M.A., F.L.S., of Tunbridge Wells, photographed the sections at the author's request.

It is remarked that, although alternating green and red clays in geological deposits are generally of freshwater origin, there is a similar alternation in some of the old Cambrian slates.

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8. *On some Crush-Conglomerates in Anglesey.* *By* Sir ARCHIBALD GEIKIE, *F.R.S.*

The important observations made by Mr. Lamplugh among the 'crush-conglomerates' of the Isle of Man suggest that the phenomena described by him may have a much wider range than had previously been supposed. Ever since the author had the opportunity of going over the Manx evidence with him, he has suspected that some of the fragmental rocks which he has himself regarded as volcanic agglomerates might prove to be due, not to volcanic explosions, but to the same kind of underground movements which have undoubtedly given rise to the enormous masses of 'crush-conglomerate' in the Isle of Man. The breccias of Anglesey seemed to the author likely, on renewed examination, to prove to belong to the latter series. Accordingly he recently took occasion to revisit these rocks, both in the centre and along the north coast of the island. The result was entirely confirmatory of his suspicions. The breccias in question are, he now feels convinced, true crush conglomerates.

The amount of mechanical deformation which these rocks have undergone is one of their most obvious characteristics. On the supposition of their volcanic origin, it was quite conceivable that coarse agglomerates and volcanic breccias might undergo crushing together with the sedimentary series to which they belonged, so that the evidence of deformation formed is itself no proof that they were not of pyroclastic derivation. But more detailed investigation, in the light of the Manx examples, brings to view proofs that the conglomeratic structure has been produced by the breaking up of stratified rocks *in situ.* At Llangefni, for example, the strata affected appear to have been originally shales or mudstones (with possibly some fine felsitic tuffs), alternating with bands of hard siliceous grit. They have been crumpled up and crushed into fragments, which have been driven past each other along the planes of movement. Every stage may be traced, from a long piece of one of the grit-bands down to mere rounded and isolated pebbles of the same material. The grits, being much more resisting, have withstood the deformation better than the argillaceous strata, which have been crushed into a kind of broken slate or phyllite. Everywhere the signs of movement, or 'flow-structure,' meet the eye. It is not that the rocks have been merely crushed to fragments; the differential movements which produced the ruptures also made the materials to flow onwards, the dislocated bands of grit being reduced to separate blocks and pebbles entirely surrounded in the moving matrix of finer shaly paste.

The 'agglomerates' on the coast near Cemmaes, so singularly deceptive as to be easily mistaken for volcanic necks, prove to be capable of a like interpretation. The huge blocks of limestone there to be seen, isolated among fragmentary grits and slates, are referable to the disruption of some of the limestone bands which occur abundantly in the neighbourhood. A gradation may be traced from the slates and grits outside the areas of more severe dislocation into the intensely crushed and sheared 'agglomerate.' The dykes which cut through these rocks and increase the likeness to true volcanic vents are later than the period of crushing, and may be traced in the surrounding slates and grits.

But though the volcanic nature of the rocks formerly believed to be agglomerates must be abandoned, the question of the original formation of the strata which have been so greatly ruptured remains quite distinct. The author agrees with Mr. Blake in regarding these strata as largely composed of volcanic detritus. The breccias and fine tuffs which alternate with and overlie the Lower Silurian black shales can be traced upward into the mass of the Amlwch slates, which are full of volcanic dust. The evidence for the existence of Lower Silurian volcanoes in the north of Anglesey remains quite valid and ample, though we must abandon the volcanic origin of the 'agglomerates' which seemed to form part of that evidence. The crush-conglomerates have involved the volcanic as well as the non-volcanic parts of the series in the same destruction. But it is obvious that in a region which has undergone such severe compression and disruption it cannot be always an easy task to distinguish between breccias due to original volcanic explosions and those produced among these very volcanic rocks by subsequent mechanical stresses.

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9. *Report on Seismological Investigations.*—See Reports, p. 180.

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10. *Note on some Fossil Plants from South Africa. By* A. C. SEWARD, *M.A., F.G.S.*

The author has recently had an opportunity, through the kindness of Mr. David Draper, F.G.S., of examining a collection of fossil plants from a locality a short distance south of Johannesburg. The collection forwarded to England by Mr. Draper includes examples of *Glossopteris*, *Vertebraria*, and other genera, associated with specimens of *Lepidophloios* The occurrence of Lepidodendrons in strata containing typical members of the Glossopteris flora is extremely important from the point of view of the geological and geographical distribution of fossil plants, and specially interesting in connection with a similar association lately recorded by Professor Zeiller in Brazilian plant-bearing beds. In South Africa, as in South America, we have evidence of the existence of a plant genus characteristic of the Upper Palæozoic flora of the northern hemisphere, in the same region with the Permo-Carboniferous Glossopteris flora.

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11. *On the Production of Corundum by Contact Metamorphism on Dartmoor. By* Professor KARL BUSZ.

At South Brent the valley of the Avon cuts right through the contact-zone of the Dartmoor granite. The clay-slate is altered into chiastolite slate and spotted mica schist, and small interbedded seams of limestone are represented by aggregates of garnet, malacolite, axinite, and what seems to be anorthite. The crystals of andalusite in one of the altered slates have proved to contain a small quantity of cassitorite in minute crystals. This stream also exposes the intimate contact between a felspar porphyry and clay-slate: irregular pieces of the latter rock are included in the former. Around these pieces there occurred a large number of minute colourless hexagonal crystals, which, when isolated by the action of hydrofluoric and hydrochloric acids, proved to consist of alumina with a very little iron oxide. Their hardness was also greater than that of topaz, so that it is clear they must consist of corundum. In the opinion of the author the melted porphyry has dissolved the clay, and thus become supersaturated with alumina, which has crystallised out as crystalline corundrum.

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12. *Interim Report on the Age and Relation of Rocks near Moreseat, Aberdeen.*

SECTION D.—ZOOLOGY.

PRESIDENT OF THE SECTION—E. B. POULTON, M.A., F.R.S., F.L.S., Professor of Zoology in the University of Oxford.

THURSDAY, SEPTEMBER 17.

The President delivered the following Address:—

A NATURALIST'S CONTRIBUTION TO THE DISCUSSION UPON THE AGE OF THE EARTH.

A VERY brief study of the proceedings of this Section in bygone years will show that Presidents have exercised a very wide choice in the selection of subjects. At the last Meeting of the Association in this city in 1870 the Biological Section had as its President the late Professor Rolleston, a man whose remarkable personality made a deep impression upon all who came under his influence, as I have the strongest reason for remembering, inasmuch as he was my first teacher in zoology, and I attended his lectures when but little over seventeen. His address was most characteristic, glancing over a great variety of subjects, literary as well as scientific, and abounding in quotations from several languages, living and dead. A very different style of address was that delivered by the distinguished zoologist who presided over the Meeting. Professor Huxley took as his subject 'The History of the Rise and Progress of a Single Biological Doctrine.'

Of these two types I selected the latter as my example, and especially desired to attempt the discussion, however inadequate, of some difficulty which confronts the zoologist at the very outset when he begins to reason from the facts around him—a difficulty which is equally obvious and of equal moment to the highly trained investigator and the man who is keenly interested in the results obtained by others, but cannot himself lay claim to the position and authority of a skilled observer—to the naturalist and to one who follows some other branch of knowledge, but is interested in the progress of a sister science.

Two such difficulties were alluded to by Lord Salisbury, in his interesting presidential address to the British Association at Oxford in 1894, when he spoke of 'two of the strongest objections to the Darwinian explanation' of evolution—viz., the theory of natural selection—as appearing 'still to retain all their force.' The first of these objections was the insufficiency of the time during which the earth has been in a habitable state, as calculated by Lord Kelvin and Professor Tait, 100 million years being conceded by the former, but only ten million by the latter. Lord Salisbury quite rightly stated that for the evolution of the organic world as we know it by the slow process of natural selection at least many hundred million years are required; whereas, 'if the mathematicians are right, the biologists cannot have what they demand. . . . The jelly-fish would have been dissipated in steam long before he had had a chance of displaying the advantageous variation which was to make him the ancestor of the human race.'

The second objection was that 'we cannot demonstrate the process of natural selection in detail; we cannot even, with more or less ease, imagine it.' 'In natural selection who is to supply the breeder's place?' 'There would be nothing but mere chance to secure that the advantageously varied bridegroom at one end of the wood should meet the bride, who by a happy contingency had been advantageously varied in the same direction at the same time at the other end of the wood. It would be a mere chance if they ever knew of each other's existence—a still more unlikely chance that they should resist on both sides all temptations to a less advantageous alliance. But unless they did so the new breed would never even begin, let alone the question of its perpetuation after it had begun.'

Professor Huxley, in seconding the vote of thanks to the President, said that he could imagine that certain parts of the address might raise a very good discussion in one of the Sections, and I have little doubt that he referred to these criticisms and to this Section. When I had to face the duty of preparing this address, I could find no subjects better than those provided by Lord Salisbury.

At first the second objection seemed to offer the more attractive subject. It was clear that the theory of natural selection as held by Darwin was misconceived by the speaker, and that the criticism was ill-aimed. Darwin and Wallace, from the very first, considered that the minute differences which separate individuals were of far more importance than the large single variations which occasionally arise—Lord Salisbury's advantageously varied bride and bridegroom at opposite ends of the wood. In fact, after Fleeming Jenkins's criticisms in the 'North British Review' for June 1867, Darwin abandoned these large single variations altogether. Thus he wrote in a letter to Wallace (February 2, 1869): 'I always thought individual differences more important; but I was blind, and thought single variations might be preserved much oftener than I now see is possible or probable. I mentioned this in my former note merely because I believed that you had come to a similar conclusion, and I like much to be in accord with you.'[1] Hence we may infer that the other great discoverer of natural selection had come to the same conclusion at an even earlier date. But this fact removes the whole point from the criticism I have just quoted. According to the Darwin-Wallace theory of natural selection, individuals sufficiently advantageously varied to become the material for a fresh advance when an advance became necessary, and at other times sufficient to maintain the ground previously gained—such individuals existed not only at the opposite ends of the wood, but were common enough in every colony within its confines. The mere fact that an individual had been able to reach the condition of a possible bride or bridegroom would count for much. Few will dispute that such individuals 'have already successfully run the gauntlet of by far the greatest dangers which beset the higher animals [and, it may be added, the lower animals also]—the dangers of youth. Natural selection has already pronounced a satisfactory verdict upon the vast majority of animals which have reached maturity.'[2]

But the criticism retains much force when applied to another theory of evolution by the selection of large and conspicuous variations, a theory which certain writers have all along sought to add to or substitute for that of Darwin. Thus Huxley from the very first considered that Darwin had burdened himself unnecessarily in rejecting *per saltum* evolution so unreservedly.[3] And recently this view has been revived by Bateson's work on variation and by the writings of Francis Galton. I had at first intended to attempt a discussion of this view, together with Lord Salisbury's and other objections which may be urged against it; but the more the two were considered, the more pressing became the claims of the criticism alluded to at first—the argument that the history of our planet does not allow sufficient time for a process which all its advocates admit to be extremely slow in its operation. I select this subject because of its transcendent importance in relation to organic evolution, and because I hope to show that the naturalist has something of weight to contribute to the controversy which has been waged intermittently ever since Lord Kelvin's paper 'On Geological Time'[4] appeared in 1868. It has been urged by the great worker and teacher who occupied the Presidential Chair

[1] *Life and Letters*, vol. iii. [2] Poulton, *Colours of Animals*, p. 308.

[3] See his letter to Darwin, November 23, 1859: *Life and Letters*, vol. ii.

[4] *Trans. Geol. Soc.*, Glasgow, vol. iii. See also 'On the Age of the Sun's Heat,' Macmillan, March 1862: reprinted as Appendix to Thomson and Tait, *Natural Philo-*

of this Association when it last met in this city that biologists have no right to take part in this discussion. In his Anniversary Address to the Geological Society in 1869 Huxley said: 'Biology takes her time from geology. . . . If the geological clock is wrong, all the naturalist will have to do is to modify his notions of the rapidity of change accordingly.' This contention is obviously true as regards the time which has elapsed since the earliest fossiliferous rocks were laid down. For the duration of the three great periods we must look to the geologist; but the question as to whether the whole of organic evolution is comprised within these limits, or, if not, what proportion of it is so contained, is a question for the naturalist. The naturalist alone can tell the geologist whether his estimate is sufficient, or whether it must be multiplied by a small or by some unknown but certainly high figure, in order to account for the evolution of the earliest forms of life known in the rocks. This, I submit, is a most important contribution to the discussion.

Before proceeding further it is right to point out that obviously these arguments will have no weight with those who do not believe that evolution is a reality. But although the causes of evolution are greatly debated, it may be assumed that there is no perceptible difference of opinion as to evolution itself, and this common ground will bear the weight of all the zoological arguments we shall consider to-day.

It will be of interest to consider first how the matter presented itself to naturalists before the beginning of this controversy on the age of the habitable earth. I will content myself with quotations from three great writers on biological problems—men of extremely different types of mind, who yet agreed in their conclusions on this subject.

In the original edition of the 'Origin of Species' (1859), Darwin, arguing from the presence of trilobites, Nautilus, Lingula, &c., in the earliest fossiliferous rocks, comes to the following conclusion (pages 306, 307): 'Consequently, if my theory be true, it is indisputable that before the lowest Silurian stratum was deposited long periods elapsed, as long as, or probably far longer than, the whole interval from the Silurian age to the present day; and that during these vast yet quite unknown periods of time the world swarmed with living creatures.'

The depth of his conviction in the validity of this conclusion is seen in the fact that the passage remains substantially the same in later editions, in which, however, Cambrian is substituted for Silurian, while the words 'yet quite unknown' are omitted, as a concession, no doubt, to Lord Kelvin's calculations, which he then proceeds to discuss, admitting as possible a more rapid change in organic life, induced by more violent physical changes.[1]

We know, however, that such concessions troubled him much, and that he was really giving up what his judgment still approved. Thus he wrote to Wallace on April 14, 1869: 'Thomson's views of the recent age of the world have been for some time one of my sorest troubles. . . .' And again, on July 12, 1871, alluding to Mivart's criticisms, he says: 'I can say nothing more about missing links than what I have said. I should rely much on pre-Silurian times; but then comes Sir W. Thomson, like an odious spectre.'

Huxley's demands for time in order to account for pre-Cambrian evolution, as he conceived it, were far more extensive. Although in 1869 he bade the naturalist stand aside and take no part in the controversy, he had nevertheless spoken as a naturalist in 1862, when, at the close of another Anniversary Address to the same Society, he argued from the prevalence of persistent types 'that any admissible hypothesis of progressive modification must be compatible with persistence without progression through indefinite periods'; and then maintained that 'should such an hypothesis eventually be proved to be true . . . the conclusion will inevitably present itself that the Palæozoic, Mesozoic, and Cainozoic faunæ

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sophy, vol. i. part 2, second edition; and 'On the Secular Cooling of the Earth,' *Royal Society of Edinburgh*, 1862.

[1] 6th ed., 1872, p. 286.

and floræ, taken together, bear somewhat the same proportion to the whole series of living beings which have occupied this globe as the existing fauna and flora do to them.'

Herbert Spencer, in his article on Illogical Geology in the 'Universal Review' for July 1859,[1] uses these words: 'Only the last chapter of the earth's history has come down to us. The many previous chapters, stretching back to a time immeasurably remote, have been burnt, and with them all the records of life we may presume they contained.' Indeed, so brief and unimportant does Herbert Spencer consider this last chapter to have been that he is puzzled to account for 'such evidences of progression as exist'; and finally concludes that they are of no significance in relation to the doctrine of evolution, but probably represent the succession of forms by which a newly upheaved land would be peopled. He argues that the earliest immigrants would be the lower forms of animal and vegetable life, and that these would be followed by an irregular succession of higher and higher forms, which 'would thus simulate the succession presented by our own sedimentary series.'

We see, then, what these three great writers on evolution thought on this subject: they were all convinced that the time during which the geologists concluded that the fossiliferous rocks had been formed was utterly insufficient to account for organic evolution.

Our object to-day is first to consider the objections raised by physicists against the time demanded by the geologist, and still more against its multiplication by the student of organic evolution; secondly, to inquire whether the present state of palæontological and zoological knowledge increases or diminishes the weight of the threefold opinion quoted above—an opinion formed on far more slender evidence than that which is now available. And if we find this opinion sustained, it must be considered to have a very important bearing upon the controversy.

The arguments of the physicists are three:—

First, the argument from the observed secular change in the length of the day the most important element of which is due to tidal retardation. It has been known for a very long time that the tides are slowly increasing the length of our day. Huxley explains the reason with his usual lucidity: 'That this must be so is obvious, if one considers, roughly, that the tides result from the pull which the sun and the moon exert upon the sea, causing it to act as a sort of break upon the solid earth.'[2]

A liquid earth takes a shape which follows from its rate of revolution, and from which, therefore, its rate of revolution can be calculated.

The liquid earth consolidated in the form it last assumed, and this shape has persisted until now, and informs us of the rate of revolution at the time of consolidation. Comparing this with the present rate, and knowing the amount of lengthening in a given time due to tidal friction, we can calculate the date of consolidation as certainly less than 1000 million years ago.

This argument is fallacious, as many mathematicians have shown. The present shape tells us nothing of the length of the day at the date of consolidation; for the earth, even when solid, will alter its form when exposed for a long time to the action of great forces. As Professor Perry said in a letter to Professor Tait:[3] 'I know that solid rock is not like cobbler's wax, but 1000 million years is a very long time, and the forces are great.' Furthermore, we know that the earth is always altering its shape, and that whole coast-lines are slowly rising or falling, and that this has been true, at any rate, during the formation of the stratified rocks.

This argument is dead and gone.[4] We are, indeed, tempted to wonder that the

[1] Reprinted in his *Essays*, 1868, vol. i. pp. 324–376.

[2] Anniv. Address to Geol. Soc., 1869.

[3] *Nature*, Jan. 3, 1895.

[4] It must not be forgotten, however, that this argument and those which follow it have done very good work in modifying the unreasonable demands of geologists a quarter of a century ago.

physicist, who was looking about for arguments by which to revise what he conceived to be the hasty conclusions of the geologist as to the age of the earth, should have exposed himself to such an obvious retort in basing his own conclusions as to its age on the assumption that the earth, which we know to be always changing in shape, has been unable to alter its equatorial radius by a few miles under the action of tremendous forces constantly tending to alter it, and having 1000 million years in which to do the work.

With this flaw in the case it is hardly necessary to insist on our great uncertainty as to the rate at which the tides are lengthening the day.

The spectacle presented by the geologist and biologist, deeply shocked at Lord Kelvin's extreme uniformitarianism in the domain of astronomy and cosmic physics, is altogether too comforting to be passed by without remark; but in thus indulging in a friendly *tu quoque* I am quite sure that I am speaking for every member of this Section in saying that we are in no way behind the members of Section A in our pride and admiration at the noble work which he has done for science, and we are glad to take this opportunity of congratulating him on the half-century of work and teaching—both equally fruitful—which has reached its completion in the present year.

The second argument is based upon the cooling of the earth, and this is the one brought forward and explained by Lord Salisbury in his Presidential Address. It has been the argument on which perhaps the chief reliance has been placed, and of which the data—so it was believed—were the least open to doubt.

On the Sunday during the meeting of the British Association at Leeds (1890) I went for a walk with Professor Perry, and asked him to explain the physical reasons for limiting the age of the earth to a period which the students of other sciences considered to be very inadequate. He gave me an account of the data on which Lord Kelvin relied in constructing this second argument, and expressed the strong opinion that they were perfectly sound, while, as for the mathematics, it might be taken for granted, he said, that they were entirely correct. He did not attach much weight to the other arguments, which he regarded as merely offering support to the second.

This little piece of personal history is of interest, inasmuch as Professor Perry has now provided us with a satisfactory answer to the line of reasoning which so fully satisfied him in 1890. And he was led to a critical examination of the subject by the attitude taken up by Lord Salisbury in 1894. Professor Perry was not present at the meeting, but when he read the President's address, and saw how other conclusions were ruled out of court, how the only theory of evolution which commands anything approaching universal assent was set on one side because of certain assumptions as to the way in which the earth was believed to have cooled, he was seized with a desire to sift these assumptions, and to inquire whether they would bear the weight of such far-reaching conclusions. Before giving the results of his examination, it is necessary to give a brief account of the argument on which so much has been built.

Lord Kelvin assumed that the earth is a homogeneous mass of rock similar to that with which we are familiar on the surface. Assuming, further, that the temperature increases, on the average, 1° F. for every 50 feet of depth near the surface everywhere, he concluded that the earth would have occupied not less than twenty, nor more than four hundred, million years in reaching its present condition from the time when it first began to consolidate and possessed a uniform temperature of 7000° F.

If, in the statement of the argument, we substitute for the assumption of a homogeneous earth an earth which conducts heat better internally than it does toward the surface, Professor Perry, whose calculations have been verified by Mr. O. Heaviside, finds that the time of cooling has to be lengthened to an extent which depends upon the value assigned to the internal conducting power. If, for instance, we assume that the deeper part of the earth conducts ten times as well as the outer part, Lord Kelvin's age would require to be multiplied by 56. Even if the conductivity be the same throughout, the increase of density in the deeper part, by augmenting the capacity for heat of unit volume, implies a longer age than that conceded by Lord Kelvin. If the interior of the earth be fluid or contain fluid in a honeycomb structure, the rate at which heat can travel would be immensely increased by convection currents, and the age would have to be correspondingly lengthened. If, furthermore, such conditions, although not obtaining now, did obtain in past times, they will have operated in the same direction.

Professor Tait, in his letter to Professor Perry (published in 'Nature' of January 3, 1895), takes the entirely indefensible position that the latter is bound to prove the higher internal conductivity. The obligation is all on the other side, and rests with those who have pressed their conclusions hard and carried them far. These conclusions have been, as Darwin found them, one of our 'sorest troubles'; but when it is admitted that there is just as much to be said for another set of assumptions leading to entirely different conclusions, our troubles are at an end, and we cease to be terrified by an array of symbols, however unintelligible to us. It would seem that Professor Tait, without, as far as I can learn, publishing any independent calculation of the age of the earth, has lent the weight of his authority to a period of ten million years, or half of Lord Kelvin's minimum. But in making this suggestion he apparently feels neither interest nor responsibility in establishing the data of the calculations which he borrowed to obtain therefrom a very different result from that obtained by their author.

Professor Perry's object was not to substitute a more correct age for that obtained by Lord Kelvin, but rather to show that the data from which the true age could be calculated are not really available. We obtain different results by making different assumptions, and there is no sufficient evidence for accepting one assumption rather than another. Nevertheless, there is some evidence which indicates that the interior of the earth in all probability conducts better than the surface. Its far higher density is consistent with the belief that it is rich in metals, free or combined. Professor Schuster concludes that the internal electric conductivity must be considerably greater than the external. Geologists have argued from the amount of folding to which the crust has been subjected that cooling must have taken place to a greater depth than 120 miles, as assumed in Lord Kelvin's argument. Professor Perry's assumption would involve cooling to a much greater depth.

Professor Perry's conclusion that the age of the habitable earth is lengthened by increased conductivity is the very reverse of that to which we should be led by a superficial examination of the case. Professor Tait, indeed, in the letter to which I have already alluded, has said: 'Why, then, drag in mathematics at all, since it is absolutely obvious that the better conductor the interior in comparison with the skin, the longer ago must it have been when the whole was at 7000 F., the state of the skin being as at present?' Professor Perry, in reply, pointed out that one mathematician who had refuted the tidal retardation argument [1] had assumed that the conditions described by Professor Tait would have involved a shorter period of time. And it is probable that Lord Kelvin thought the same; for he had assumed conditions which would give the result—so he believed at the time—most acceptable to the geologist and biologist. Professor Perry's conclusion is very far from obvious, and without the mathematical reasoning would not be arrived at by the vast majority of thinking men.

The 'natural man' without mathematics would say, so far from this being 'absolutely obvious,' it is quite clear that increased conductivity, favouring escape of heat, would lead to more rapid cooling, and would make Lord Kelvin's age even shorter.

The argument can, however, be put clearly without mathematics, and, with Professor Perry's help, I am able to state it in a few words. Lord Kelvin's assumption of an earth resembling the surface rock in its relations to heat leads to the present condition of things, namely, a surface gradient of 1° F. for every 50 feet, in 100,000,000 years, more or less. Deeper than 150 miles he imagines

[1] Rev. M. H. Close in *R. Dublin Soc.*, February 1878.

that there has been almost no cooling. If, however, we take one of the cases put by Professor Perry, and assume that below a depth of four miles there is ten times the conductivity, we find that after a period of 10,000,000,000 years the gradient at the surface is still 1° F. for every 50 feet; but that we have to descend to a depth of 1500 miles before we find the initial temperature of 7000° F. undiminished by cooling. In fact the earth, as a whole, has cooled far more quickly than under Lord Kelvin's conditions, the greater conductivity enabling a far larger amount of the internal heat to escape; but in escaping it has kept up the temperature gradient at the surface.

Lord Kelvin, replying to Professor Perry's criticisms, quite admits that the age at which he had arrived by the use of this argument may be insufficient. Thus, he says, in his letter:[1] 'I thought my range from twenty millions to 400 millions was probably wide enough, but it is quite possible that I should have put the superior limit a good deal higher, perhaps 4000 instead of 400.'

The third argument was suggested by Helmholtz, and depends on the life of the sun. If the energy of the sun is due only to the mutual gravitation of its parts, and if the sun is now of uniform density, 'the amount of heat generated by his contraction to his present volume would have been sufficient to last eighteen million years at his present rate of radiation.'[2] Lord Kelvin rejects the assumption of uniform density, and is, in consequence of this change, able to offer a much higher upward limit of 500 million years.

This argument also implies the strictest uniformitarianism as regards the sun. We know that other suns may suddenly gain a great accession of energy, so that their radiation is immensely increased. We only detect such changes when they are large and sudden, but they prepare us to believe that smaller accessions may be much more frequent, and perhaps a normal occurrence in the evolution of a sun. Such accessions may have followed from the convergence of a stream of meteors. Again, it is possible that the radiation of the sun may have been diminished and his energy conserved by a solar atmosphere.

Newcomb has objected to these two possible modes by which the life of the sun may have been greatly lengthened, that a lessening of the sun's heat by under a quarter would cause all the water on the earth to freeze, while an increase of much over half would probably boil it all away. But such changes in the amount of radiation received would follow from a greater distance from the sun of 15½ per cent., and a greater proximity to him of 18·4 per cent., respectively. Venus is inside the latter limit, and Mars outside the former; and yet it would be a very large assumption to conclude that all the water in the former is steam, and all in the latter ice. Indeed, the existence of water and the melting of snow on Mars are considered to be thoroughly well authenticated. It is further possible that in a time of lessened solar radiation the earth may have possessed an atmosphere which would retain a larger proportion of the sun's heat; and the internal heat of the earth itself, great lakes of lava under a canopy of cloud for example, may have played an important part in supplying warmth.

Again we have a greater age if there was more energy available than in Helmholtz's hypothesis. Lord Kelvin maintains that this is improbable because of the slow rotation of the sun, but Perry has given reasons for an opposite conclusion.

The collapse of the first argument of tidal retardation and of the second of the cooling of the earth warn us to beware of a conclusion founded on the assumption that the sun's energy depends, and has ever depended, on a single source of which we know the beginning and the end. It may be safely maintained that such a conclusion has not that degree of certainty which justifies the followers of one science in assuming that the conclusion of other sciences must be wrong, and in disregarding the evidence brought forward by workers in other lines of research.

We must freely admit that this third argument has not yet fully shared the fate

[1] *Nature*, January 3, 1895.
[2] Newcomb's *Popular Astronomy*, p. 523.

of the two other lines of reasoning. Indeed, Professor George Darwin, although not feeling the force of these latter, agrees with Lord Kelvin in regarding 500 million years as the maximum life of the sun.[1]

We may observe, too, that 500 million years is by no means to be despised; a great deal may happen in such a period of time. Although I should be very sorry to say that it is sufficient, it is a very different offer from Professor Tait's ten million.

In drawing up this account of the physical arguments, I owe almost everything to Professor Perry for his articles in 'Nature' (January 3 and April 18, 1895), and his kindness in explaining any difficulties that arose. I have thought it right to enter into these arguments in some detail, and to consume a considerable proportion of our time in their discussion. This was imperatively necessary, because they claimed to stand as barriers across our path, and, so long as they were admitted to be impassable, any further progress was out of the question. What I hope has been an unbiassed examination has shown that, as barriers, they are more imposing than effective; and we are free to proceed, and to look for the conclusions warranted by our own evidence. In this matter we are at one with the geologists; for, as has been already pointed out, we rely on them for an estimate of the time occupied by the deposition of the stratified rocks, while they rely on us for a conclusion as to how far this period is sufficient for the whole of organic evolution.

First, then, we must briefly consider the geological argument, and I cannot do better than take the case as put by Sir Archibald Geikie in his Presidential Address to this Association at Edinburgh in 1892.

Arguing from the amount of material removed from the land by denuding agencies, and carried down to the sea by rivers, he showed that the time required to reduce the height of the land by one foot varies, according to the activity of the agencies at work, from 730 years to 6800 years. But this also supplies a measure of the rate of deposition of rock; for the same material is laid down elsewhere, and would of course add the same height of one foot to some other area equal in size to that from which it was removed.

The next datum to be obtained is the total thickness of the stratified rocks from the Cambrian system to the present day. 'On a reasonable computation these stratified masses, where most fully developed, attain a united thickness of not less than 100,000 feet. If they were all laid down at the most rapid recorded rate of denudation, they would require a period of seventy-three millions of years for their completion. If they were laid down at the slowest rate, they would demand a period of not less than 680 millions.'

The argument that geological agencies acted much more vigorously in past times he entirely refuted by pointing to the character of the deposits of which the stratified series is composed. 'We can see no proof whatever, nor even any evidence which suggests that on the whole the rate of waste and sedimentation was more rapid during Mesozoic and Palæozoic time than it is to-day. Had there been any marked difference in this rate from ancient to modern times, it would be incredible that no clear proof of it should have been recorded in the crust of the earth.'

It may therefore be inferred that the rate of deposition was no nearer the more rapid than the slower of the rates recorded above, and, if so, the stratified rocks would have been laid down in about 400 million years.

There are other arguments favouring the uniformity of conditions throughout the time during which the stratified rocks were laid down, in addition to those which are purely geological and depend upon the character of the rocks themselves. Although more biological than geological, these arguments are best considered here.

The geological agency to which attention is chiefly directed by those who desire to hurry up the phenomena of rock formation is that of the tides. But it seems

[1] *British Association Reports*, 1886, pp. 514–518.

certain that the tides were not sufficiently higher in Silurian times to prevent the deposition of certain beds of great thickness under conditions as tranquil as any of which we have evidence in the case of a formation extending over a large area. From the character of the organic remains it is known that these beds were laid down in the sea, and there are the strongest grounds for believing that they were accumulated along shores and in fairly shallow water. The remains of extremely delicate organisms are found in immense numbers, and over a very large area. The recent discovery, in the Silurian system of America, of trilobites, with their long delicate antennæ perfectly preserved, proves that in one locality (Rome, New York State) the tranquillity of deposition was quite as profound as in any locality yet discovered on this side of the Atlantic.

There are, then, among the older Palæozoic rocks a set of deposits than which we can imagine none better calculated to test the force of the tides; and we find that they supply evidence for exceptional tranquillity of conditions over a long period of time.

There is other evidence of the permanence, throughout the time during which the stratified rocks were deposited, of conditions not very dissimilar to those which obtain to-day. Thus the attachments of marine organisms, which are permanently rooted to the bottom or on the shores, did not differ in strength from those which we now find—an indication that the strains due to the movements of the sea did not greatly differ in the past.

We have evidence of a somewhat similar kind to prove uniformity in the movements of the air. The expanse of the wings of flying organisms certainly does not differ in a direction which indicates any greater violence in the atmospheric conditions. Before the birds had become dominant among the larger flying organisms, their place was taken by the flying reptiles, the pterodactyls, and before the appearance of these we know that, in Palæozoic times, the insects were of immense size, a dragon-fly from the Carboniferous rocks of France being upwards of 2 feet in the expanse of its wings. As one group after another of widely dissimilar organisms gained control of the air, each was in turn enabled to increase to the size which was best suited to such an environment, but we find that the limits which obtain to-day were not widely different in the past. And this is evidence for the uniformity in the strains due to wind and storm no less than to those due to gravity. Furthermore, the condition of the earth's surface at present shows us how extremely sensitive the flying organism is to an increase in the former of these strains, when it occurs in proximity to the sea. Thus it is well known that an unusually large proportion of the Madeiran beetles are wingless, while those which require the power of flight possess it in a stronger degree than on continental areas. This evolution in two directions is readily explained by the destruction by drowning of the winged individuals of the species which can manage to live without the power of flight, and of the less strongly winged individuals of those which need it. Species of the latter kind cannot live at all in the far more stormy Kerguelen Land, and the whole of the insect fauna is wingless.

The size and strength of the trunks of fossil trees afford, as Professor George Darwin has pointed out, evidence of uniformity in the strains due to the condition of the atmosphere.

We can trace the prints of raindrops at various geological horizons, and in some cases found in this country it is even said that the eastern side of the depressions is the more deeply pitted, proving that the rain drove from the west, as the great majority of our storms do to-day.

When, therefore, we are accused of uniformitarianism, as if it were an entirely unproved assumption, we can at any rate point to a large body of positive evidence which supports our contention, and the absence of any evidence against it. Furthermore, the data on which we rely are likely to increase largely, as the result of future work.

After this interpolation, chiefly of biological argument in support of the geologist, I cannot do better than bring the geological evidence to a close in the words which conclude Sir Archibald Geikie's address: 'After careful reflection on the subject, I affirm that the geological record furnishes a mass of evidence which no arguments drawn from other departments of Nature can explain away, and which, it seems to me, cannot be satisfactorily interpreted save with an allowance of time much beyond the narrow limits which recent physical speculation would concede.'

In his letter to Professor Perry,[1] Lord Kelvin says:—

'So far as underground heat alone is concerned, you are quite right that my estimate was 100 million, and please remark[2] that that is all Geikie wants; but I should be exceedingly frightened to meet him now with only twenty million in my mouth.'

We have seen, however, that Geikie considered the rate of sedimentation to be, on the whole, uniform with that which now obtains, and this would demand a period of nearly 400 million years. He points out, furthermore, that the time must be greatly increased on account of the breaks and interruptions which occur in the series, so that we shall probably get as near an estimate as is possible from the data which are available by taking 450 million as the time during which the stratified rocks were formed.

Before leaving this part of the subject, I cannot refrain from suggesting a line of inquiry which may very possibly furnish important data for checking the estimates at present formed by geologists, and which, if the mechanical difficulties can be overcome, is certain to lead to results of the greatest interest and importance. Ever since the epoch-making voyage of the 'Challenger,' it has been known that the floor of the deep oceans outside the shallow shelf which fringes the continental areas is covered by a peculiar deposit formed entirely of meteoric and volcanic dust, the waste of floating pumice, and the hard parts of animals living in the ocean. Of these latter only the most resistant can escape the powerful solvent agencies. Many observations prove that the accumulation of this deposit is extremely slow. One indication of this is especially convincing: the teeth of sharks and the most resistant part of the skeleton—the ear-bones—of whales are so thickly spread over the surface that they are continually brought up in the dredge, while sometimes a single haul will yield a large number of them. Imagine the countless generations of sharks and whales which must have succeeded each other in order that these insignificant portions of them should be so thickly spread over that vast area which forms the ocean floor! We have no reason to suppose that sharks and whales die more frequently in the deep ocean than in the shallow fringing seas; in fact, many observations point in the opposite direction, for wounded and dying whales often enter shallow creeks and inlets, and not uncommonly become stranded. And yet these remains of sharks and whales, although well known in the stratified rocks which were laid down in comparatively shallow water and near coasts, are only found in certain beds, and then in far less abundance than in the oceanic deposit. We can only explain this difference by supposing that the latter accumulate with such almost infinite slowness as compared with the continental deposits that these remains form an important and conspicuous constituent of the one, while they are merely found here and there when looked for embedded in the other. The rate of accumulation of all other constituents is so slow as to leave a layer of teeth and ear-bones uncovered, or covered by so thin a deposit that the dredge can collect them freely. Dr. John Murray calculates that only a few inches of this deposit have accumulated since the Tertiary period. These most interesting facts prove, furthermore, that the great ocean basins and continental areas have occupied the same relative positions since the formation of the first stratified rocks; for no oceanic deposits are found anywhere in the latter. We know the sources of the oceanic deposit, and it might be possible to form an estimate, within wide limits, of its rate of accumulation. If it were possible to ascertain its thickness by means of a boring, some conclusions as to the time which has elapsed during the lifetime of certain species—perhaps even the lifetime of the oceans themselves—might be arrived at. Lower down the remains of earlier species would probably be found. The depth of this deposit and its character at deeper levels are questions of overwhelming interest; and perhaps even more so is

[1] *Nature*, Jan. 3, 1895. [2] *P. L. and A.*, vol. ii. p. 87.

the question as to what lies beneath. Long before the 'Challenger' had proved the persistence of oceanic and continental areas, Darwin, with extraordinary foresight, and opposed by all other naturalists and geologists, including his revered teacher, Lyell, had come to the same conclusion. His reasoning on the subject is so convincing that it is remarkable that he made so few converts, and this is all the more surprising since the arguments were published in the 'Origin of Species,' which in other respects produced so profound an effect. In speculating as to the rocks in which the remains of the ancestors of the earliest known fossils may still exist, he suggested that, although the existing relationship between the positions of our present oceans and continental areas is of immense antiquity, there is no reason for the belief that it has persisted for an indefinite period, but that at some time long antecedent to the earliest known fossiliferous rocks 'continents may have existed where oceans are now spread out; and clear and open oceans may have existed where our continents now stand.' Not the least interesting result would be the test of this hypothesis, which would probably be forthcoming as the result of boring into the floor of a deep ocean; for although, as Darwin pointed out, it is likely enough that such rocks would be highly metamorphosed, yet it might still be possible to ascertain whether they had at any time formed part of a continental deposit, and perhaps to discover much more than this. Such an undertaking might be carried out in conjunction with other investigations of the highest interest, such as the attempt to obtain a record of the swing of a pendulum at the bottom of the ocean.

We now come to the strictly biological part of our subject—to the inquiry as to how much of the whole scheme of organic evolution has been worked out in the time during which the fossiliferous rocks were formed, and how far, therefore, the time required by the geologist is sufficient.

It is first necessary to consider Lord Kelvin's suggestion that life may have reached the earth on a meteorite—a suggestion which might be made the basis of an attempt to rescue us from the dilemma in which we were placed by the insufficiency of time for evolution. It might be argued that the evolution which took place elsewhere may have been merely completed, in a comparatively brief space of time, on our earth.

We know nothing of the origin of life here or elsewhere, and our only attitude towards this or any other hypothesis on the subject is that of the anxious inquirer for some particle of evidence. But a few brief considerations will show that no escape from the demands for time can be gained in this way.

Our argument does not deal with the time required for the origin of life, or for the development of the lowest beings with which we are acquainted from the first formed beings, of which we know nothing. Both these processes may have required an immensity of time; but as we know nothing whatever about them, and have as yet no prospect of acquiring any information, we are compelled to confine ourselves to as much of the process of evolution as we can infer from the structure of living and fossil forms—that is, as regards animals, to the development of the simplest into the most complex Protozoa, the evolution of the Metazoa from the Protozoa, and the branching of the former into its numerous Phyla, with all their classes, orders, families, genera, and species. But we shall find that this is quite enough to necessitate a very large increase in the time estimated by the geologist.

The Protozoa, simple and complex, still exist upon the earth in countless species, together with the Metazoan Phyla. Descendants of forms which in their day constituted the beginning of that scheme of evolution which I have defined above, descendants, furthermore, of a large proportion of those forms which, age after age, constituted the shifting phases of its onward progress, still exist, and in a sufficiently unmodified condition to enable us to reconstruct, at any rate in mere outline, the history of the past. Innumerable details and many phases of supreme importance are still hidden from us, some of them perhaps never to be recovered. But this frank admission, and the eager and premature attempts to expound too much, to go further than the evidence permits, must not be allowed to throw an undeserved suspicion upon conclusions which are sound and well supported, upon the firm conviction of every zoologist that the general trend of evolution has been, as I have stated it, that each of the Metazoan Phyla originated, directly or indirectly, in the Protozoa.

The argument founded on the meteorite hypothesis would, however, require that the process of evolution went backward on a scale as vast as that on which it went forward; that certain descendants of some central type, coming to the earth on a meteorite, gradually lost their Metazoan complexity and developed backward into the Protozoa, throwing off the lower Metazoan Phyla on the way, while certain other descendants evolved all the higher Metazoan groups. Such a process would shorten the period of evolution by half, but it need hardly be said that all available evidence is entirely against it.

The only other assumption by means of which the meteorite hypothesis might be used to shorten the time is even more wild and improbable. Thus it might be supposed that the evolution which we believe to have taken place on this earth really took place elsewhere—at any rate as regards all its main lines—and that samples of all the various phases, including the earliest and simplest, reached us by a regular meteoric service, which was established at some time after the completion of the scheme of organic evolution. Hence the evidences which we study would point to an evolution which occurred in some unknown world with an age which even Professor Tait has no desire to limit.

If these wild assumptions be rejected, there remains the supposition that, if life was brought by a meteorite, it was life no higher than that of the simplest Protozoon—a supposition which leaves our argument intact. The alternative supposition, that one or more of the Metazoan Phyla were introduced in this way while the others were evolved from the terrestrial Protozoa, is hardly worth consideration. In the first place, some evidence of a part in a common scheme of evolution is to be found in every Phylum. In the second place, the gain would be small; the arbitrary assumption would only affect the evidence of the time required for evolution derived from the particular Phylum or Phyla of supposed meteoric origin.

The meteoric hypothesis, then, can only affect our argument by making the most improbable assumptions, for which, moreover, not a particle of evidence can be brought forward.

We are therefore free to follow the biological evidence fearlessly. It is necessary, in the first place, to expand somewhat the brief outline of the past history of the animal kingdom, which has already been given. Since the appearance of the 'Origin of Species,' the zoologist, in making his classifications, has attempted as far as possible to set forth a genealogical arrangement. Our purpose will be served by an account of the main outlines of a recent classification, which has been framed with a due consideration for all sides of zoological research, new and old, and which has met with general approval. Professor Lankester divides the animal kingdom into two grades, the higher of which, the Enterozoa (Metazoa), were derived from the lower, the Plastidozoa (Protozoa). Each of these grades is again divided into two sub-grades, and each of these is again divided into Phyla, corresponding more or less to the older sub-kingdoms. Beginning from below, the most primitive animals in existence are found in the seven Phyla of the lower Protozoan sub-grade, the Gymnomyxa. Of these unfortunately only two, the Reticularia (Foraminifera) and Radiolaria, possess a structure which renders possible their preservation in the rocks. The lowest and simplest of these Gymnomyxa represent the starting-point of that scheme of organic evolution which we are considering to-day. The higher order of Protozoan life, the sub-grade Corticata, contains three Phyla, no one of which is available in the fossil state. They are, however, of great interest and importance to us as showing that the Protozoan type assumes a far higher organisation on its way to evolve the more advanced grade of animal life. The first-formed of these latter are contained in the two Phyla of the sub-grade Cœlentera, the Porifera or Sponges, and the Nematophora or Corals, Sea-anemones, Hydrozoa and allied groups. Both of these Phyla are plentifully represented in the fossil state. It is considered certain that the latter of these, the Nematophora, gave rise to the higher sub-grade, the Cœlomata, or animals with a cœlom or body-cavity surrounding the digestive tract. This latter includes all the remaining species of animals in nine Phyla, five of which are found fossil—the Echinoderma, Gephyrea, Mollusca, Appendiculata, and Vertebrata.

Before proceeding further I wish to lay emphasis on the immense evolutionary history which must have been passed through before the ancestor of one of the higher of these nine Phyla came into being. Let us consider one or two examples, since the establishment of this position is of the utmost importance for our argument. First, consider the past history of the Vertebrata—of the common ancestor of our Balanoglossus, Tunicates, Amphioxus, Lampreys, Fishes, Dipnoi, Amphibia, Reptiles, Birds, and Mammals. Although zoologists differ very widely in their opinions as to the affinities of this ancestral form, they all agree in maintaining that it did not arise direct from the Nematophora in the lower sub-grade of Metazoa, but that it was the product of a long history within the Cœlomate sub-grade. The question as to which of the other Cœlomate Phyla it was associated with will form the subject of one of our discussions at this meeting; and I will therefore say no more upon this period of its evolution, except to point out that the very question itself, 'the ancestry of Vertebrates,' only means a relatively small part of the evolutionary history of the Vertebrate ancestor within the Cœlomate group. For when we have decided the question of the other Cœlomate Phylum or Phyla to which the ancestral Vertebrate belonged, there remains of course the history of that Phylum or those Phyla earlier than the point at which the Vertebrate diverged, right back to the origin of the Cœlomata; while, beyond and below, the wide gulf between this and the Cœlentera had to be crossed, and then, probably after a long history as a Cœlenterate, the widest and most significant of all the morphological intervals—that between the lowest Metazoon and the highest Protozoon—was traversed. But this was by no means all. There remains the history within the higher Protozoan sub-grade, in the interval from this to the lower, and within the lower sub-grade itself, until we finally retrace our steps to the lowest and simplest forms. It is impossible to suppose that all this history of change can have been otherwise than immensely prolonged; for it will be shown below that all the available evidence warrants the belief that the changes during these earlier phases were at least as slow as those which occurred later.

If we take the history of another of the higher Phyla, the Appendiculata, we find that the evidence points in the same direction. The common ancestor of our Rotifera, earthworms, leeches, Peripatus, centipedes, insects, Crustacea, spiders and scorpions, and forms allied to all these, is generally admitted to have been Chætopod-like, and probably arose in relation to the beginnings of certain other Cœlomate Phyla, such as the Gephyrea and perhaps Mollusca. At the origin of the Cœlomate sub-grade the common ancestor of all Cœlomate Phyla is reached, and its evolution has been already traced in the case of the Vertebrata.

What is likely to be the relation between the time required for the evolution of the ancestor of a Cœlomate Phylum and that required for the evolution, which subsequently occurred, within the Phylum itself? The only indication of an answer to this question is to be found in a study of the rate of evolution in the lower parts of the animal kingdom as compared with that in the higher. Contrary, perhaps, to anticipation, we find that all the evidences of rapid evolution are confined to the most advanced of the smaller groups within the highest Phyla, and especially to the higher classes of the Vertebrata. Such evidence as we have strongly indicates the most remarkable persistence of the lower animal types. Thus in the class Imperforata of the Reticularia (Foraminifera) one of our existing genera (Saccamina) occurs in the Carboniferous strata, another (Trochammina) in the Permian, while a single new genus (Receptaculites) occurs in the Silurian and Devonian. The evidence from the class Perforata is much stronger, the existing genera Nodosaria, Dentalina, Textularia, Grammostomum, Valvulina, and Nummulina all occurring in the Carboniferous, together with the new genera Archædiscus (?) and Fusulina.

I omit reference to the much-disputed Eozoon from the Laurentian rocks far below the horizon, which for the purpose of this address I am considering as the lowest fossiliferous stratum. We are looking forward to the new light which will be thrown upon this form in the communication of its veteran defender, Sir William Dawson, whom we are all glad to welcome.

Passing the Radiolaria, with delicate skeletons less suited for fossilisation, and largely pelagic, and therefore less likely to reach the strata laid down along the fringes of the continental areas, the next Phylum which is found in a fossil state is that of the Porifera, including the sponges, and divided into two classes, the Calcispongiæ and Silicospongiæ. Although the fossilisation of sponges is in many cases very incomplete, distinctly recognisable traces can be made out in a large number of strata. From these we know that representatives of all the groups of both classes (except the Halisarcidæ, which have no hard parts) occurred in the Silurian, Devonian, and Carboniferous systems. The whole Phylum is an example of long persistence with extremely little change. And the same is true of the Nematophora: new groups indeed come in, sometimes extremely rich in species, such as the Palæozoic Rugose corals and Graptolites; but they existed side by side with representatives of existing groups, and they are not in themselves primitive or ancestral. A study of the immensely numerous fossil corals reveals no advance in organisation, while researches into the structure of existing Alcyonaria and Hydrocorallina have led to the interpretation of certain Palæozoic forms which were previously obscure, and the conclusion that they find their place close beside the living species.

All available evidence points to the extreme slowness of progressive evolutionary changes in the Cœlenterate Phyla, although the Protozoa, if we may judge by the Reticularia (Foraminifera), are even more conservative.

When we consider later on the five Cœlomate Phyla which occur fossil, we shall find that the progressive changes were slower and indeed hardly appreciable in the two lower and less complex Phyla, viz., the Echinoderma, and Gephyrea, as compared with the Mollusca, Appendiculata, and Vertebrata.

Within these latter Phyla we have evidence for the evolution of higher groups presenting a more or less marked advance in organisation. And not only is the rate of development more rapid in the highest Phyla of the animal kingdom, but it appears to be most rapid when dealing with the highest animal tissue, the central nervous system. The chief, and doubtless the most significant, difference between the early Tertiary mammals and those which succeeded them, between the Secondary and Tertiary reptiles, between man and the mammals most nearly allied to him, is a difference in the size of the brain. In all these cases an enormous increase in this, the dominant tissue of the body, has taken place in a time which, geologically speaking, is very brief.

When glancing later on over the evolution which has taken place within the Phyla, further details upon this subject will be given, although in this as in other cases the time at our disposal demands that the exposition of evidence must largely yield to an exposition of the conclusions which follow from its study. And undoubtedly a study of all the available evidence points to the conclusion that in the lower grade, sub-grades, and Phyla of the animal kingdom evolution has been extremely slow as compared with that in the higher. We do not know the reason. It may be that this remarkable persistence through the stratified series of deposits is due to an innate fixity of constitution which has rigidly limited the power of variation; or, more probably perhaps, that the lower members of the animal kingdom were, as they are now, more closely confined to particular environments, with particular sets of conditions, with which they had to cope, and, this being successfully accomplished, natural selection has done little more than keep up a standard of organisation which was sufficient for their needs; while the higher and more aggressive forms, ranging over many environments and always prone to encounter new sets of conditions, were compelled to undergo responsive changes or to succumb. But, whatever be the cause, the fact remains, and is of importance for our argument. When the ancestor of one of the higher Phyla was associated with the lower Phyla of the Cœlomate sub-grade, when further back it passed through a Cœlenterate, a higher Protozoan, and finally a lower

Protozoan phase, we are led to believe that its evolution was probably very slow as compared with the rate which it subsequently attained. But this conclusion is of the utmost importance; for the history contained in the stratified rocks nowhere reveals to us the origin of a Phylum. And this is not mere negative evidence, but positive evidence of the most unmistakable character. All the five Cœlomate Phyla which occur fossil appear low down in the Palæozoic rocks, in the Silurian or Cambrian strata, and they are represented by forms which are very far from being primitive, or, if primitive, are persistent types, such as Chiton, which are now living. Thus Vertebrata are represented by fishes, both sharks and ganoids; the Appendiculata by cockroaches, scorpions, Limulids, Trilobites, and many Crustacea; the Mollusca by Nautilus and numerous allied genera, by Dentalium, Chiton, Pteropods, and many Gastropods and Lamellibranchs; the Gephyrea by very numerous Brachiopods, and many Polyzoa; the Echinoderma by Crinoids, Cystoids, Blastoids, Asteroids, Ophiuroids, and Echinoids. It is just conceivable, although, as I believe, most improbable, that the Vertebrate Phylum originated at the time when the earliest known fossiliferous rocks were laid down. It must be remembered, however, that an enormous morphological interval separates the fishes which appear in the Silurian strata from the lower branches, grades, and classes of the Phylum in which Balanoglossus, the Ascidians, Amphioxus, and the Lampreys are placed. The earliest Vertebrates to appear are, in fact, very advanced members of the Phylum, and, from the point of view of anatomy, much nearer to man than to Amphioxus. If, however, we grant the improbable contention that so highly organised an animal as a shark could be evolved from the ancestral vertebrate in the period which intervened between the earliest Cambrian strata and the Upper Silurian, it is quite impossible to urge the same with regard to the other Phyla. It has been shown above that when these appear in the Cambrian and Silurian, they are flourishing in full force, while their numerous specialised forms are a positive proof of a long antecedent history within the limits of the Phylum.

If, however, we assume for the moment that the Phyla began in the Cambrian, the geologist's estimate must still be increased considerably, and perhaps doubled, in order to account for the evolution of the higher Phyla from forms as low as many which are now known upon the earth; unless, indeed, it is supposed, against the weight of all such evidence as is available, that the evolutionary history in these early times was comparatively rapid.

To recapitulate, if we represent the history of animal evolution by the form of a tree, we find that the following growth took place in some age antecedent to the earliest fossil records, before the establishment of the higher Phyla of the animal kingdom. The main trunk representing the lower Protozoa divided, originating the higher Protozoa; the latter portion again divided, probably in a threefold manner, originating the two lowest Metazoan Phyla, constituting the Cœlentera. The branch representing the higher of these Phyla, the Nematophora, divided, originating the lower Cœlomate Phyla, which again branched and originated the higher Phyla. And, as has been shown above, the relatively ancestral line, at every stage of this complex history, after originating some higher line, itself continued down to the present day, throughout the whole series of fossiliferous rocks, with but little change in its general characters, and practically nothing in the way of progressive evolution. Evidences of marked advance are to be found alone in the most advanced groups of the latest highest products—the Phyla formed by the last of these divisions.

It may be asked, How is it possible for the zoologist to feel so confident as to the past history of the various animal groups? I have already explained that he does not feel this confidence as regards the details of the history, but as to its general lines. The evidence which leads to this conviction is based upon the fact that animal structure and mode of development can be, and have been, handed down from generation to generation from a period far more remote than that which is represented by the earliest fossils; that fundamental facts in structure and development may remain changeless amid endless changes of a more general character; that especially favourable conditions have preserved ancestral forms comparatively unchanged. Working upon this material, comparative anatomy and embryology can reconstruct for us the general aspects of a history which took place long before the Cambrian rocks were deposited. This line of reasoning may appear very speculative and unsound, and it may easily become so when pressed too far. But applied with due caution and reserve, it may be trusted to supply us with an immense amount of valuable information which cannot be obtained in any other way. Furthermore, it is capable of standing the very true and searching test supplied by the verification of predictions made on its authority. Many facts taken together lead the zoologist to believe that A was descended from C through B; but if this be true, B should possess certain characters which are not known to belong to it. Under the inspiration of hypothesis a more searching investigation is made, and the characters are found. Again, that relatively small amount of the whole scheme of animal evolution which is contained in the fossiliferous rocks has furnished abundant confirmation of the validity of the zoologist's method. The comparative anatomy of the higher vertebrate classes leads the zoologist to believe that the toothless beak and the fused caudal vertebræ of a bird were not ancestral characters, but were at some time derived from a condition more conformable to the general plan of vertebrate construction, and especially to that of reptiles. Numerous secondary fossils prove to us that the birds of that time possessed teeth and separate caudal vertebræ, culminating in the long lizard-like tail of Archæopteryx.

Prediction and confirmation of this kind, both zoological and palæontological, have been going on ever since the historic point of view was adopted by the naturalist as the outcome of Darwin's teaching, and the zoologist may safely claim that his method, confirmed by palæontology so far as evidence is available, may be extended beyond the period in which such evidence is to be found.

And now our last endeavour must be to obtain some conception of the amount of evolution which has taken place within the higher Phyla of the animal kingdom during the period in which the fossiliferous rocks were deposited. The evidence must necessarily be considered very briefly, and we shall be compelled to omit the Vertebrata altogether.

The Phylum Appendiculata is divided by Lankester into three branches, the first containing the Rotifera, the second the Chætopoda, the third the Arthropoda. Of these the second is the oldest, and gave rise to the other two, or at any rate to the Arthropoda, with which we are alone concerned, inasmuch as the fossil records of the others are insufficient. The Arthropoda contain seven classes, divided into two grades, according to the presence or absence of antennæ—the Ceratophora, containing the Peripatoidea, the Myriapoda, and the Hexapoda (or insects); the Acerata, containing the Crustacea, Arachnida, and two other classes (the Pantopoda and Tardigrada) which we need not consider. The first class of the antenna-bearing group contains the single genus Peripatus—one of the most interesting and ancestral of animals, as proved by its structure and development, and by its immense geographical range. Ever since the researches of Moseley and Balfour, extended more recently by those of Sedgwick, it has been recognised as one of the most beautiful of the connecting links to be found amongst animals, uniting the antenna-bearing Arthropods, of which it is the oldest member, with the Chætopods. Peripatus is a magnificent example of the far-reaching conclusions of zoology, and of its superiority to palæontology as a guide in unravelling the tangled history of animal evolution. Peripatus is alive to-day, and can be studied in all the details of its structure and development; it is infinitely more ancestral, and tells of a far more remote past than any fossil Arthropod, although such fossils are well known in all the older of the Palæozoic rocks. And yet Peripatus is not known as a fossil. Peripatus has come down, with but little change, from a time, on a moderate estimate, at least twice as remote, and probably many times as remote, as the earliest known Cambrian fossil. The agencies which, it is believed, have crushed and heated the Archæan rocks so as to obliterate the traces of life which they contained were powerless to efface this ancient type; for, although the passing generations may have escaped record, the likeness of each was stamped on that which succeeded it, and has continued down to the present day. It is, of course, a perfectly trite and obvious conclusion, but not the less one to be wondered at, that the force of heredity should thus far outlast the ebb and flow of terrestrial change throughout the vast period over which the geologist is our guide.

If, however, the older Palæozoic rocks tell us nothing of the origin of the antenna-bearing Arthropods, what do they tell us of the history of the Myriapod and Hexapod classes?

The Myriapods are well represented in Palæozoic strata, two species being found in the Devonian and no less than thirty-two in the Carboniferous. Although placed in an order (Archipolypoda) separate from those of living Myriapods, these species are by no means primitive, and do not supply any information as to the steps by which the class arose. The imperfection of the record is well seen in the traces of this class; for between the Carboniferous rocks and the Oligocene there are no remains of undoubted Myriapods.

We now come to the consideration of insects, of which an adequate discussion would occupy a great deal too much of your time. An immense number of species are found in the Palæozoic rocks, and these are considered by Scudder, the great authority on fossil insects, to form an order, the Palæodictyoptera, distinct from any of the existing orders. The latter, he believes, were evolved from the former in Mesozoic times. These views do not appear to derive support from the wonderful discoveries of M. Brongniart [1] in the Upper Carboniferous of Commentry in the Department of Allier in Central France. Concerning this marvellous assemblage of species, arranged by their discoverer into 46 genera and 101 species, Scudder truly says:—

'Our knowledge of Palæozoic insects will have been increased three or four fold at a single stroke. . . . . No former contribution in this field can in any way compare with it, nor even all former contributions taken together.' [2]

When we remember that the group of fossil insects, of which so much can be affirmed by so great an authority as Scudder, lived at one time and in a single locality, we cannot escape the conclusion that the insect fauna of the habitable earth during the whole Palæozoic period was of immense importance and variety. Our knowledge of this single group of species is largely due to the accident that coal-mining in Commentry is carried on in the open air.

Now, these abundant remains of insects, so far from upholding the view that the existing orders had not been developed in Palæozoic times, are all arranged by Brongniart in four out of the nine orders into which insects are usually divided, viz., the Orthoptera, Neuroptera, Thysanoptera, and Homoptera. The importance of the discovery is well seen in the Neuroptera, the whole known Palæozoic fauna of this order being divided into 45 genera and 99 species, of which 33 and 72 respectively have been found at Commentry.

Although the Carboniferous insects of Commentry are placed in new families, some of them come wonderfully near those into which existing insects are classified, and obviously form the precursors of these. This is true of the Blattidæ, Phasmidæ, Acridiidæ, and Locustidæ among the Orthoptera, the Perlidæ among the Neuroptera, and the Fulgoridæ among the Homoptera. The differences which separate these existing families from their Carboniferous ancestors are most interesting and instructive. Thus the Carboniferous cockroaches possessed ovipositors, and probably laid their eggs one at a time, while ours are either viviparous or lay their eggs in a capsule. The Protophasmidæ resemble living species in the form of the head, antennæ, legs, and body; but while our species are either wingless or, with the exception of the female Phyllidæ, have the anterior pair reduced to tegmina, useless for flight, those of Palæozoic times possessed four well-developed wings. The forms representing locusts and grasshoppers (Palæacridiidæ) possessed long slender antennæ like the green grasshoppers (Locustidæ), from which the Acridiidæ are now distinguished by their short antennæ. The divergence and specialisation which are thus shown are amazingly small in amount. In

[1] Ch. Brongniart.—'Recherches pour servir à l'Histoire des Insectes fossiles des temps primaires, précédées d'une Etude sur la nervation des ailes des Insectes.' 1894.
[2] S. H. Scudder, *Am. Journ. Sci.*, vol. xlvii. February 1894. Art. viii.

the vast period between the Upper Carboniferous rocks and the present day the cockroaches have gained a rather different wing venation, and have succeeded in laying their eggs in a manner rather more specialised than that of insects in general; the stick insects and leaf insects have lost or reduced their wings, the grasshoppers have shortened their antennæ. These, however, are the insects which most closely resemble the existing species; let us turn to the forms which exhibit the greatest differences. Many species have retained in the adult state characters which are now confined to the larval stage of existence, such as the presence of tracheal gills on the sides of the abdomen. In some the two membranes of the wing were not firmly fixed together, so that the blood could circulate freely between them. On the other hand, they are not very firmly fixed together in existing insects. Another important point was the condition of the three thoracic segments, which were quite distinct and separate, instead of being fused, as they are now, in the imago stage. This external difference probably also extended to the nervous system, so that the thoracic ganglia were separate instead of concentrated. The most interesting distinction, however, was the possession by many species of a pair of prothoracic appendages much resembling miniature wings, and which especially suggest the appearance assumed by the anterior pair (tegmina) in existing Phasmidæ. There is some evidence in favour of the view that they were articulated, and they exhibit what appears to be a trace of venation. Brongniart concludes that in still earlier strata, insects with six wings will be discovered, or rather insects with six of the tracheal gills sufficiently developed to serve as parachutes. Of these the two posterior pair developed into the wings as we know them, while the anterior pair degenerated, some of the Carboniferous insects presenting us with a stage in which degeneration had taken place, but was not complete.

One very important character was, as I have already pointed out, the enormous size reached by insects in this distant period. This was true of the whole known fauna as compared with existing species, but it was especially the case with the Protodonata, some of these giant dragon-flies measuring over two feet in the expanse of the wings.

As regards the habits of life and metamorphoses, Brongniart concludes that some species of Protoephemeridæ, Protoperlidæ, &c., obtained their food in an aquatic larval stage, and did not require it when mature. He concludes that the Protodonata fed on other animals, like our dragon-flies; that the Palæacridiidæ were herbivorous like our locusts and grasshoppers, the Protolocustidæ herbivorous and animal feeders like our green grasshoppers, the Palæoblattidæ omnivorous like our cockroaches. The Homoptera, too, had elongated sucking mouth-parts like the existing species. It is known that in Carboniferous times there was a lake with rivers entering it, at Commentry. From their great resemblance to living forms of known habits, it is probable that the majority of these insects lived near the water and their larvæ in it.

When we look at this most important piece of research as a whole, we cannot fail to be struck with the small advance in insect structure which has taken place since Carboniferous times. All the great questions of metamorphosis, and of the structures peculiar to insects, appear to have been very much in the position in which they are to-day. It is indeed probable enough that the orders which zoologists have always recognised as comparatively modern and specialised, such as the Lepidoptera, Coleoptera, and Hymenoptera, had not come into existence. But as regards the emergence of the class from a single primitive group, as regards its approximation towards the Myriapods, which lived at the same time, and of both towards their ancestor Peripatus, we learn absolutely nothing. All we can say is that there is evidence for the evolution of the most modern and specialised members of the class, and some slight progressive evolution in the rest. Such evolution is of importance as giving us some vague conception of the rate at which the process travels in this division of the Arthropoda. If we look upon development as a series of paths which, by successively uniting, at length meet in a common point, then some conception of the position of that distant centre may be gained by measuring the angle of divergence and finding the number of unions which occur in a given length. In this case the amount of approximation and union shown in the interval between the Carboniferous period and the present day is relatively so small that it would require to be multiplied many times before we could expect the lines to meet in the common point, the ancestor of insects, to say nothing of the far more distant past, in which the Tracheate Arthropods met in an ancestor presenting many resemblances to Peripatus. But it must not be forgotten that all this vast undefined period is required for the history of one of the two grades of one of the three branches of the whole Phylum.

Turning now to the brief consideration of the second grade of Arthropods, distinguished from the first grade by the absence of antennæ, the Trilobites are probably the nearest approach to an ancestral form met with in the fossil state. Now that the possession of true antennæ is certain, it is reasonable to suppose that the Trilobites represent an early class of the Aceratous branch which had not yet become Aceratous. They are thus of the deepest interest in helping us to understand the origin of the antennaless branch, not by the ancestral absence, but by the loss of true antennæ which formerly existed in the group. But the Trilobites did not themselves originate the other classes, at any rate during Palæozoic times. They represent a large and dominant class, presenting more of the characters of the common ancestor than the other classes; but the latter had diverged and had become distinct long before the earliest fossiliferous rocks; for we find well-marked representatives of the Crustacea in Cambrian, and of the Arachnida in Silurian strata. The Trilobites, moreover, appear in the Cambrian with many distinct and very different forms, contained in upwards of forty genera, so that we are clearly very far from the origin of the group.

Of the lower group of Crustacea, the Entomostraca, the Cirripedes are represented by two genera in the Silurian, the Ostracodes by four genera in the Cambrian and over twenty in the Silurian: of these latter, two genera (Cythere and Bairdia) continue right through the fossiliferous series and exist at the present day. Remains of Phyllopods are more scanty, but can be traced in the Devonian and Carboniferous rocks. The early appearance of the Cirripedes is of especial interest, inasmuch as the fixed condition of these forms in the mature state is certainly not primitive, and yet, nevertheless, appears in the earliest representatives.

The higher group, the Malacostraca, are represented by many genera of Phyllocarida in the Silurian and Devonian, and two in the Cambrian. These also afford a good example of the imperfection of the record, inasmuch as no traces of the group are to be found between the Carboniferous and our existing fauna in which it is represented by the genus Nebalia. The Phyllocarida are recognised as the ancestors of the higher Malacostraca, and yet these latter already existed—in small numbers, it is true—side by side with the Phyllocarida in the Devonian. The evolution of the one into the other must have been much earlier. Here, as in the Arthropoda, we have evidence of progressive evolution among the highest groups of the class, as we see in the comparatively late development of the Brachyura as compared with the Macrura. We find no trace of the origin of the class, or of the larger groups into which it is divided, or, indeed, of the older among the small groupings into families and genera.[1]

Of the Arachnida, although some of the most wonderful examples of persistent types are to be found in this class, but little can be said. Merely to state the bare fact that three kinds of scorpion are found in the Silurian, two Pedipalpi, eight scorpions, and two spiders in the Carboniferous, is sufficient to show that the period computed by geologists must be immensely extended to account for the development of this class alone, inasmuch as it existed in a highly specialised condition almost at the beginning of the fossiliferous series; while, as regards so extraordinarily complex an animal as a scorpion, nothing apparent in the way of progressive development has happened since. Professor Lankester has, however, pointed out to me that the Silurian scorpion Palæophonus possessed heavier limbs than those of existing species, and this is a point in favour of an aquatic life like that of its near relation, Limulus. If so, it is probable that it possessed external

[1] For an account of the evolution of the Crustacea see the Presidential Addresses to the Geological Socie in 1895 and 1896 by Dr. Henry Woodward.

gills, not yet inverted to form the lung-book. The Merostomata are of course a Palæozoic group, and reach their highest known development at their first appearance in the Silurian; since then they have done nothing but disappear gradually, leaving the single genus Limulus, unmodified since its first appearance in the Trias, to represent them. It is impossible to find clearer evidence of the decline rather than the rise of a group. No progressive development, but a gradual or rapid extinction, and consequent reduction in the number of genera and species, is a summary of the record of the fossiliferous rocks as regards this group and many others, such as the Trilobites, the Brachiopods, and the Nautilidæ. All these groups begin with many forms in the oldest fossiliferous rocks, and three of them have left genera practically unchanged from their first appearance to the present day. What must have been the time required to carry through the vast amount of structural change implied in the origin of these persistent types and the groups to which they belong—a period so extended that the interval between the oldest Palæozoic rocks and the present day supplies no measurable unit!

But I am digressing from the Appendiculate Phylum. We have seen that the fossil record is unusually complete as regards two classes in each grade of the Arthropod branch, but that these classes were well developed and flourishing in Palæozoic times. The only evidence of progressive evolution is in the development of the highest orders and families of the classes. Of the origin of the classes nothing is told, and we can hardly escape the conclusion that for the development of the Arthropod branches from a common Chætopod-like ancestor, and for the further development of the classes of each branch, a period many times the length of the fossiliferous series is required, judging from the insignificant amount of development which has taken place during the formation of this series.

It is impossible to consider the other Cœlomate Phyla as I have done the Appendiculata. I can only briefly state the conclusions to which we are led.

As regards the Molluscan Phylum, the evidence is perhaps even stronger than in the Appendiculata. Representatives of the whole of the classes are, it is believed, found in the Cambrian or Lower Silurian. The Pteropods are generally admitted to be a recent modification of the Gastropods, and yet, if the fossils described in the genera Conularia, Hyolithes, Pterotheca, &c., are true Pteropods, as they are supposed to be, they occur in the Cambrian and Silurian strata, while the group of Gastropods from which they almost certainly arose, the Bullidæ, are not known before the Trias. Furthermore, the forms which are clearly the oldest of the Pteropods—Limacina and Spirialis—are not known before the beginning of the Tertiary period. Either there is a mistake in the identification of the Palæozoic fossils as Pteropods, or the record is even more incomplete than usual, and the most specialised of all Molluscan groups had been formed before the date of the earliest fossiliferous rocks. Even if this should hereafter be disproved, there can be no doubt about the early appearance of the Molluscan classes, and that it is the irony of an incomplete record which places the Cephalopods and Gastropods in the Cambrian, and the far more ancestral Chiton no lower than the Silurian. Throughout the fossiliferous series the older families of Gastropods and Lamellibranchs are followed by numerous other families, which were doubtless derived from them; new and higher groups of Cephalopods were developed, and, with the older groups, either persisted until the present time or became extinct. But in all this splitting up of the classes into groups of not widely different morphological value, there is very little progressive modification; and, taking such changes in such a period as our unit for the determination of the time which was necessary for the origin of the classes from a form like Chiton, we are led to the same conclusion as that which followed from the consideration of the Appendiculata, viz., that the fossiliferous series would have to be multiplied several times in order to provide it.

Of the Phylum Gephyrea I will only mention the Brachiopods, which are found in immense profusion in the early Palæozoic rocks and which have occupied the subsequent time in becoming less dominant and important. So far from helping us to clear up the mystery which surrounds the origin of the class, the earliest forms are quite as specialised as those living now, and, some of them (Lingula, Discina) even generically identical. The demand for time to originate the group is quite as grasping as that of the others we have been considering.

All the classes of Echinoderma, except the Holothurians, which do not possess a structure favourable for fossilisation, are found early in the Palæozoic rocks, and many of them in the Cambrian. Although these early forms are very different from those which succeeded them in the later geological periods, they do not possess a structure which can be recognised as in any way primitive or ancestral. The Echinoderma are the most distinct and separate of all the Cœlomate Phyla, and they were apparently equally distinct and separate at the beginning of the fossiliferous series.

In concluding this imperfect attempt to deal with a very vast subject in a very short time, I will remind you that we were led to conclude that the evolution of the ancestor of each of the higher animal Phyla probably occupied a very long period, perhaps as long as that required for the evolution which subsequently occurred within the Phylum. But the consideration of the higher Phyla which occur fossil, except the Vertebrata, leads to the irresistible conclusion that the whole period in which the fossiliferous rocks were laid down must be multiplied several times for this later history alone. The period thus obtained requires to be again increased, and perhaps doubled, for the earlier history.

In the preparation of the latter part of this address I have largely consulted Zittel's great work. I wish also to express my thanks to my friend Professor Lankester, whom I have consulted on many of the details, as well as the general plan which has been adopted.

The following Papers and Reports were read:—

1. *On the Cultivation of Oysters as Practised by the Romans.* *By* R. T. Günther, *M.A.*

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2. *On the Function of certain Diagnostic Characters of Decapod Crustacea.* *By* Walter Garstang, *M.A., Fellow of Lincoln College, Oxford.*

The author deals with the functions of various minor characteristics of Decapod Crustacea, especially the Brachyura.

A crab's carapace shows two regions subject to great variability of form. These regions are—

1. The frontal area between the orbits.
2. The pair of lateral margins.

The variability consists in the absence or presence of spines and teeth, and the varying length, shape, and number of these structures. These characters are employed by systematic writers to distinguish the different species and genera from one another.

The author's investigations show that it is not merely the function of the spines and teeth which is to be considered, but also the function of the spaces and notches between them.

The frontal area of crabs is frequently either 3- or 5-toothed—*i.e.*, either 2- or 4-notched. Examination of living crabs shows that the notches are correlated functionally with the play of the two pairs of antennæ. When the frontal area is 3-toothed (e.g., *Portunus pusillus*) the first antennæ are lodged in the two notches, and the second antennæ project on each side of the frontal prominence. When the frontal area is 5-toothed (e.g., *Polybius Henslowii*) the first antennæ are lodged in the inner, and the second antennæ in the outer pair of notches. This type of denticulation is simply an arrangement by which crabs may have their antennæ protected by a projection of the frontal area, while the possibility of free movement for the antennæ is provided by the notches along its margin. It is scarcely needful to point out that the antennæ of a crab are organs of great importance to it in the search for food, and that in the case of the antennules a power of free movement is necessary to enable the crab to detect the direction of odoriferous bodies in its neighbourhood. At the same time the situation of the antennæ in front of the body renders these organs particularly liable to injury unless specially protected.

In regard to the denticulation of the lateral margins of the carapace experiments show that in sand-burrowing species a most important function of the denticulated margins is in connection with the process of respiration. It may be termed the 'sieve-function.'

It is not generally known that a crab's chelipeds are in many cases not merely organs of prehension, but important agents in the respiratory process. The principal afferent apertures to the branchial chambers are situated at the base of the chelipeds. When the chelipeds are folded against the sides of the carapace (for which purpose they are in many forms specially curved and moulded) a pair of lateral slit-like channels is produced which lead directly downwards to the afferent apertures at the basement of the chelipeds. The lateral denticulated margins of the crab's carapace overhang the slit-like orifices of these accessory water-channels. When the crab is partially imbedded in sand it is possible, by the addition of colouring matter to the water, to demonstrate that a constant stream of water flows from above downwards through these accessory channels between chelipeds and carapace. The stream enters through the gaps between the teeth or spines on the lateral margins of the carapace. The teeth act as a coarse sieve or grating over the slit-like orifice, and prevent foreign bodies, such as particles of sand and shell, from falling into the channel and blocking its lumen. The water, after traversing these channels, enters the branchial chambers by the afferent apertures at the base of the chelipeds, and emerges in front by the lateral apertures at the sides of the mouth.

As examples of sand-burrowing crabs to which the above remarks apply, *Bathynectes longipes* and *Atelecyclus heterodon* may be mentioned. In each case the lateral denticulated margins of the carapace subserve this sieve-function. The number of teeth is five in *Bathynectes* and nine in *Atelecyclus*, but in each case the extent of the denticulated area is commensurate with the extent of the lateral inhalant gap between chelipeds and carapace.

This view is confirmed by the fact that in *Ebalia* and other Leucosiidæ, in which the afferent water-channel is entirely independent of the chelipeds, the lateral margins of the carapace are smooth and free from denticulations.

In *Calappa granulata* of the Mediterranean the chelipeds can be pressed against the smooth sides of the carapace with extreme nicety. The author has not yet had an opportunity of studying this crab alive; but, if the chelipeds are held tightly to the body when the animal is buried in the sand, it must be impossible for water to enter between them and the carapace, except at one point on each side, between the anterior margin of the carapace and the curious cock's-comb-like crests with which the chelipeds in this genus are provided. The antero-lateral margin of the carapace is smooth throughout, but the crests of the chelipeds are conspicuously denticulated. The structure of the surrounding parts renders it extremely probable that the inhalant current of water passes to the afferent aperture through the notches between the spines on the crest-like expansions.

In *Matuta victor*, an East Indian sand-burrowing crab, the inhalant current actually seems to enter through the crab's orbits, flowing thence downwards through a special pair of orbital gutters. Here also we find the marginal teeth of the carapace obsolete and scarcely recognisable.

A complete reversal of the ordinary branchial currents may take place in certain sand-burrowing crabs, as the author has experimentally determined in the case of *Corystes cassivelaunus, Atelecyclus heterodon,* and *Platyonichus nasutus.* A similar reversal probably occurs also in *Albunea symnista, Platyonichus latipes,* and several other forms.

In *Corystes* and *Atelecyclus* filtration is effected during reversal by an inhalant sieve-tube formed by the second antennæ, with the participation of the third maxillipeds. In *Albunea* a similar tube is formed by the apposition of the first antennæ. In *Platyonichus nasutus,* which burrows in coarse shell gravel, a remarkable and characteristic prominence of the frontal area protects the anterior apertures from the accidental intrusion of foreign bodies.

It thus appears that many of the specific and generic characteristics of Crustacea, which have been hitherto regarded as features of trivial significance are really of primary importance to their possessors under the particular conditions of their existence.

It is both remarkable and interesting that the same function in relation to the process of respiration should be discharged by organs and parts so dissimilar from one another as are the first antennæ of *Albunea,* the second antennæ of *Corystes,* the frontal area of *Platyonichus nasutus,* the five lateral spines of the carapace of *Bathynectes,* the nine lateral spines of *Atelecyclus,* the crests of the chelipeds of *Calappa granulata,* and the orbits of *Matuta victor.*

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3. *Report on the Zoology of the Sandwich Islands.*—See Reports, p. 492.

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4. *Report on the Occupation of a Table at the Marine Biological Laboratory, Plymouth.*—See Reports, p. 485.

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5. *Report on the Occupation of a Table at the Zoological Station, Naples.* See Reports, p. 478.

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6. *Report on the Fauna and Flora of the West Indies.* See Reports, p. 493.

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7. *Report on the Biological Investigation of Oceanic Islands.* See Reports, p. 487.

FRIDAY, SEPTEMBER 18.

1. A Discussion on Neo-Lamarckism was opened by Professor LLOYD-MORGAN.

The following Reports and Papers were read:—

2. *Report on the Coccidæ of Ceylon.*—See Reports, p. 450.

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3. *Report on the Transmission of Specimens by Post.*—See Reports, p. 477.

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4. *Report on Zoological Bibliography and Publication.* See Reports, p. 490.

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5. *Report on the Index generum et specierum animalium.* See Reports, p. 489.

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6. *On the Life-history of the Tiger Beetle* (Cicindela campestris). *By* F. Enock.

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7. *The Hatchery for Marine Fishes at Flodevigen, Norway.* *By* G. M. Dannevig.

[Communicated by J. W. Woodall.]

The Flodevigen Hatchery for Salt-water Fish was, at Captain Dannevig's proposal, erected in 1883 by a private society in Arundal, with the object of ascertaining whether it was possible to produce large numbers of fry of the better class of salt-water fish at a reasonable cost, the decrease in the fisheries, especially the cod fishing, being then greatly felt.

The work commenced in February 1884, and, as neither methods nor serviceable apparatus were invented, the troubles at the beginning were great and many.

Five millions of cod and nearly two millions of flounders and dabs were hatched at a cost of about 1*s*. 3*d*. per 1000 fry.

The author gave details of the operations carried on from 1884 until the present year.

During the later period—1890–96—1203 millions of fry were hatched at a cost of 0·65*d*. per 1000 fry. The last season the cost was one-third of a penny per 1000, and there is still a good chance of diminishing the expenses. The hatchery cost about 800*l*., and the annual expenditure is about 500*l*.

The practical result of the work is that the cod is rapidly increasing on the south coast, and more especially where fry have been planted.

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8. *On the Necessity for a British Fresh-water Biological Station.* *By* D. J. Scourfield.

Although there are fresh-water biological stations actively at work in Germany, Bohemia, the United States, and other countries, the idea of founding such an institution in this country has received very little attention. In fact the only tangible proposal to found such a station appears to be that made by the Norfolk and Norwich Naturalists' Society.[1] But surely it is time, now that the more pressing need for British marine biological stations has been largely satisfied, and the anticipations as to their value are being steadily realised, to consider if the careful study of fresh-water biology in this country cannot be helped forward by the establishment of a properly equipped station. There can be no doubt that many of the most interesting problems in fresh-water biology, problems of great general importance bearing on vexed points of variation, heredity, selection, and the influence of environment, will never be solved without the continuity of observation which can practically only be secured by means of a station definitely working towards this end.

Of the three principal districts in England and Wales offering suitable conditions for a fresh-water station, viz., the Lake District, North Wales, and the Norfolk Broads, the main work to be done in the two former would probably be directed towards the fresh-water 'plankton,' while in the latter the influence of the gradation from fresh to brackish water would be the most characteristic feature. Many other lines of investigation could of course be followed in either district, and the mere working-up of the aquatic fauna and flora of the immediately surrounding neighbourhood, which is almost essential as a preliminary step to deeper investigation, would be in itself no small gain to science.

The minimum cost of an efficient fresh-water station would probably amount to about 500*l*., and the cost of maintenance to 250*l*. a year; for it is evident that if the station is to be a success there must be at least one trained biologist to live and work at it continuously.

[1] See *Trans. Norf. and Norw. Nat. Soc.*, vol. vi. Part I. p. 108; also *Natural Science*, Jan. 1896, p. 8.

Compared with the large sums spent on marine biological stations, the amount required for a fresh-water station, even if provided with a little more than the minimum outfit, is evidently very modest, and it seems hardly necessary to advocate the formation of a special society to carry out the proposal to found such a station. A little co-operation on the part of the many existing institutions interested in biology with a local society willing to undertake the work of organisation and supervision seems to be all that is required. At least, so far as the Norfolk Broads are concerned, this method would suffice, for there is the proposal of the Norfolk and Norwich Naturalists' Society already in the field, and it would be a great pity if a scheme should be allowed to fall through which, if carried out, would remove the reproach that the United Kingdom is almost the only country in Europe without a fresh-water biological station.

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9. *On Improvements in Trawling Apparatus.* *By* J. H. MACLURE.

SATURDAY, SEPTEMBER 19.

The following Report was read :—

Report on the Migration of Birds.—See Reports, p. 451.

MONDAY, SEPTEMBER 21.

1. A Discussion was held in conjunction with Sections H and I on the *Ancestry of the Vertebrata.*

The following Paper was read :—

2. *On Palæospondylus Gunni.* *By* Dr. R. H. TRAQUAIR, *F.R.S.*

TUESDAY, SEPTEMBER 22.

1. A Discussion was held in conjunction with Section K on the Cell Theory.

The following Papers and Report were read :—

2. *The Theory of Panplasm.*
By Professor CHARLES S. MINOT, *Harvard University, Boston.*

The author reviews the series of theories which attribute essential general vital functions to small particles, which may be called life units, and are present in large numbers within a single cell. Such life units have been named Gemmules, Physiological Units, Pangenes, Biophores, Plastidules, Ids, Idiosomes, &c. The author regards all these theories as erroneous. They are to be looked upon as little more than survivals of the old conception of absolute distinction between living and non-living matter.

The *Theory of Panplasm* supposes that all the materials by their interaction produce the vital phenomena of Protoplasm, and that therefore life can exist only in Protoplasm of relatively large bulk, as compared with the hypothetical life units. This view has experimental support. It also is in accordance with Bütschli's foam theory of Protoplasm. All vital phenomena depend upon the arrangement and composition of the multifarious constituents of Protoplasm. The Theory of Panplasm, therefore, calls for a chemical explanation of Protoplasmatic functions.

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3. *On Multiple Cell Division as compared with Bi-partition as Herbert Spencer's limit of growth. By* Professor MARCUS HARTOG, *M.A., D.Sc., F.L.S.*

Herbert Spencer showed that the growth of the cell without change of shape necessarily reduced the area of surface in proportion to the mass, and gave this as a sufficient explanation of ordinary cell-division. Another type of cell-division is that in which successive divisions occur without any interval for growth; such divisions are variously known as Sporulation, Segmentation, and Brood formation, but a more convenient term is 'multiple cell-formation.' This frequently occurs determined by considerations of space; as, for instance, when an elongated cell rounds off, its superficial area is much reduced, and multiple cell-formation restores the necessary ratio.

Another case is that of a cell in which the food has been utilised largely for the storage of reserve materials instead of for the growth of protoplasm. Judging from what takes place in plants, we might anticipate that the protoplasm could not utilise these materials without the previous formation of a zymose or chemical ferment with which to render such reserves available for growth. This anticipation has been confirmed; by appropriate methods the author has extracted a peptonising zymose from the segmenting egg of the frog at a time when the hypoblast was still visible through the blastopore; and from the hen's embryo at twenty-four hours, and from the extravascular blastoderm at later stages. This affords a key to multiple cell-formation in a large number of cases, where the secretion of a ferment has, by an abundant food-supply, determined protoplasmic growth at the expense of the reserves, and so determined the need for an extension of surface.

A probable deduction from this observation is that where reserves are to be utilised by the containing-cell, the antecedent formation of a zymose is necessary, and that digestion is a function, not of protoplasm, but of the ferments which protoplasm may secrete.

The zymoses obtained by the author from segmenting embryos were active in neutral as well as in acid solution, and in this respect appear to differ from the ferments observed in protozoa.

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4. *The Present Position of Morphology in Zoological Science. By* E. W. MACBRIDE, *M.A., Fellow of St. John's College, Cambridge; University Demonstrator of Animal Morphology.*

For some time back a distrust of the morphological method of studying evolution has been growing up amongst zoologists. Alternative methods have been suggested as more fruitful lines of research. These will be examined in the first place to show that they labour from defects from which morphology is free; then the causes of the discontent with morphology will be inquired into; and finally some new points of view from which morphological facts may be regarded will be put forward.

The most important alternative methods which have been put forward are three:—

1. Mechanics of development or experimental embryology.

In this method the endeavour is made to separate into its factors the complex process known as development, and it is shown that the organs of the adult are not traceable back into definite areas of the ovum, or even blastula. So far as it goes, this is a most valuable kind of dissection; but it does not touch the question of how the hereditary powers of animals may be altered and so congenital inheritable variations produced; and this is the main problem of zoology.

2. The study of individual variations.

The drawbacks to this method are—

(*a*) It is often quite impossible to distinguish a congenital variation from a variation produced in the particular individual examined by some accident in the environment.

(*b*) Many of the most conspicuous variations are shown by a study of specific and generic characters to have had no part in the evolutionary process.

(*c*) It is not enough that a variation should occur; it must occur in a sufficient number of individuals to prevent its being immediately swamped by intercrossing.

3. The statistical study of individual variations or mathematical zoology.

The drawbacks to this method are—

(*a*) It is only capable of application to one character at a time, and a character is only a mental abstraction; natural selection acts on the balance of all the characters.

(*b*) Even if we could establish that a certain value of a given character was accompanied by a low death rate, and that therefore this value was likely to become a specific character, the success of its possessors might be due to some obscure constitutional change associated with it.

(*c*) But the only way it is possible to get such a result is to compare the variations with respect to a particular character of young and fully adult animals. To attribute the lesser number of deviations from the mean in the latter case to the death of individuals which had widely varied is to overlook the possibility of a self-regulating tendency in growth.

The reason of the discontent with the morphological method is that it proves too much, *i.e.*, the most contradictory conclusions may be drawn from the same premisses, for

(*a*) Evolution is not only a progress from the simple to the complex; degeneracy or simplification of structure plays an important part, and so also does homoplasy or parallel development, the evolution of similar structures in different animals independently.

(*b*) It has been customary to postulate modifications as part of evolutionary history, the utility of which is to be taken on faith; and if this principle be admitted, the evolutionary theorist can, armed with progressive degeneracy, as well as progressive differentiation, derive any one animal from any other.

Suggestions as to better ways of dealing with morphological facts:—

1. There are many cases where the fact that a certain modification has taken place is doubted by no one; for instance, no one seriously doubts that Teredo and Pecten have been derived from the ordinary Lamellibranch type.

The evolutionary changes which can be deduced from such cases as these are really the data the morphologist has to go on; if he departs from these he is on unsafe ground. It is possible that by a comparative study of such cases, 'laws of evolution' might be formulated.

2. In relation to the question of how degenerate and primitive structures are to be distinguished, we have to consider two subsidiary questions:—

(*a*) Does the fact that an animal is obviously degenerate in some points invalidate any conclusions that may be arrived at as to its general primitive character?

(*b*) Can an animal which has descended to a degenerate mode of life give rise to highly organised descendants?

The answer to the first question is that all animals which in their general organisation are primitive are likewise degenerate, since they have by their degeneracy escaped competition with their more highly organised relatives.

Amount of modification is an ambiguous term, and covers two distinct varieties of evolution:

(i.) Increase in differentiation of organs fulfilling the main functions (nervous, muscular, circulatory, and reproductive organs, for instance), correlated with greater intensity of metabolism.

(ii.) Modification of shape, size, and external organs.

(i.) is regarded by most zoologists as the essence of progressive evolution. The lesser value assigned to (ii.) justifies the separation of the Thylacine and Dog.

The answer to the second question is, so far as can be inferred from data laid down above, in the negative.

Hence it is not legitimate to assume that Vertebrata are directly descended from Balanoglossus or even Amphioxus.

On the main question as to the criteria of primitive and degenerate characters. Primitive structures are synthetic in nature; they either serve to link together different groups, as the flat foot of Nucula connects Gastropods and Lamellibranchs, or different organs, as the cœlom of the lower Annelids and of Brachiopods unites the functions of the renal and reproductive organs; for new organs have not arisen *de novo* from functionless rudiments, but by the modification of pre-existing organs.

Degenerate structures do not recall structures of other groups, and their condition does not correspond to the evolutionary level deducible from the condition of the other organs of the body.

Example: Rudimentary limbs of certain Urodeles.

3. One of the most vexed questions in zoology is the value to be attached to ontogeny as a record of phylogeny. Some have denied that it has any such value, but cases exist where the phylogenetic value is simply undeniable.

It is highly improbable that ontogeny is a process of an essentially different nature in different cases; therefore there is probably a phylogenetic element in all ontogeny.

Many features in embryology are, as all admit, secondary.

The key to the puzzle is that the embryo is a modified larva, and that the larva recapitulates not primarily ancestral structure but—

(*a*) Ancestral habits.

(*b*) Ancestral level of differentiation of functions, and ancestral structure so far as is demanded by these conditions.

4. In relation to the question as to how far homoplasy interferes with the conclusions we are accustomed to base on similarity of structure, it must be admitted that parallel development has not only taken place in widely separated groups, where there is no danger of confusion, but again and again in narrow circles of affinity; the researches of modern systematists seem to show that it is the normal thing. Instances of this, Arion and Limax amongst Pulmonata, &c.

Criticism of the conception of identity of ancestry.

We do not mean that animals belonging to different families are ultimately descended from the same pair. We mean only from ancestors so similar as to have been able to pair with one another, or in other words belonging to same species.

Species are, however, often separated by trivial marks, so far as we can see, of a non-adaptive character. It is a gratuitous assumption that similarity in broad outlines of structure which are adaptive indicates descent from same species.

Closely allied species exposed to same environmental influence would undergo the same change; descent from same species is only the extreme term in a series in which there is a gradual passage from what would be called homology to undeniable homoplasy. Structural resemblance indicates not primarily identity of ancestry, but similarity of past environment; and there may be all degrees in this similarity, both in extent and duration.

A conclusion like this is tacitly admitted by systematists who make the basis of their system minute and apparently unimportant peculiarities of external form, colour, or arrangement of similar organs; it is, however, the origin and history of adaptations which interest the morphologist, and his task must be, not primarily to draw up genealogical trees, but to correlate these adaptations as far as possible to the external conditions which have caused them.

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5. *The Olfactory Lobes.*
By Professor Charles S. Minot, *Harvard University, Boston.*

The author reports observations on the stratification and on the cell forms to be found in the developing and mature olfactory lobes, and deduces the conclusion that the lobes must be regarded as modifications of the cortex cerebri. He also emphasises the fact that the form of the cells of the cerebral cortex is extremely variable, so that the current descriptions, especially of the pyramidal cells, are really more or less conventionalised. These variations greatly facilitate the comparison of the cells of the cortex proper with those of the olfactory lobe.

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6. *On the relation of the Rotifera to the Trochophore.*
By Professor Marcus Hartog, *M.A., D.Sc., F.L.S.*

The author gave reasons for regarding the usually accepted affinities of the Rotifera to the Trochophore as due to similarity of conditions and to no more morphological identity. He regards the Rotifera as primitively aproctous, and suggests that the anus has been formed by the fusion of the blind end of the gut with a genito-urinary cloaca. This is indicated by the absence of the anus in the males of most Rotifers and the females of one family. Again, while the anus of the Trochophore is formed from part of the blastoporal area, the proctodæum in Rotifera is formed outside this area. The author regards the Rotifera as corresponding with Pilidum, in which the apical organ has been transformed into glands for attachment, as occurs in the larva of certain Echinoderms. All the orientation of the Rotifera is, according to this view, comparable with that of the cuttlefish. 'Anterior' and 'posterior' become replaced by oral and apical ends, 'dorsal' and 'ventral' by anterior and posterior, while right and left are unchanged.

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7. *Statistics of Wasps. By* Professor F. Y. Edgeworth.

By new methods and a new application of old methods (which are described in the 'Journal of the Royal Statistical Society' for June 1896) the writer confirms the conclusion formerly obtained, that the average duration of a wasp's absence from the nest is about a quarter of an hour in the evening. But for the daytime the average duration of a voyage is considerably longer.

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8. *Note on Genyornis*, Stirling, *an Extinct Ratite Bird supposed to belong to the Order Megistanes. By* Prof. A. Newton, *F.R.S.*

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9. *Report on the Fauna of African Lakes.*—See Reports, p. 484.

WEDNESDAY, SEPTEMBER 23.

The following Report and Papers were read:—

1. *Report on the Zoology, Botany, and Geology of the Irish Sea.*
See Reports, p. 417.

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2. *Phoronis, the Earliest Ancestor of the Vertebrata.* *By* A. T. Masterman.

The constitution of the group Chordata. The Hemichorda—*Balanoglossus*—*Cephalodiscus*, *Rhabdopleura*—The claims of *Phoronis* to be allied to the Hemichorda—Structural comparison of *Phoronis* to the Hemichorda (1) to *Cephalodiscus*, (2) to *Balanoglossus*—Absence of gill-slits and notochord—The 'branchial fissure' —Discovery of notochord in *Actinotrocha*—Structure and relations of notochord in *Actinotrocha*—Segments of the mesoblast in *Actinotrocha*—Relationship to *Tornaria*—Suggested group 'Diplochorda' and division of Chordate into Trimetamera and Polymetamera—Relationship to lower organisms (Echinodermata, &c.).

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3. *The Effects of Pelagic Spawning Habit on the Life Histories of Fishes.* *By* A. T. Masterman.

The present position of work on Teleostean development—The 'ontogenetic migration' as exemplified by plaice, herring, and sand-eel—Method of investigation —Division of eggs into 'pelagic' and 'demersal'—Suggested ancestral character of pelagic eggs—Explanation of ontogenetic migration by phyletic migrations—Reasons for holding 'pelagic' spawning habit to be ancestral—Effect of physical surroundings upon the pelagic stage—(1) Surface-currents (*e.g.*, plaice)—Displacement in two directions. (2) Change of salinity—Plaice of the Baltic—Freshwater fish of pelagic descent—Flounder—Eel. (3) Temperature—Hastening of development and of ontogenetic migration—Fatality to fry—Plaice in Danish waters. (4) Change of life habit of fish—Change to demersal (littoral)—The 'demersal' a specialised development—Littoral fish—Graphic representation of the life histores and solution of types from 'pelagic' type.

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4. *The Structure of the Male Apus.* *By* Dr. Benham.

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5. *On the Life History of the Haddock.* *By* Prof. W. C. M'Intosh, *M.D.*, *F.R.S.*

SECTION E.—GEOGRAPHY.

PRESIDENT OF THE SECTION—MAJOR DARWIN, SEC. R.G.S.

THURSDAY, SEPTEMBER 17.

The President delivered the following Address:—

IN reviewing the record of geographical work during the past year, all other performances pale in comparison with the feat accomplished by Nansen. It is not merely that he has gone considerably nearer the North Pole than any other explorer, it is not only that he has made one of the most courageous expeditions ever recorded, but he has established the truth of his theory of Polar currents, and has brought back a mass of valuable scientific information. When Nansen comes to England I am certain that we shall give him a reception which will prove how much we admire the heroism of this brave Norwegian.

Besides the news of this most remarkable achievement, the results of a considerable amount of useful exploratory work have been published since the British Association met last at Ipswich. With regard to other Arctic Expeditions, we have had the account of Lieutenant Peary's third season in Northern Greenland, from which place he came back in September last, and to which he has again returned, though without the intention of passing another winter there. In October the 'Windward' brought home more ample information as to the progress of the Jackson-Harmsworth Expedition than that communicated by telegram to the Association at Ipswich, and on her return from her remarkably rapid voyage this summer she brought back the record of another year. As to geographical work in Asia, Mr. and Mrs. Littledale returned safely from their explorations of the little known parts of Tibet; the Pamir Boundary Commission, under Colonel Holdich, has collected a great deal of accurate topographical information in the course of its labours; Dr. Sven Hedin continues his important researches in Turkestan; and the Royal Geographical Society was glad to welcome Prince Henry of Orleans when he came to tell us about his journey near the sources of the Irrawaddy. As to Africa, the most important additions to our knowledge of that continent are due to the French surveyors, who have accurately mapped the recently discovered series of lakes in the neighbourhood of Timbuktu, Lake Faguibine, the largest, being found to be 68 miles in length; Dr. Donaldson Smith has filled up some large blanks in the map of Somaliland; and Mr. and Mrs. Theodore Bent have investigated some interesting remains of ancient gold workings inland of the Red Sea. In other parts of the world less has been done, because there is less to do. Mr. Fitzgerald has proved for the first time the practicable character of a pass across the Southern Alps, thus supplementing the excellent work of Mr. Harper and other pioneers of the New Zealand Alpine Club; and Sir W. M. Conway has commenced a systematic exploration of the interior of Spitzbergen, a region to which the attention of several other geographers is also directed.

It is impossible in such a brief sketch to enumerate even the leading events of the geographical year; but what I have said is enough to remind us of the great amount of valuable and useful work which is being done in many quarters of the world. It is true that if we compare this record with the record of years gone by we find a marked difference. Then, there was always some great geographical problem to be attacked: the sources of the Nile had to be discovered; the course of the Niger had to be traced; and the great white patches on our maps stimulated the imagination of explorers with the thought of all sorts of possibilities. Now, though there is much to be learned, yet, with the exception of the Poles, the work will consist in filling in the details of the picture, the general outlines being all drawn for us already. Personally I cannot help feeling a completely unreasoning regret that we have almost passed out of the heroic period of geography. Whatever the future may have in store for us, it can never give us another Columbus, another Magellan, or another Livingstone. The geographical discoverers of the future will win their fame in a more prosaic fashion, though their work may in reality be of even greater service to mankind. There are now few places in the world where the outline of the main topographical features is unknown; but, on the other hand, there are vast districts not yet thoroughly examined. And, in examining these more or less known localities, geographers must take a far wider view than heretofore of their methods of study in order to accommodate themselves to modern conditions.

But even if we confine our attention to the older and more narrow field of geography, it will be seen that there is still an immense amount of work to be done. We have been filling in the map of Africa during recent years with extraordinary rapidity, but yet that map is likely to remain in a very unsatisfactory condition for a long time to come. Englishmen and other Europeans have always shown themselves to be ready to risk their lives in exploring unknown regions, but we have yet to see how readily they will undertake the plodding work of recording topographical details when little renown is to be won by their efforts. It should be one of the objects of geographical societies to educate the public to recognise the importance of this work, and General Chapman deserves great credit for bringing the matter before the International Congress last year in such a prominent manner. He confined himself to four main recommendations: (1) The extension of accurate topographical surveys in regions likely to be settled by Europeans. (2) The encouragement of travellers to sketch areas rather than routes. (3) The study of astronomical observations already taken in the unsurveyed parts of Africa in a systematic manner, and the publication of the results. (4) The accurate determination of the latitude and longitude of many important places in unsurveyed Africa. I am certain that all geographers are in hearty accord with General Chapman in his views, and it is, perhaps, by continually bringing this matter before the public that we shall best help this movement forward.

Not only do we want a more accurate filling in of the picture, but we have yet to learn to read its lessons aright. The past cannot be understood, and still less can the future be predicted, without a wider conception of geographical facts. Look, for example, at the European colonies on the West Coast of Africa. Here we find that there have been Portuguese settlements on the Gold Coast since the year 1471, the French possibly having been established there at an even earlier date; whilst we English, who pride ourselves on our go-ahead character, have had trading factories on the Coast since 1667. I have here a map showing the state of our geographical knowledge in 1815. Why was it that Europeans have never, broadly speaking, pushed into the interior from their base on the coast, which they had occupied for so many centuries? That they had not done so, at least to any purpose, is proved by this map. Why had four centuries of contact with Europeans done so little even for geographical knowledge at that time? The answer to this question may be said to be mainly historical; but the history of our African colonies can never be understood without a study of the distribution of the dense belt of unhealthy forest along the shore; of the distribution of the different types of native inhabitants; and of the courses of the navigable rivers, all strictly geographical considerations.

Geography is the study of distribution, and early in that study we must be struck with the correlation of these different distributions. If we take a map of Africa, and mark on it all the areas within the tropics covered with dense forest or scrub, we shall find we have drawn a map showing accurately the distribution of the worst types of malarial fever; and that we have also indicated with some approach to accuracy—with, however, notable exceptions—the habitat of the lowest types of mankind. These are the facts which give the key to understanding why the progress of European colonisation on the West Coast has been so slow.

Along the coast of the Gulf of Guinea we find settlements of Europeans at more or less distant intervals. All along, or nearly all along, this same coast we find a wide belt of fever-stricken forest, fairly thickly inhabited by uncivilised Negro and Bantu tribes. Inside this belt of forest the country rises in altitude, and becomes more open, whilst at the same time there is a distinct improvement in the type of native; and the more we proceed inland, the more marked does this improvement become. There appear in fact to have been a number of waves of advancing civilisation, each one pressing the one in front of it towards these inhospitable forest belts. Near the coast the lowest type of Negro is, generally speaking, to be found; then, as the more open country is reached, higher types of Negroes are encountered: for example, the Mandingoes of the Senegal region are distinctly higher than the Jolas inhabiting the mouths of the Gambia; and the Hausas of the Sokoto Empire are vastly superior to the cannibals of the Oil Rivers. In both these cases the higher types are probably not pure Negroes, but have Fulah, Berber, or Arab blood in their veins; for we see, in the case of the Fulahs, how they become absorbed into the race they are conquering; near the Senegal River they are comparatively light in colour, but in Adamawa they are hardly to be distinguished by their features from the negroes they despise. Thus the process appears to have been a double one; the higher race driving some of the lower aboriginal tribes before them out of the better lands, and, at the same time, raising other tribes by means of an admixture of better blood. These waves of advancing civilisation seem to have advanced from the north and east, for the more we penetrate in these directions, the higher is the type of inhabitant met with, until at last we reach the pure Berbers and the pure Arabs. Thus there are two civilising influences visible in this part of Africa: one coming from the north and east—a Mahommedan advance—which keeps beating up against this forest belt and occasionally breaking into it; the other, a Christian movement, which, until the middle of this century, was brought to a dead halt by this same obstacle. The map of Africa, showing the state of geographical knowledge in 1815, makes it clear that, except in a few cases where rivers helped travellers through these malarial regions, nothing was known about the interior. No doubt much has been done since those days, but this barrier still remains the great impediment to progress from the West Coast; and those who desire our influence to spread more effectively into the interior must wish to see some means of overcoming this obstacle. On the East Coast of Africa the conditions are somewhat different, as there is comparatively little dense forest there; but the districts near that coast are also usually unhealthy, and how to cross those malarial regions quickly into the healthy or less unhealthy interior is the most important problem connected with the development of Tropical Africa.

Other influences have been at work, no doubt, in checking our progress from the West Coast. In old days the European possessions in these districts were mere depôts for the export of slaves. As the white residents could not hope to compete with the natives in the actual work of catching these unfortunate creatures, and as the lower the type the more easily were they caught, as a rule, there was no reason whatever for attempting to penetrate into the interior, where the higher types are met with. But, though this export trade in human beings is now no longer an impediment to progress, the slave trade in the interior still helps to bar the way. When the forest belt is passed, we now come, generally speaking, to the line of demarcation between the Mahommedan and the Pagan tribes, and here slave catching is generally rife; when it is so, the constant raids of the Mahommedan chiefs keep these border districts in a state of unrest which in every way tends to impede progress. Thus a mere advance to the higher inland regions will not by any means solve all our difficulties; but it will greatly lessen them; and it is universally admitted that the more communication with the interior is facilitated, the more easy will it be to suppress this terrible traffic in human beings. By the General Act of the Brussels Anti-Slavery Conference of 1890–91, it was agreed by the assembled delegates that the construction of roads, and, in particular, of railways, connecting the advanced stations with the coast, and permitting easy access to the inland waters, and to the upper courses of rivers, was one of the most effective means of counteracting the slave trade in the interior. Here, then, we have the most formal admission which could be given of the necessity of opening up main trunk lines of communication into the interior.

But not only does geographical knowledge help to demonstrate the necessity of improving the means of communication between the coast and the interior, but it helps us to decide where it is wise to make our first efforts in this direction. In the first place, it is essential to note that if the Continent of Africa is compared with other Continents, its general poverty is clearly seen. Mr. Keltie, in his excellent work on the Partition of Africa, tells us that 'at present (1895) it is estimated that the total exports of the whole of Central Africa by the east and west coast do not amount to more than 20,000,000*l.* sterling annually.' For the purposes of comparison it may be mentioned that the export trade of India is between sixty and seventy millions sterling annually, and that India is only about one-seventh or one-eighth of the area of the whole of Africa. On the other hand, the trade of India has been increasing by leaps and bounds, largely in consequence of the country being opened out by railways, and there is every reason to hope that somewhat similar results would occur in Africa under similar circumstances, though the lower civilization of the people would prevent the harvest being so quickly reaped. But, however it may be as to the future, the present poverty of Africa is enough to demonstrate the necessity of pushing ahead cautiously and steadily, and of doing so in the most economical manner possible.

M. Decle, in an interesting paper, read before the International Geographical Congress in London last year, strongly advocated the construction of cheap roads for use by the natives, taking precautions to prevent any traffic in slaves along them. His suggestions are well worthy of consideration; but the cost of transport along any road would, I should have thought, soon have eaten up any profits on the import or export trade to or from Africa. What must be done in the first instance is to utilise to the utmost all the natural lines of communication which require little or no expenditure to render them serviceable; in fact, to turn our attention at first to the rivers and to the lakes. I have already pointed out that the early maps of Africa prove that the rivers have almost invariably been the first means of communication with the interior, and until this continent is rich enough to support an extensive railway system, we must rely largely on the waterways as means of transport.

It may be as well here to remark that geographical knowledge is often required in order to control the imagination. I do not know why it is, but almost everyone will admit that if he sees a lake of considerable size depicted on a map, he immediately feels a desire to visit or possess that locality in preference to others. A lake may be of far less commercial value than an equal length of thoroughly navigable river, and yet it will always appear more attractive. Look at the way in which the English, the French, and the Germans are all pressing forward to Lake Chad; and yet Lake Chad is in reality not much more than a huge swamp, and, in all probability, it is excessively unhealthy. Again, it is probable that the Albert Nyanza will prove to be of comparatively small value, because the mountains come down so close to its shores. Of course, the great lakes form an immensely important feature in African geography, but we must judge their commercial value rationally, and without the bias of imagination.

To develop the traffic along the rivers and on the lakes is the first stage in the commercial evolution of a continent like Africa. But it cannot carry us very far. Africa is badly supplied with navigable rivers, chiefly as a natural result of the general formation of the land. The continent consists, broadly speaking, of a huge plateau, and the rivers flowing off this plateau are obstructed by cataracts in exactly the places where we most want to use them—that is, when approaching the coasts. The second stage in the commercial evolution will therefore be the construction of railways with the view of supplementing this river traffic. Finally, no doubt, a further stage will be reached, when railways will cut out the rivers altogether; for few of the navigable rivers are really well suited to serve as lines of communication. This last stage is, however, so far off that we may neglect it for the present; though it must be noted that there are some parts of Africa where there are no navigable rivers, and where, if anything is to be done, it must be entirely by means of railways.

Thus, as far as the immediate future is concerned, the points to which our attention should be mainly directed are (1) the courses of the navigable parts of the rivers, and (2) the routes most suitable for the construction of railways in order to connect the navigable rivers and lakes with the coast. As to the navigable rivers, little more remains to be discovered with regard to them, and we can indicate the state of our geographical knowledge on this point with sufficient accuracy for our purposes by means of a map. Of course the commercial value of a waterway depends greatly on the kind of boats which can be used, and that point cannot well be indicated cartographically.

As to the railways, we must study the physical features of the country through which the proposed lines of communication would pass. All the obstacles on rival routes should be most carefully surveyed when considering the construction of railways in an economical manner. Great mountain chains are seldom met with in Africa, and from that point of view the continent is as a whole remarkably free from difficulties. But drifting sand is often a serious trouble, and that is met with commonly enough in many parts. Wide tracks of rocky country also form serious impediments, both because of the cost of construction, and also because the supply of water for the engines becomes a problem not to be neglected. Such arid and sandy districts are of course thinly inhabited, and we may therefore generally conclude that where the population is scanty, there railway engineers will have special difficulties to face. On the other hand, dense forests are also very unsuitable. We have not much experience to guide us, but it would appear probable that the initial expense of clearing the forest, and the cost of maintenance, in perpetually battling against the tropical vegetable growth, will be very heavy; for it will not do to allow the line to be in constant danger of being blocked. The dampness of the forest, which will cause all woodwork and wooden sleepers to rot, will be no small source of trouble, and the virulent malarial fevers, always met with where the vegetation is very rank, will add immensely to the difficulty both of construction and of maintenance. The health of the European *employés* will be a most serious question in considering the construction of railways in all parts of tropical Africa, for the turning up of the soil is the most certain of all methods of causing an outbreak of malarial fever; and the evil results would be most severely felt in constructing ordinary railways in dense forests. In making the short Senegal railway, where the climate is healthier than in many of the districts further south, the mortality was very great. Perhaps we shall have to modify our usual methods of construction so as to mitigate this danger, and, in connection with this subject, I may perhaps mention that the Lartigue system seems to be specially worthy of consideration—a system by which the train is carried on a single elevated rail. This is perhaps travelling rather wide of the mark of ordinary geographical studies, but it illustrates the necessity of a thorough examination of the environment before we try to transplant our own methods to other climes.

We may, however, safely conclude that we must as far as possible avoid both dense forests and sandy and rocky wastes in the construction of our first railways.

Then, as to the lines of communication, considered as a whole, rail and river combined, we must obviously, if any capital is to be expended, make them in the directions most likely to secure a profitable traffic. In considering this part of the question, it will be seen that there are several different problems to be discussed:

(1) trade with the existing population in their present condition; (2) trade with the native inhabitants when their countries have been further developed with the aid of European supervision; and (3) trade with actual colonies of European settlers. To many minds the last of these problems will appear to be the most important, and in the end it may prove to be so. But the time at my disposal compels me to limit myself to the consideration of trade with the existing native races within the tropics, with only an occasional reference to the influence of white residents. We must, no doubt, carefully consider which are the localities most likely to attract those Europeans who go to Africa with the view of establishing commercial intercourse and commercial methods in the interior; and there can be no doubt that considerations of health will play a prominent part in deciding this point. Moreover, as the lowest types of natives have few wants, the more primitive the inhabitants of the districts opened up, the less will be the probability of a profitable trade being established. For both these reasons the coast districts are not likely in the end to be as good a field for commercial enterprise as the higher lands in the interior; for the more we recede from the coast, the less unhealthy the country becomes, and the more often do we find traces of native civilisation. To put it simply, we must consider both the density of the population and the class of inhabitant in the districts proposed to be opened up. Of course, the exact nature of the products likely to be exported, and the probability of demands for European goods arising amongst the natives of different districts, are vitally important considerations in estimating the profits of any proposed line of railway; but to discuss such problems in commercial geography at length would open up too wide a field on an occasion like this.

If the importance of considering the density of the population in the different districts in such a preliminary survey is admitted, we may then simplify our inquiry by declining to discuss any lines of communication intended to open up regions where the population falls below some fixed minimum—whatever we may like to decide on. Of course, the question of the greater or less probability of a locality attracting white temporary residents is very important, but unless there is a native population ready to work on, there will be little done for many years to come. Politically it may or may not be right to open up new districts by railways for the sake of finding outlets for our home or our Indian population; but here I am considering the best lines for the development of commerce, taking things as they are. What then shall be this minimum of population? The population of Bengal is 470 per square mile; of India, as a whole, about 180; and of the United States, about 21 or 22. If it is remembered that the inhabitants of the United States are, per head, vastly more trade-producing than the natives of Africa, it will be admitted that we may for the present exclude from our survey all districts in which the population does not reach a minimum of 8 per square mile; it might be right to put the minimum much higher than this. On the map now before you, the uncoloured parts show where the density of population does not come up to this minimum, and we can see at a glance how enormously this reduces the area to be considered. The light pink indicates a population of from 8 to 32 per square mile, and the darker pink a denser population than that. Of course, such a map, in the very imperfect state of our knowledge, must be very inaccurate, as I am sure the compiler would be the first to admit. On the same map are marked the navigable parts of rivers. I should like to have shown the dense forests also, but the difficulty of giving them with any approach to correctness is at present insuperable.

Here, then, is the kind of map we want in order to consider the broad outline of the questions connected with the advisability of attempting to push lines of communication into the interior. The problem is how to connect the inland parts of Africa, which are coloured pink on this map, with the coast, by practicable lines of communications, at the least cost, with the least amount of dense forest to be traversed, and, in the case of railways, whilst avoiding as far as possible all thinly populated districts.

It is of course quite impossible here to discuss all the great routes into the interior, and I should like to devote the remaining time at my disposal to the consideration of this problem as far as a few of the most important districts are concerned, confining myself, as I have said, to trade with existing native races within the tropics. Taking the East Coast first, and beginning at the north, the first region sufficiently populous to attract our attention is the Valley of the Nile, and parts of the Central Sudan. Wadai, Darfur, and Kordofan are but scantily inhabited, according to our map, and this is probably the case now that the Khalifa has so devastated these districts; but, without doubt, much of this country could support a teeming population, and is capable of great commercial development. The Bahr-el-Ghazal districts are especially attractive, being fertile and better watered than the somewhat arid regions further north. These remarks remind me how difficult it is at this moment to touch on this subject without trenching on politics. Few will deny that the sooner this region is connected with the civilised world the better, and it is only as to the method of opening it up, and as to who is to undertake the work, that burning political questions will arise. The geographical problems connected with the lines of communication to the interior can be considered whilst leaving these two points quite on one side.

A glance at the map reminds us of the well-known fact that, below Berber, the Nile is interrupted by cataracts for several hundred miles, whilst above that town there is a navigable water-way at high Nile until the Fola rapids are reached, a distance of about 1,400 miles, not to mention the 400 to 600 miles of the Blue Nile and the Bahr-el-Gazal, which are also navigable. The importance of a railway from Suakin to Berber is thus at once evident, and there is perhaps only one other place in Africa where an equal expenditure would open up such a large tract of country to European trade. This route, however, is not free from difficulties. Suakin is hot and unhealthy. Then the railway, about 260 miles in length, passes over uninhabited or thinly inhabited districts the whole way. Though the hills over which it would pass are of no great height, the highest part of the track being under 3,000 feet above the sea, it is often said that the desert to be traversed would add greatly to the difficulty of construction. According to Lieut.-Colonel Watson, R.E., however, these difficulties have been greatly exaggerated, for the water supply would give no great trouble. The sixth cataract, between Metemma and Khartum, would make navigation for commercial purposes impossible when the waters are low; it is probable that this impediment could be overcome by erecting locks, but it is impossible to estimate the cost of such works. Then, again, the Nile above Khartum is much obstructed by floating grass or sudd, making navigation at times almost impossible; but it was Gordon's opinion that a line of steamers on the river, even if running at rare intervals, would keep the course of the stream clear; this, however, remains to be proved.

If the canalisation of the sixth cataract should prove to be too costly an undertaking, then it would be most advisable to carry on the railway beyond that obstacle. This might be done by prolonging the line along the banks of the Nile, or by adopting an entirely different route from Suakin through Kassala. I hope we shall hear something from Sir Charles Wilson as to the relative merits of these proposals during the course of our proceedings. Proposals have also been made for connecting the Nile with other ports on the Red Sea, and all of these suggestions should be carefully examined before a decision is made as to the exact route to be adopted. But in any case, considering the matter merely from a geographical standpoint, and putting politics on one side—a very large omission in the case of the Sudan—it would appear that one or other of these routes should be one of the very first to be constructed in all Africa.

Passing further south, it is obvious from the configuration of the shore, and from the distribution of the population, that the lines of communication next to be considered are those leading to the Victoria Nyanza, and on to the regions lying north and west of the lake.

Two routes for railways from the coast to the Victoria Nyanza have been proposed, one running through the British and the other through the German sphere of influence. Looking at the matter from a strictly geographical point of view, there is perhaps hardly sufficient information to enable us to judge of the relative merits of the two proposals. Both run through an unhealthy coast zone, and both traverse thinly inhabited districts until the lake is reached. The German route, as originally proposed, would be the shorter of the two; but there is some reason to think that the British line will open up more country east of the lake, which will be suitable for prolonged residence by white men. Sir John Kirk, in discussing the question of the possible colonisation of tropical Africa by Europeans, said: 'These uplands vary from 5,000 to 7,000 feet in height, the climate is cool, and, as far as known, very healthy for Europeans. This district is separated from the coast by the usual unhealthy zone, which, however, is narrower than elsewhere on the African littoral. Between the coast zone and the highlands stretches a barren belt of country, which attains a maximum width of nearly 200 miles. The rise is gradual, and throughout the whole area to be crossed the climate is drier and the malarial diseases are certainly much less frequent and less severe than in the regions further south.' These very advantages, however, may have to be paid for by the greater difficulty of railway construction. Putting aside future prospects, the map shows that the populous region to the west of the lake makes either of these proposed lines well worthy of consideration, though it would perhaps be rash to predict how soon the commerce along them would pay for the interest on the capital expended. What will be the fate of the German project I do not know, but we may prophecy with some confidence that the British line, the construction of which has been commenced, will be completed sooner or later.

The two lines of communication we have discussed—the Suakin and the Victoria Nyanza routes—are intended to supply the wants of widely separated districts; but, looking to a more distant future, they must sooner or later come into competition one with the other, in attracting trade from the Central Sudan. Before this can occur, communication by steamboat and by railway must be opened up between the coast and the navigable Nile by both routes. This will necessitate a railway being constructed, not only to the Victoria Nyanza, but also from that lake, or round it, to the Albert Nyanza; and, as the Nile is rendered unnavigable by cataracts about Dufile, and as the navigation is difficult between Dufile and Lado, here also a railway would be necessary in order to complete the chain of steam communication with the coast. If goods were brought across the Victoria Nyanza by steamer, and taken down the Nile in the same manner from the Albert Nyanza to Dufile, this route would necessitate bulk being broken six times before the merchandise was under way on the Nile; by the Suakin route, on the other hand, bulk would only have to be broken twice, provided the sixth cataract were rendered navigable. Thus, if this latter difficulty can be overcome, and if the sudd on the Nile is not found to impede navigation very much, this Nyanza route will certainly not compete with the Suakin route for any trade on the banks of the navigable Nile until a railway is made from the coast to Lado, a distance of over 800 miles as the crow flies, and certainly over 1,000 miles by rail. It must be remembered also that the Nyanza route passes over mountains 8,700 feet above the sea; that the train will have to mount, in all, nearly 13,000 feet in the course of its journey from the coast; and that a difficult gorge has to be crossed to the eastward of the Victoria Nyanza. From these facts we may conclude that it will be a very long time before the Nyanza route will draw any trade from the Central Sudan.

The line through the British sphere of influence runs to the northern end of Victoria Nyanza, but from Mr. Vandeleur's recent expedition into these regions we learn that a shorter route, striking the eastern shore of the lake, is under consideration. To lessen the expense of construction would be a great boon, but if we look to the more ambitious schemes for the future, something may be said in favour of the original proposal as being better adapted to form part of a line of railway reaching the navigable Nile.

With regard to the comparison between the German and British routes to the Victoria Nyanza, the latest accounts seem to imply that the Germans have practically decided on a line from the coast to Ujiji, with a branch from Tabora to the Victoria Nyanza. This would be a most valuable line of communication; but it seems a pity that capital should be expended in competitive routes when there are so many other directions in which it is desirable to open up the continent. If the Germans wish to launch out on great railway projects in Africa, let them make a line from the south end of Lake Tanganyika to the northern end of Lake Nyasa, and thence on to the coast; they would thus open up a vast extent of territory, and Baron von Schele tells us that a particularly easy route can be found from Kilva to the lake. Such a line of communication, especially if eventually connected with the Victoria Nyanza to the north, would be more valuable than any other line in Africa in putting an end to the slave trade, as it would make it possible to erect a great barrier, as it were, running north and south across the roads traversed by the slave traders.

A line through German territory connecting Lake Nyasa with the sea would, no doubt, come into competition with the route connecting the southern end of that lake with the Zambesi, and thus with the coast. The mouths of the Zambesi, though they are passable, will always present some impediment to commerce. But after entering the river navigation is not obstructed until the Murchison Rapids on the Shirè River are reached. Here there are at present sixty miles of portage to be traversed, and this transit must be facilitated by the construction of a railway, if this route is to be properly developed; Mr. Scott Elliot tells us that 120 miles of railway, from Chiromo to Matope, would be necessary for this purpose. Beyond this latter point there is a good waterway to Lake Nyasa. Thus a comparatively short line of railway would open up this lake to European commerce, and this route is likely to be developed at a much earlier stage of the commercial evolution of Africa than the one through German territory above suggested. It will be seen that these routes connect fairly populous districts with the coast, and it must also be recollected that the high plateau between Lake Nyasa and the Kafue River is one of the very few regions in tropical Africa likely to attract white men as more or less permanent residents.

Further south we come to the Zambesi River, which should, of course, be utilised as far as possible. But this line of communication to the interior has many faults. The difficulties to be met with at the mouths of the Zambesi have already been alluded to. Then the whole valley is unhealthy, and white travellers would prefer any route which would bring them on to high land more quickly. Moreover the Kebrabasa rapids cause a serious break in the waterway, and, as the river above that point is only navigable for canoes, it is doubtful if it would ever be worth making a railway for the sole purpose of connecting these two portions of the river.

As the population of the upper Zambesi valley is considerable, and as the country further from its banks is said to be likely to be attractive to white men, there can be no doubt of the advisability of connecting it with the coast. This naturally leads us to consider the Beira route, as a possible competitor with the Zambesi. A sixty centimetre railway is now open from Fontesvilla to Chimoio (190 kilometres), and it is probable that during the course of the next two years the construction of the railway will be completed from the port of Beira itself as far as the territory of the Chartered Company. This will form the first step in the construction of a much better line of communication to the Upper Zambesi regions than that afforded by the river itself. It is true that the gauge is very narrow, and that the first part of the line passes through very unhealthy districts; but this line will nevertheless be a most valuable addition to the existing means of penetrating into the interior of the continent. It is needless to say that the object of this railway is to open up communications with Mashonaland, not for the purposes now suggested.

South of the Zambesi the map shows us that there are no regions in tropical Africa where the density of the native population reaches the minimum of eight per square mile. Here, however, we come to the gold fields, where there is attractive force enough to draw white men in great numbers within the tropics, and where, no doubt, some of the most important problems connected with railway communications will have to be solved in the immediate future. But, for reasons of time and space, I have limited myself to the discussion of districts within the tropics, where trade with the existing native races is the object in view. The Beira railway does not in reality come within the limits I have imposed on myself, except as to its future development. Had time permitted, I should like to have discussed the route leading directly from the Cape to Mashonaland, its relative merits in comparison with the Beira railway, and as to where the two will come into competition one with the other. But I must pass on at once to consider the main trunk routes from the West Coast leading into the interior of Africa.

Passing over those regions on the West Coast where railways would only be commenced because of the probable settlement, temporary or permanent, of white men—passing over, that is, the whole of the German sphere of influence—we first come to more dense native populations near the coast towns of Benguela and St. Paul de Loanda. The latter locality is the more hopeful of the two, according to our map, and here we find that the Portuguese have already constructed a railway leading inland for 191 miles to close to Ambaca. The intention of connecting this railway with Delagoa Bay was originally announced, and I am not aware to what extent this vast project has now been cut down, so as to bring it within the region of practical proposals. A further length of 35 miles is, at all events, being constructed, and 87 more miles have been surveyed. The Portuguese appear to be very active at present in this district, as there are several other railways already under consideration; one from Benguela to Bihe, of which 16 miles is in operation, another from Mossamedes to the Huilla Plateau, and a third from the Congo to the Zambesi. It is difficult to foretell what will be the outcome of these schemes, but our population map is not very encouraging.

Next we come to the Congo, and here there is a grand opportunity of opening up the interior of the continent. In going up this great stream from the coast we first traverse about 150 miles of navigable waterway, and afterwards we come to some 200 miles of cataracts, through which steamers cannot pass. Round this impediment a railway is now being pushed, 189 kilometres of rails (117 miles) being already laid. Then we enter Stanley Pool, and from this point we have open before us—if Belgian estimates are to be accepted—7,000 miles of navigable waterway. If this fact is correct, and if the population is accurately marked on our map, then there is no place in all Africa where 200 miles of railway may be expected to produce such marked results. The districts traversed are unhealthy, and the natives are, generally speaking, of a low type; but in spite of these drawbacks, which no doubt will delay progress considerably, we may confidently predict a grand future for this great natural route into the interior.

To the north of the Congo, the next great navigable waterway met with is the Niger. Again, granting the correctness of the population map, it can be seen at a glance that there is no area of equal size in all Africa so densely inhabited, and no district where trade with the existing native population appears to offer greater inducement to open up a commercial route into the interior. Luckily little has to be done in this respect, for the Niger is navigable for light-draught steamers in the full season as far as Rabba, about 550 miles from the sea; here the navigation soon becomes obstructed by rocks, and at Wuru, about 70 miles further up the river, the rapids are so unnavigable that even the light native canoes have to be emptied before attempting a passage, and there are frequent upsets. From Wuru the rapids extend to Wara, after which a stretch of clear and slow-running river is met with. Above this, again, the Altona Rapids extend for a distance of 15 miles; then 15 miles of navigable waterway, and then 20 miles more of rapids are encountered. Yelo, the capital of Yauri, is situated on these latter cataracts, above which the Middle Niger is navigable for a considerable length. The Binue is also navigable in the floods for many miles, the limits being at present unknown; part of the year, however, it is quite impassable except for canoes. The trade with the Western Sudan, which has been made possible by the opening up of this river, is still only in its infancy, and to get the full benefit of this waterway a line of railway ought to be carried on from Lokoja to Kano, the great commercial centre of Hausal and Mr. Robinson's recent journeys over this country, which we hope to hear about at a later period of our proceedings, have served to confirm the impression that no great physical difficulties would be encountered. The political condition of the country may, however, make the construction of this railway quite impossible for the present; for here we are on the borderland between Mahommedanism and Paganism, where the slave trade always puts great impediments in the path of progress, but where the same circumstances make it so eminently desirable to introduce a higher condition of civilisation. The only drawback to the Niger as a line of communication to the Western Sudan is the terribly unhealthy nature of the coast districts which have to be traversed. Any man, who finds a means of combating the deadly diseases here met with, will be the greatest benefactor that Africa has ever had; but of such a discovery there are but few signs at present.

It is perhaps too soon to speculate as to the best means of opening a trade route to Wadai and the more central parts of the Western Sudan; for we may be sure that little will be done in this direction for years to come. Several competing routes are possible. From the British sphere, we may try to extend our communications eastward from the navigable parts of the Binue. The French, on the other hand, may push northwards from the Ubangi; whilst, in a later stage of commercial evolution, the best route of all may be found through German terrritory, by pushing a railway from the shore in a direct line towards Bagirmi and Wadai. To compare the relative merits of these trunk lines is perhaps looking too far into the future, and traversing too much unknown country, to make the discussion at all profitable.

Proceeding northwards, or rather westwards, along the coast we find ourselves skirting the belt of dense forest already described as being the great obstacle to advance in this part of Africa. It is to be hoped that this barrier will be pierced in several places before long. Naturally we turn our attention to the different spheres of British influence, and here we are glad to learn that there are several railways being constructed or being considered, with a view to opening up the interior.

At Lagos a careful survey of a railway running in the direction of Rabba has been made, and the first section is to be commenced at once. To connect the Niger with the coast in this way would require 240 miles of railway, but the immediate objectives are the towns of Abeokuta and Ibadan, which are said to contain more than a third of a million inhabitants between them. No doubt the populous coast region makes such a line most desirable; but whether it would be wise to push on at all quickly to the Niger, and thus to come into competition with the steamboat traffic on that river, is a very different question.

Surveys have also been made for a railway to connect either Kormantain or Apan on the Gold Coast with Insuaim, a town situated on a branch of the Prah. It is believed that the local traffic will be sufficiently remunerative to justify the construction of this line. But, looking to the further prolongation of this railway into the interior, it appears possible that those who selected this route were too much influenced by the desire to reach Kumasi, which is a political rather than a commercial centre. According to the views I have been advocating to-day, the main object of a railway in this quarter should be the crossing of the forest belt, and if, as there is some reason to believe, that belt is exceptionally wide and dense in this locality, the choice of Kumasi as a main point on the route will have been an unfortunate selection. A little further south, nearer the banks of the Volta, it is probable that more open land would be met with, and moreover that river itself, which is navigable for steam launches from Ada to Akusi, would be of use as a preliminary means of transport. It is to be hoped that the merits of a line from Accra through Odumase will be considered before it is too late.

I am now approaching the end of my brief survey of tropical Africa, for the best method of opening communication between the Upper Niger and the coast is the last subject I shall touch on. With this object in view, the French have constructed a railway from Kayes, the head of steam navigation during high water, on the Senegal to Bafulabé, with the intention of ultimately continuing the line to Bamaku on the Niger Unexpected difficulties have been met with in the construction of this railway, and, as the Senegal River between Kayes and St. Louis is only navigable for about a quarter of the year, it would hardly appear as if the selection of this route had been based on sound geographical information. No doubt the French will find some other practicable way of connecting the Upper

Niger with the coast, and surveys are already in progress with that object in view. It may be worth mentioning that the Gambia is navigable as far as Yarbutenda, and that it affords on the whole a better waterway than the Senegal; it is possible, therefore, that a railway from Yarbutenda to Bamaku might form a better means of connecting the Niger with the coast, than the route the French have selected.

At Sierra Leone a railway is now being constructed in a south-easterly direction with a view of tapping the country at the back of Liberia. But here, as in the case of the Gambia route, political considerations are of paramount importance; for no doubt the best commercial route, geographically speaking, would have been a line run in a north-easterly direction to some convenient point on the navigable part of the Upper Niger. If such a railway were ever constructed, it would connect the longest stretch of navigable waterway in this region with the best harbour on the coast. But the fact that it would cross the Anglo-French boundary is a complete bar to this project at present.

Proposals for connecting Algeria with the Upper Niger by rail have often been discussed in the French press, the idea being to unite the somewhat divided parts of the French sphere of influence by this means. If the views here sketched forth as to the necessity of selecting more or less populous districts for the first opening up of lines of communication into the interior are at all correct, these projects would be simple madness. For many a year to come Algeria and the Niger will be connected by sea far more efficiently than by any overland route, and I feel sure that when the details of these plans are properly worked out we shall not find the French wasting their money on such purely sentimental schemes.

I must now conclude, and must give place to the other geographers who have kindly undertaken to read papers to us on many interesting subjects. All I have attempted to do is briefly to sketch out some of the main geographical problems connected with the opening of Central Africa in the immediate future. Such a review is necessarily imperfect, but its very imperfections illustrate the need of more accurate geographical information as to many of the districts in question. Many blunders may have been made by me in consequence of our inaccurate knowledge, and, from the same cause, many blunders will certainly be made in future by those who have to lay out these routes into the interior. In fact my desire has been to prove that, notwithstanding the vast strides that geography has made in past years in Africa, there is yet an immense amount of valuable work ready for anyone who will undertake it.

Possibly, in considering this subject, I have been tempted to deviate from the strictly geographical aspect of the case. Where geography begins and where it ends is a question which has been the subject of much dispute. Whether geography should be classed as a separate science or not has been much debated. No doubt it is right to classify scientific work as far as possible; but it is a fatal mistake to attach too much importance to any such classification. Geography is now going through a somewhat critical period in its development, in consequence of the solution of nearly all the great geographical problems that used to stir the imagination of nations; and for this reason such discussions are now specially to the fore. My own humble advice to geographers would be to spend less time in considering what geography is and what it is not; to attack every useful and interesting problem that presents itself for solution; to take every help we can get from every quarter in arriving at our conclusions; and to let the name that our work goes by take care of itself.

The following Papers were read:—

1. *On a Journey in Tripoli.* *By* H. S. Cowper.

The author gave some account of a short journey made in March, 1896, in the Tarhuna and M'salata districts of Tripoli. During his visit he examined or noted about forty additional megalithic ruins of the type called by the Arabs *Senam*. The route taken was by the Wadi Terr'qurt, a fine valley running parallel to the

Wadi Doga, by which he entered the hills in 1895. He then proceeded to the districts of Ghirrah and Mamurah, south of Ferjana, through which runs a great wadi, the Tergilat. This reaches the sea at Kam, twelve miles south-east of the ruins of Leptis Magna, and is undoubtedly the Cinyps of Herodotus. On reaching the coast a week was spent at the ruins of Leptis and the Kam district, and the return journey was made to Tripoli by sea.

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2. *The Land of the Hausa.* *By* Rev. J. C. Robinson.

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3. *Photographic Surveying.* *By* John Coles.

This paper contains a concise history of the application of perspective drawings and photographs to surveying. It then states the manner in which photographs taken with an ordinary camera may be utilised in filling in the details of a map, and proceeds to describe two surveying cameras of recent date, constructed on different principles. The paper concludes with a reference to the method of photographic surveying, which is being extensively employed by the department of the Surveyor-General of the Dominion of Canada.

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4. *Marine Research in the North Atlantic.* *By* H. N. Dickson, *F.R.S.E.*

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5. *On a Proposed Geographical Description of the British Islands.* *By* Hugh Robert Mill, *D.Sc.*, *F.R.S.E.*

The scheme submitted is that of providing for each sheet of the 1-inch Ordnance Survey map a memoir giving a succinct account of the geography of the district represented. For this purpose it would be necessary to give an index of the names on the map, certain measurements of natural features, *e.g.*, mean height of land, length of rivers, &c., a full discussion of the physical geography in the light of modern geographical methods, and an indication of the influence exerted by geographical conditions on the utilisation of natural resources, the sites of towns, and the movements of population. The scheme has been published in full in the 'Geographical Journal' for April 1896; but since, if it is ever to be carried out, it will require the co-operation of an immense number of workers throughout the country, it is desirable that no opportunity be lost for making it known and eliciting criticisms or suggestions.

FRIDAY, SEPTEMBER 18.

The following Papers were read:—

1. *The Weston Tapestry Maps.* *By* Rev. W. K. R. Bedford, *M.A.*

William Sheldon, of Weston and Beoley (died 1570), was an enterprising man, who conceived the idea of introducing the art of tapestry weaving into England. He sent to Flanders one Richard Hicks, of Barcheston, to learn the work and bring back artisans. Among other results of the looms which were kept in work for at least half a century after Sheldon's death are five maps of the Midland counties which were bought by Horace Walpole after the mansion at Weston was pulled down in 1776 for the sum of thirty guineas, and given by him to Earl Harcourt, who presented two to the Bodleian and kept three at Nuneham, where they remained until 1827, when Archbishop Harcourt presented them to the Museum at York. Gough has described them at this period in his British Topographer, 1780. The first noticed represents Warwickshire, and is now at York. It is 13 ft. × 17 ft. × 3 ft. exclusive of the border, and contains a long inscription copied from Camden. Its date is ascertained by the arms of Sheldon impaling Markham, viz., Edward Sheldon, grandson of William, who married Elizabeth Markham about 1588, which date is on the map.

The second of the York maps is the most modern, having the arms of Ralph Sheldon, born 1623, and his wife Henrietta, daughter of Viscount Rocksavage. In this map the north is at the top, but in the former map the north is upon the east side. This represents the valley of the Thames from Chippenham (spelt Chipnam) to London Bridge, the dimensions are 13 ft. × 17 ft. 9 inches.

The third map at York is one of Worcestershire, and is so begrimed with soot as to be almost undecipherable, though enough can be made out to identify it with Gough's description.

The Bodleian maps are much mutilated. A large fragment cut off one made into a screen was sold at the Strawberry Hill Sale, 1842, and Mr. D. P. (Dudley Perceval?) in 'Notes and Queries,' June 26, 1869, says that he had lately been offered a portion of the West of Gloucestershire at an old curiosity shop. Still there are remnants of great beauty and interest. On the fragments of the border are many ornamental and allegorical figures, one favourite subject being the exploits of Hercules. There is a small map of Africa also which has unfortunately suffered terribly, though the Capo de Bona Speranza and the island of Madagascar are quite distinct. Another feature is that poetical inscriptions in decorative panels form part of the border.

On this side which the sonne doth warme With his declining beames,
  Severn and Teme in channell deepe Doo run, too ancient stremes,
Thes make the neibor's pasture riche. Thes yeld of fruit great store,
  And do convey tho out the shire, Commodities many more.

Again, under the word Occidens,

Here hills do lift their heads aloft. From whence sweet springes doo flow,
  Whose moistur good doth firtil make The vallies coucht below.
Here goodly orchards planted are, Infinite which doo abounde
  Thine ey wold make thin heart rejoyce To see such pleasant grounde.

The Tudor arms also date the map as having been executed before the accession of James I., and Richard Hyckes has placed his name upon it. 'Wigom: comit: Compiletata, Rich. Hyckes.' The remaining map is one of the valley of the Thames similar to the one at York already described. It was from this that Walpole cut the piece for the screen. Fortunately, the piece containing London is intact 18 × 36 inches, and gives a most graphic and curious portraiture of the suburbs. The manor houses and deer parks, the churches, villages, bridges, and windmills, are all represented in a bird's-eye view, and the colours have stood the test of time remarkably well. Every village is named, and the spelling even to some obvious mistakes seems to follow that of Saxton's maps, but these maps are so much larger a scale, 3 inches to the mile, that it is evident some personal observation or survey was undertaken, I am inclined to believe, by Francis Hicks, of Barcheston, who was a student at St. Mary Hall, Oxford, and a good scholar. He died in 1630.

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2. *The Altels Avalanche.* *By* Tempest Anderson, *M.D., B.Sc.*

On September 11, 1895, an enormous avalanche fell from the Altels mountain and overwhelmed a large pasture; it destroyed 6 men and 150 cattle.

About two hours to the south of Kandersteg the Gemmi path traverses an upland valley with the Altels rising steeply from the stream on the east side and with gentle slopes on the west, rising to the foot of the Oeschinen Grat, a precipitous wall of rocks which separates it from the Oeschinen Thal. The basin of

Spittalmatte thus formed is about $1\frac{1}{2}$ mile long from north to south and $\frac{3}{4}$ mile wide. Its southern portion is diversified by low wooded hills, the Arvenwald, obviously formed by avalanches in past ages, and the northern portion was an open pasture or Alp now overwhelmed.

The Altels is a roughly pyramidal mountain. The west face from which the avalanche descended slopes at a high angle, and the limestone strata of which it is composed dip at about the same angle. The upper part is, or rather was, covered with snow and glacier ice. At a certain distance from the top the glacier ceases to spread, and becomes confined within rocky walls on either side, where the strata, formerly continuous, have been removed in past ages by avalanches. The whole width of the glacier at the place where it has slid appears from the Sigfried map to be about a kilometre, and the middle half of this descended, leaving a portion of about $\frac{1}{4}$ kilometre standing at each side. The portion on the south side which has not descended is separated from the rest by a wall of rock, and this separation probably accounts for it not having come down at the same time; it extends lower down the mountain than the fallen part appears to have done.

The avalanche descended to the bottom of the valley, a vertical distance of about 4,000 feet, and the acquired momentum carried the greater part of it up the slope on the other side to a height of about 400 feet above the lowest point. Here it spread out in a fan shape, and formed a return current on each side, the northern one of which descended again quite to the bottom of the valley. There were also local return slips. The stream was covered up by the avalanche ice, but speedily worked a way underneath it, and the glacier bridge thus formed had not quite melted on a second visit a year after the event. The area covered was about 1 mile by $\frac{1}{2}$ mile. The average thickness, as estimated in the sections exposed by the return slips, was about 6 feet, but there were places 20 feet thick, and some doubtless more, near the bed of the stream. The materials of which the avalanche was composed were an intimate mixture of snow and glacier ice with stones and mud, the two former, perhaps, on the whole, predominating; but in one good exposure, though the ice and snow predominated in the upper part the stones and mud did so near the base. Many of the stones showed marks of rubbing and scratching, especially those at the parts of the avalanche further from the Altels; nearly all of these, however, retained some angle unworn, and thus differed from ordinary river gravel.

The effects of the wind which always accompanies avalanches was strikingly shown by the over-turning of about 1,000 trees and the destruction of some chalets, the materials of which were carried above 100 yards. The tops of the trees all pointed radially away from the direction of the couloir, down which the avalanche had fallen. This destruction by the wind was in an area outside that actually overwhelmed by the avalanche, and here also large boulders could be seen which had been rocked by the force of the wind. Six men were killed in the chalets, and about 160 cattle on the pasture.

The ice cliff left standing by the fall of the avalanche was semi-elliptical in shape, about $\frac{1}{2}$ a kilometre in extent, and from 50 feet to 70 feet high. Nearly all of it presented the appearance of a perfectly fresh fracture. There were blue veins of more compact ice in many parts, and also a few dirt bands of stones in the substance of the ice. One was specially conspicuous towards the south end of the cliff, and about one-third of its height from the bottom. Its presence here was very remarkable, as there are no rocks overhanging the glacier from which the stones could have fallen. A few rocks just peep through the snow at the edge of the arête, and if the stones did not come from this source, which seems unlikely, they must have been picked up by the glacier from its floor. There were slight indications of another crack in the glacier parallel with, and perhaps 100 yards further up than, the cliff, but the author is inclined to think that it was only the usual bergschrund.

The rocky floor of the glacier left exposed by the fall was singularly smooth, and its inclination coincided with the dip of the limestone strata of which it was composed. Dr. Heim believes that the glacier is usually frozen in its bed, and that the catastrophe is due to the unusual period of hot weather which preceded it.

A similar avalanche which took place at the same place in 1782 also followed a period of unusual heat.

The author visited and photographed the scene of the avalanche in the first instance on September 23, 1895, and following days, and again visited it September 9, 1896. A good deal of ice still remains unmelted. The stones, having been washed by rain, show their scratchings much more conspicuously than last year. Vegetation is beginning to show itself in many places, spreading chiefly from sods and pieces of earth dislodged by, and mixed up with, the avalanche material.

The ice cliff has altered very little in appearance, though it is somewhat rounded by melting. The dirt bands are still conspicuous.

The total loss in land and cattle has been estimated at 130,000 francs, or above 5,000*l.*

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3. *On Uganda and the Upper Nile.* *By* Lieutenant C. F. S. Vandeleur, *Scots Guards.*

Lieutenant Vandeleur started from Mombasa on September 7, 1894, with Mr. Jackson and Captain Ashburnham, and a large caravan of about 400 men, carrying arms and ammunition, and after a most successful march reached Uganda at the end of November, at the time Colonel, now Sir H. E. Colvile, was Commissioner. He started again with Major Cunningham on December 19 for Unyoro and Lake Albert. The road used at that time led by Singo and across the river Kafu at Barauwa, and was a very bad one, crossing many large and deep swamps. The first Wanyoro were met with at Kaduma, and there is a marked difference between them and the Waganda, the former having much sharper features, and being of a slighter build than the Waganda. Having arrived at Fort Hoima, the headquarters, on January 1, 1895, after a halt of five days they continued their journey to the Albert Nyanza. On nearing the lake the country became more open and rocky in places, until the edge of the escarpment was reached, where the lake lies 1,200 feet below it, bordered by a strip of yellow sand, the Sudanese fort and the native village called Kibero looking mere specks close to the water's edge. Lieutenant Vandeleur then described the journey down the Nile in a steel boat with a crew of sixteen men. A friendly Wanyoro chief called Keyser, who spoke the Lure language, and had lived at Wadelai, went as guide. They sailed all the first day with a good breeze, and camped on the western shore at Mahagi after dark, where they had difficulty in finding a landing place, owing to the reeds and swampy nature of the shore. They eventually reached Wadelai, and camped one mile further on at Emin Pasha's old fort, which was then completely overgrown. The natives appeared very hostile, and had evidently thrown in their lot with Kabba Rega, king of Unyoro. After Wadelai the stream was very strong, and they glided rapidly past narrow channels through the floating vegetation and papyrus, stopping sometimes near the villages on the banks to ask for news, at all of which they were informed that the dervishes were advancing from Dufile by both banks. The first Madi village was met with at Towara, and the natives became more friendly as they made their way down the river. The natives are continually fighting among themselves, and lead a precarious existence; several of the latter came to have their wounds dressed.

An enormous amount of floating vegetation passes down the Nile; it is gradually broken off from the sides of the river by the force of the current, and floats down until it attaches itself to the sides again, or reaches the cataracts below Dufile, where it gets broken up into little pieces. After Bora, an old Egyptian fort on the right bank, the river is very broad, about 1½ miles, though the actual channel through the mud is only about 500 yards in breadth. The banks between Unigwe and Dufile seemed well populated; several of the villages were hidden away among the high rocks and boulders on small hills close to the river, and there was a certain amount of dhurra and mtama cultivation, but very few sheep and goats. Late in the afternoon of January 14 they arrived at the old fort at Dufile, situated close to the water's edge at a bend of the river on the left bank. The parapet and ditch were still very distinct; some mud-brick houses, some lemon and cotton trees, were the only signs remaining of the Egyptian occupation. It is believed they were the first white men to have reached Dufile since the abandonment of the place in 1888. The native reports proved quite untrue, and the dervishes were now at Regaff, below the cataracts, which they went to inspect the next day. The Madi natives are a fine, strong-looking race; they wear little or no clothes, and have no wants excepting beads and iron wire. At Umiaa's village, at the bend of the Nile, a representative of Abu Sulla was met with, an important chief living one day's march below Dufile, on the right bank. He was dressed in white cloth, which was probably obtained from the Arabs or Mahdists to the north. Most of the villages are reached by narrow channels, cut through the floating vegetation, and are almost impossible to find. The return journey to the Albert Nyanza was long and tedious, owing to the strong stream. On reaching the Albert Nyanza camp was pitched at Boki; it was a very dark night, and a large herd of elephants came down on both sides of the camp to drink, some of them coming unpleasantly close.

The people on the west of the Albert Nyanza used to pay tribute to Kabba Rega, but that is at an end now. The Shulis, in the angle contained by the two Niles, are inclined to be friendly. With steamers on the lake and railway communication, a large extent of country would be opened for trade, and there is no limit at present to the ivory to be obtained from the countries bordering the Albert. There is no hindrance to navigation down to Dufile. The road now used between Unyoro and Uganda passes by Mrulfi at the junction of the Kafu river, where there is a fort garrisoned by Sudanese, and on along the Victoria Nile to Lake Kioja, from where it runs in a direct line to Mengo, the capital of Uganda. The road is a very good one, and has been carried across the swamps or causeways.

In Kampala there are broad roads which enclose houses and shambas. The railway will make a great difference to this country. There is a large demand for European clothes, boots, and shoes; the people are very imitative, and already the king and chiefs have given orders to traders for various articles which they see the Europeans possess. A great deal of rice and a certain amount of English potatoes and native coffee are grown in Uganda. Cotton has been found to grow well. One result of the railway will be that horses and donkeys will be transported rapidly through the belt of country infested by the tsetse fly, and ought to reach Uganda in good condition. Animals do well there, if well looked after, though dangers exist in snakes and bad grass met with in places.

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4. *Coast-forms of Romney Marsh.* *By* Dr. F. G. Gulliver.

Dungeness Point in south-eastern England projects from the dissected Weald dome into the English Channel. It consists of two classes of recent deposits, shingle and marsh. It is proposed here to discuss these deposits, formed during the present cycle of shore development, as representing a coastal form characteristic of a certain stage of a cycle.

The whole deposit may be called a cuspate foreland.[1] *Foreland* is here used as a technical term, meaning those deposits which are built in front of the oldland, including all those forms that project into the sea beyond the initial coastline, which was formed where the sea surface intersected the land at the beginning of the cycle.

This initial coast was attacked by the sea, and early in the development of the coast and shore form a low cliff or 'nip' was made in the coast all along the shore.

At a later stage in the development the supply of load was just enough to equal the ability of the sea to transport, and a graded condition resulted. A beach now was seen at the foot of the cliff. This equilibrium would not last at all

[1] *Bull. G.S.A.*, vol. vii. 1895, p. 399.

points, and aggradation would necessarily occur when more waste was supplied than the sea could carry. This aggradation would take place where the action of the sea wasting was least. The writer has suggested eddies in the tidal in and outflow as the determining agent in the location of some of the cuspate forelands.[1]

Topley recognised the action of the sea upon the oldland previous to the building out of this foreland. He said: 'Along the northern boundary of Romney Marsh the termination of the Weald Clay is certainly an old sea-cliff, now worn down into undulating ground.'[2] The much fresher cliff north from Rye along the military road indicates a more recent action of the sea upon this portion of the initial shoreline.

The geographic interpretation from form is corroborated by the history and tradition of Romney Marsh.[3]

The historical students of Romney Marsh do not sufficiently regard the line of former shorelines indicated by the ridges of shingle, but place rather too much reliance upon outlines given on early maps, many of which show poor sketching and little knowledge of geographic form. It has been very common to attribute the formation of this great deposit to the tides, but the details of the process have not been explained except in a most general manner by such expression as the 'meeting of the tides.'

Diagrams were shown illustrating the formation of tidal cuspate forelands, and it was pointed out that Dungeness with its included marshes corresponds to the filled stage plus cutting back and rebuilding of the Point.

The most recent curves of aggradation are very prettily shown at the Point when looking toward the centre of the cuspate foreland from the lighthouse. Recent observations at the Point indicate that this shoreline is here advancing at the rate of 9 feet a year. A mile to the west the sea is at present cutting into the shingle. Upon the eastern side of this foreland there are some twenty-three successive shorelines shown between Lydd and the present shoreline. These all curve sympathetically, indicating steps in the eastward growth of the foreland. These ridges are not absolutely parallel or continuous, for some twenty lines of aggradation at the Point were traced by the writer into fourteen at a point a mile north, and these fourteen were in turn traced into seventeen ridges at a point a couple of miles further north. At one time there seems to be greater advance in one place, and when the complex conditions which govern depositions are changed another point receives the most waste.

The hypothetical initial shoreline was indicated by a diagram. Where the cliffs are high the initial land has presumably been most cut back. Behind the foreland the land probably did not extend a great deal farther than the present low cliff or 'nip' which was made in the youth of the present cycle.

On account of the graded form the present coast may appropriately be said to be in adolescence, following Professor Davis' use of this term for land surfaces.[4]

English sailors have recognised forms similar to Dungeness, and have applied the same name to forelands of like geological structure in Puget Sound, and south of Patagonia in the Straits of Tierra del Fuego.

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5. *Last Year's Work of the Jackson-Harmsworth Expedition.* *By* A. MONTEFIORE BRICE.

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[1] *Loc. cit.*, p. 413.

[2] *Geol. Weald*, pp. 251, 302.

[3] See *Cinque Ports*, by Montague Burrows; also writings of Robertson, Wm. Hollaway, Wm. Somner, F. H. Appach, Hasted, A. J. Burrows, and many other references in Topley's *Geology of the Weald.*

[4] See *Geog. Jour.*, vol. v. 1895, p. 127; 'Rivers and Valleys of Pennsylvania,' *Nat. Geog. Mag.*, p. 1; 'Geog. Development of N. New Jersey' (with J. W. Wood, jun.), *Proc. Boston Soc. Nat. Hist.*, 1889.

6. *The Influence of Climate and Vegetation on African Civilisations.* *By* G. F. Scott-Elliot, *F.L.S.*, *F.R.G.S.*

An attempt is made in this paper to connect the various African states of civilisation with the climate and vegetation of the particular districts in which they took origin. For this purpose the continent is divided into four main groups or divisions, which are characterised by the following points:—

I. *The wet jungle*, which is marked roughly by the presence of the oil or cocoanut palm, numerous creepers—especially the Landolphia (rubber vines)—and such forms as Sesamum, *Cajanus indicus*, and Manihot as cultivated plants. This region is characterised by great heat and continuous humidity, without a season sufficiently dry to leave a mark on the vegetation.

II. *The deserts.*—Characterised by xerophytic adaptations, by Zilla, Mesembryanthemum, *Capparis sodada*, &c. The climate is distinguished by possessing no proper rainy season whatever.

III. *The acacia and dry grass region.*—Characterised by acacias, tree euphorbias, giant grasses, or frequently grassy plains in which each tuft of grass is isolated. The climate is marked from all the remaining regions by distinct dry and wet seasons; the dry season occupies from five to nine months, and leaves a distinct mark on the vegetation. This region occupies practically all Africa between 3,000 feet and 5,000 feet, and also extends below 3,000 feet wherever the above climatic conditions prevail.

IV. *The temperate grass and forest area.*—This region is distinguished by having at no season of the year such drought as leaves a permanent mark on the vegetation, by a moderate rainfall, by moderate heat, &c. The grass resembles the turf of temperate countries, and the forest shows the same sorts of adaptation as occur in temperate countries. This region is found between 4,600 feet and 7,000 feet.

The paper is an attempt to trace the native races inhabiting these divisions, comparing their civilisations, so far as this is possible.

I. The wet jungle is shown to be limited by the direction of the prevalent winds ('Challenger' Reports), by various meteorological considerations, and by the elevation. It extends to 3,000 feet, but often ceases below this level. Reference is given to the works of many travellers, to the Report of the British Association dealing with African meteorology, and by the assistance of these data an attempt is made to trace its boundaries exactly. Then it is shown that it is everywhere inhabited by small tribes of a weak, enfeebled character and on the lowest stage of civilisation. All these tribes have been subdued by Arabs and Europeans without difficulty.

II. The desert is very shortly disposed of. The account is directed chiefly to the extreme severity of the climate and the exceedingly healthy and vigorous nature of the tribes inhabiting it. A short account of the causes leading to its present condition is also given.

III. The acacia region is more clearly and carefully defined, and hints are given as to the easiest means of recognising the climate from the vegetation. It is shown to vary much in character, and a brief sketch is given of the Upper Scarcies and Niger region about Falaba, of the Mombasa to Kibwezi tract, of the Shiré Highlands, and the Victoria Nyanza basin. The region is shown to be everywhere rather densely inhabited, but there has not been a swarming centre, and no emigration in large numbers has taken place from this acacia region. The nations inhabiting it have also fallen under the Arab and European with scarcely a struggle. An explanation is given of the reason of this.

IV. The temperate grass and forest regions above 5,000 feet are then shown to be the only places in Africa that have acted as swarming centres of population. The character of the native races inhabiting them is shown to be vigorous and turbulent, and often raiding is carried on. The differences in climate, vegetation, and abundance of wild and domestic animals are shown to explain why it is that these races only have, except in one instance, resisted both Arab and European. In a note an attempt is made to reconcile the classification given by Herr Engler with that adopted in this paper.

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7. *Sand Dunes.* *By* VAUGHAN CORNISH, *M.Sc.*

In the sorting of materials by wind the coarser gravel is left on stony deserts or sea-beaches, the sand is heaped up in dune tracts, and the dust (consisting largely of friable materials which have been reduced to powder in the dune district itself) forms widely scattered deposits beyond the limits of the dune district. Three principal factors operate in dune tracts, viz. (1) the wind; (2) the eddy in the lee of each obstacle; (3) gravity. The wind drifts the fine and the coarse sand. The upward motion of the eddy lifts the fine sand and, co-operating with the wind, sends it flying from the crest of the dune. The backward motion of the eddy arrests the forward drift of the coarser sand, and thus co-operates with the wind to build the permanent structure of the dune. Gravity reduces to the angle of rest any slopes which have been forced to a steeper pitch either by wind or eddy; hence in a group of dunes the amplitude cannot be greater than (about) one-third of the wave-length. This limit is most nearly approached when the wind blows alternately from opposite quarters, but does not hold in one quarter sufficiently long to completely reverse the work of preceding winds. Gravity also acts upon the sand which flies from the crests, causing it to fall across the stream lines of the air, the larger or heavier particles falling more steeply. To the varying density of the sand-shower is due the varying angle of the windward slope of dunes. When there is no sand-shower the windward becomes as steep as the leeward slope. When the dune tract is all deep sand the lower part of the eddy gouges out the trough, and, when the sand-shower fails, the wind by drifting and the eddy by gouging form isolated hills upon a hard bed. On the other hand, the sand-shower sometimes smooths over a dune tract, leaving lines of hollows ('Fuljes'), where the troughs were deepest and the wind strongest. The encroachment of a dune tract being due not only to the march of the dunes (by drifting) but also to the formation of new dunes to leeward from material supplied by the sand-shower, it follows that there is both a 'group velocity' and a 'wave velocity' of dunes. Since the wave velocity decreases as the amplitude increases, a sufficiently large dune is a stationary hill, even though composed of loose sand throughout. Binding the surface will stop the wave-motion, but not the group motion. Both may be arrested by promoting the growth of the dune.

The fundamental forms of sand-dunes include the *longitudinal,* formed where the strength of the wind is too great to permit free lateral growth. Where the wind begins to decrease a form is met with *intermediate* between the longitudinal and the *transverse.* Conical dunes may be produced by the action of varying winds upon the rudimentary longitudinal dunes, called Barchanes.

Where material is accumulated by the action of tidal currents, forms homologous with the ground plan of dunes are produced.

SATURDAY, SEPTEMBER 19.

The following Papers and Report were read:—

1. *World Maps of Mean Monthly Rainfall.* *By* ANDREW J. HERBERTSON, *F.R.S.E., F.R.G.S.*

For practical purposes it is almost as important to know how rainfall is distributed throughout the year, as to know the total annual precipitation. The best way to show this is to make maps of mean monthly rainfall that will be comparable. Each month must be considered one-twelfth of a year and the average monthly rainfall reduced accordingly. This is being done at present by Dr. Buchan, Secretary of the Scottish Meteorological Society, and the author, and, as far as they are aware, it is the first attempt to do so for the whole world. The scanty records of some regions make the positions of the lines of equal rainfall (*isohyets*) somewhat uncertain. These are dotted on the maps. The other isohyets are shown by firm lines, and the different intensities of colour indicate different quantities of water precipitated. From such maps the relationship of the distribution of rainfall to latitude and altitude, to remoteness from the coast and the nature of the land around, to the changing seasons or prevalent winds, is clearly seen. Some typical examples were given, especially those of economic importance.

2. *The Climate of Nyasaland. By* J. W. MOIR.

3. *Report on African Climate.*—See Reports, p. 495.

4. *Practical Geography in Manchester. By* J. HOWARD REED.

The author believes the Manchester Geographical Society has demonstrated that geography is popular among the people. Mr. Eli Sowerbutts, secretary of the Manchester Society, commenced giving popular geographical lectures some years ago. The demands for work of this kind grew to such proportions that a body of prominent members of the Society, including the chairman, took up the lecturing work, which has increased year by year ever since. The lecturers now form an organised body of expert geographers and practised speakers, who freely volunteer their services for the purpose of spreading reliable geographical information. The lectures are all given in a popular manner, and are mostly illustrated by lantern views. During the past five years over three hundred lectures have been delivered in Manchester and the surrounding districts, and over ninety thousand hearers have been reached. The audiences are principally of the working class, but also include the members of many well-known literary and scientific clubs, and students of continuation schools. The lectures given include such titles as: 'Shaping of the Earth's Surface by Water-action,' 'Map Projection,' 'India,' 'China, Corea, and Japan,' 'Polar Exploration,' 'Across the Rocky Mountains,' 'Canada,' 'Across Africa with Stanley,' 'Uganda,' &c. Applications for lectures are made to an hon. secretary, who conducts all correspondence and makes arrangements with the local societies and clubs and the lecturers. The engagement of halls, printing, and similar matters are carried out on the spot by the local people. This system has proved so satisfactory, and the enthusiasm of the voluntary workers has been so well maintained, that no hitch has ever occurred. The terms on which the lectures are given are very simple. Any member of the Manchester Geographical Society or any affiliated society is entitled to apply for lectures. Lantern apparatus and volunteer operator are supplied when required. A nominal fee is charged for each lecture, travelling and lantern expenses being added when incurred. Any balance in hand at the end of each season is applied to the upkeep of lantern plant and the making and purchase of new slides. Another important branch of voluntary work consists in the analysis of some two hundred British and foreign scientific journals. This is most useful for scholars and students. It enables them to follow up, with ease, the literature on any special subject. It has received the commendation of several high authorities. The Manchester geographers intend to follow up the work they are doing, and hope to more fully occupy the field. They are conscious that there is ample room for development. The author feels sure they would be glad to hear of similar organised effort in other parts of the country.

5. *Canada and its Gold Discoveries. By* Sir JAMES GRANT.

MONDAY, SEPTEMBER 21.

The following Papers were read:—

1. *A Journey towards Lhasa. By* W. A. L. FLETCHER.

2. *The Northern Glaciers of the Vatna Jökull, Iceland. By* FREDERICK W. W. HOWELL.

The route taken was from Seydifjördr on the east coast, up the valley of the fine river lake Lagarfljót.

At Valthjófstadr is the finest skogar, or wood, in the country, some trees (birch) being 20 to 25 feet high. Hengifoss is the loftiest waterfall in Iceland, the upper portion having a perpendicular drop of 350 feet. Surturbrand in the gil. Headquarters at Valthjófstadr. Thence two journeys: first viâ Brú to the unknown valley of the Kverká, which river was followed to its source in an ice-cave in the Brúar Jökull; it abounds in quicksands. The second journey was from Valthjófstadr to Snaefell and the Eyjabakka Jökull.

In the winter of 1889-90 a volcanic eruption took place under the ice of these two glaciers, causing an enormous Jökulhlaup, or glacier leap. The whole face of the 30 mile wide Brúar Jökull was carried forward, in some places for nearly 6 English miles; and the face of the 15 mile wide Eyjabakka Jökull for 2 to 3 miles. The former has since retired 16 yards, and the latter about one-eighth of a mile.

New cones on the Eyjabakka Jökull, reaching a height of 4 feet. 6in., afford an index to the rate of surface diminution which is not less than 8 inches per annum. The face of this glacier is extremely fine, the ice cliff being 100 feet high; and, being undermined by the river, it frequently gives way, exposing fresh sections.

The flowers in the valley of the Jökulsá-i-Fljótsdal call for special notice. Columnar basalt occurs throughout the district. Snæfell is not a single mountain, but a handsome group of ten to twelve peaks, mostly composed of tufa and cinder. The glaciers upon it are small, and lie at a high level. The junction of Jökulkvisl with Jökulsá-á-Brú is wrongly marked. Reindeer abound in the district.

3. *Notes on the less-known Interior of Iceland. By* KARL GROSSMANN, *M.D., F.R.C.S.E., F.G.S.*

The author's last journey to Iceland, which was undertaken in the summer 1895, for the purpose of investigating leprosy amongst the inhabitants, admitted of an exploring excursion into the lonely district to the east of Hekla, while the crossing of the island from north to south gave occasion for examining parts equally interesting and equally unvisited.

The eruptions of the various vents comprised under the name of the Hekla group are particularly rich in obsidian lavas. A very finely vesicular obsidian goes as far south as Stórolfshvoll. Of very rugged character is the landscape of the Hrafntinnuhraun, most desolate, void of vegetation, full of volcanic ashes and sand and large torrents of a peculiar obsidian lava, on which in many places the three stages of pumice, obsidian, and banded rhyolite are seen in the same blocks, the three parts following in the order given from above downwards.

The landscape in the neighbourhood of the large lake of Sudur Námur resembles a lunar landscape in appearance. Various exquisite craters are found here, amongst others one that is probably the finest ring crater in Iceland. On climbing up the wall of the ring a central cone is seen of perfect shape, built up of slags which form a sharp-edged hemispherical cup of beautiful regularity.

The journey across the island was made from Akureyi by way of the Eyjafjardará valley. The dense fogs made this part of the journey both difficult and obscured the views. When the plateau was reached, the clouds lifted, and the Hofsjökull was seen in all its enormous extent.

The country north of the Hofsjökull is absolutely barren, and consists of gently undulating territory of loose débris, many water-worn pieces of obsidian and obsidian bombs being found scattered everywhere. The hot sunshine made it impossible to cross the swollen Jökulsá vestri, which was followed up to its source on the Hofsjökull; but the mud and slush prevented a crossing. Nor could the horses be brought over the glacier itself. For more than twenty-four hours they had not had a blade of grass to eat, and it seemed impossible to proceed further southwards; but, after a severe night's frost, a fording was ultimately effected in the small hours of the following morning some miles below the source of the river.

The Hveravellir were examined and a large series of photographs taken. The sinter crater and terraces of these hot springs are the most beautiful in the island, and the territory round them forms one of the richest oases.

To the east of the Hveravellir a wide crater resembling Hverfjall, but not complete to the S.W., was seen, which is neither the Strytur nor Dúfufell of Thoroddsen's map. On the E. it is flanked by a large lake, which was named Karlsvatn. The lava flow between Hveravellir and the crater mentioned has on its surface a fine layer of black tachylite, $\frac{1}{8}$ inch thick (specimens were shown).

The further progress S was of equal interest. The "high peak" called Blágnypa could not be seen at all, although the weather was perfect during that part of the journey. On the other hand, very clear photographs were taken of a big mountain chain of quite alpine character, contrasting most strikingly with the flat and tame polagonite plateau on which the enormous ice-sheet of the Hofsjökull rests.

This mountain chain, going from N. to S., has large glaciers quite of alpine appearance; that they must be permanent is clear from the fact that the snow had melted more than usually during that year, so that the snowcap of Skjaldbreid had disappeared altogether some four weeks previously. Thoroddsen does not mention these mountains and glaciers, nor does he show them in his map; he cannot have seen them, as they are not what he figures as the Kerlingafjöll, although they take the place immediately north of where he puts the latter.

The district of the Hvitárvatn was also visited. All this district is highly interesting and full of surprises. It will well repay a careful exploration, as hitherto only a very sketchy and fragmentary outline of it is known.

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4. *The Relativity of Geographical Advantages.* *By* GEORGE G. CHISHOLM, *M.A.*, *B.Sc.*

The considerations to which attention is drawn in this paper are for the most part obvious and familiar, and the only excuse for laying them before the British Association is that they are nevertheless apt to be overlooked, especially in estimates of past conditions, and still more in forecasts based on geography as to the condition of the future.

Geographical advantages may be considered—(1) as relative to the physical condition of the surface of a country, *e.g.* the extent of forests, marshes, &c. The former and present relative importance of Liverpool and Bristol may be explained in part at least by changes that have taken place under this head. Also the difference in direction of some of the great Roman roads and those of the present day, and the consequent fact that some important Roman stations in Britain are now represented not even by a hamlet. (2) As relative to the political condition of a country and of other countries. (3) As relative to the state of military science. Under these two heads the difference in the situation of the Roman wall between Tyne and Solway and the Anglo-Scottish boundary suggests some considerations. Also the difference in the situation of some important Roman towns or stations and their modern representatives (Uriconium, Shrewsbury; Sorbiodunum, Salisbury). (4) As relative to the state of applied science—well illustrated in this country, as in the history of the iron and textile industries. (5) As relative to the density of population—another important consideration in the industrial history of our own country. (6) As relative to the mental attitude of the people where the geographical advantages exist. Many Chinese travellers and students of China have recognised the excessive reverence for ancestors in that country as one great hindrance in the way of turning the advantages of the country to account.

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5. *The various Boundary Lines between British Guiana and Venezuela attributed to Sir Robert H. Schomburgk. By* RALPH RICHARDSON, *F.R.S.E., Hon. Sec., R.S.G.S., F.S.A. Scot.*

As a Geographical curiosity, if nothing else, the Protean forms assumed by the celebrated 'Schomburgk Line' are worth noticing. Let us tabulate them as laid down by various eminent authorities in the course of their discussion of the question of the Western boundary of British Guiana:

1. *The Schomburgk Line* 1841–42 *of the Map in the British Government's Blue Book, March,* 1896.—Commencing at the mouth of the River Amacura, this line runs along that river's eastern bank, including as British territory the whole basin of the River Barima, and then proceeds S.E. to the River Acarabisi, after which it follows the course of the River Cuyuni, and passes S.E. to the summit of Mount Roraima, where it stops. It may be noticed that, whilst this Line was drawn in 1841–42, Schomburgk's surveys were not completed till 1844.

2. *The 'Historic' Schomburgk Line of Dr. Emil Reich. 'Times,' March* 14, 1896.—Dr. Reich considers that the 'Schomburgk Line, if drawn from the mouth of the River Wainy, is borne out by irrefragable historic arguments.' No map, however, shows a Schomburgk Line drawn from the mouth of the river Waini.

3. *The 'Legal' Schomburgk Line of Dr. Emil Reich. 'Times,' March* 14, 1896.—Dr. Reich holds that the Schomburgk Line, 'if drawn from the mouth of the Barima, may be defended successfully by legal arguments.' He states that the line so appears 'in all current maps'; but current maps belonging to the R.S.G.S. represent the Schomburgk line as drawn not from the mouth of the Barima, but of the Amacura.

4. *The 'Reliable' Schomburgk Line of Mr. John Bolton, F.R.G.S. 'Nineteenth Century,' February,* 1896.—Mr. Bolton says the Schomburgk Line first appeared on a crude sketch map, lithographed by Arrowsmith in 1840, and presented to Parliament, and that it was not till 1841 that Schomburgk surveyed the country north of the River Cuyuni, the original drawing of this survey being sent to the Colonial Secretary in 1841. It has never been reproduced, but this, the only reliable Schomburgk Line, begins at the Amacura mouth, includes as British territory the whole basin of the Barima, and stops at the junction of the Acarabisi and Cuyuni rivers. The 'Blue Book,' published by the British Government in August, 1896, contains a facsimile of Schomburgk's Map of 1841, showing that his 1841 Line did not stop at the Acarabisi, but was continued along the upper course of the Cuyuni.

5. *The 'Provisional' Schomburgk Line of Mr. George G. Dixon. 'The Geographical Journal,' April* 1895.—This line corresponds to No. 1, but is derived from a map published in 1875 attributed to Sir Robert H. Schomburgk, who died in 1865. The 1875 map in *Proceedings* R.G.S. 1880 contradicts this one.

6. *The 'Modified' Schomburgk Line of 'The Statesman's Year-Book,'* 1896, corresponds to Nos. 1 and 5. The 'original' Schomburgk Line is, however, also given, and is stated to have been drawn in 1840.

7. *The 'Venezuelan Government's' Schomburgk Line. Mapa de la Parte Oriental de Venezuela, published with Government authority at Caracas,* 1887.—Generally speaking, this Line is similar to the 'original' Schomburgk Line, although the former gives Venezuela both banks of the Amacura and Otomonga rivers, whereas the 'original' line gives Venezuela only their western banks.

8. *The 'Original' Schomburgk Line. Reisen in Britisch-Guiana von Richard Schomburgk. Mit Abbildungen und einer Karte von Britisch-Guiana aufgenommen von Sir Robert Schomburgk. 2 vols. Leipzig: J. J. Weber.* 1847.—Three years after Sir Robt. H. Schomburgk had completed his surveys, his brother and fellow-traveller, Richard, published this important work, to which, with the authority of

Sir Robert, he appended the latter's map of British Guiana as prepared by Sir Robert for the British Government, and showing on it the well-known 'original' Schomburgk Line. The map is dated 1846 and represents the results of Sir Robert's surveys during 1835–44 as lodged in the Colonial Office, London. Cartographers of all nations have ever since (*i.e.*, for 50 years) represented this 'original' Schomburgk Line as the western boundary of British Guiana. It was also recognised as the boundary by the Crown Surveyor of British Guiana in 1875 (Map in *Proceedings* R.G.S. 1880); by M. Smidt, Governor of Dutch Guiana, in the 'Kaart van Guiana' (1889); by Professor Sievers, of Giessen, in the 'Globus' (January, 1896); and by Mr. Gignilliat, of the U.S. War Department, in the 'National Geographic Magazine' (Washington, February 1896). With only two exceptions, all the atlases belonging to the R.S.G.S. give the 'original' Schomburgk Line as the British boundary, thus leaving the British title to territory west of that Line to be proved by treaty rights and by occupation during a prescriptive period.

6. *A Journey in Spitzbergen in* 1896. *By* Sir W. MARTIN CONWAY, *M.A.*

7. *The Present Condition of the Ruined Cities of Ceylon.* *By* HENRY W. CAVE, *M.A., Queen's College, Oxford.*

The conversion of the Singhalese to Buddhism in the third century B.C.—The first monastic establishment at Mihintale—The granite stairway of 1,840 steps illustrated and described—The Maha Seya Dagaba—Ancient rock inscriptions—The foundation of the Maha Vihara or sacred quarter of the city of Anuradhapura—Erection of the Thuparama Dagaba—Curious vessels and their uses—The Sacred Bo-Tree—The Isurumuniya Temple carved out of the natural rock, third century B.C.—Remarkable frescoes and sculptures on the terraces of the Isurumuniya Temple—The Loha Pasada or Brazen Palace—The Ruanweli or Gold-dust Dagaba—Specimens of Sculpture in the early centuries of the Christian era—Unexplored ruins of Anuradhapura—The stone-built Pokunas or baths—The Abhayagiria Dagaba, the largest tope in the world—The Peacock Palace erected in the first century of the Christian era—The Jetawanarama Dagaba (third century)—Remains of religious edifices of third century, not yet identified—Important archæological discoveries—Hermit cells of the third century—The first Dalada Maligawa, or Temple of the Tooth of Buddha (fourth century)—The past and the present condition of native life contrasted—Remains of an ancient street—The hill fortification of Sigiriya (fifth century)—Present-day travelling illustrated—Success of heretic invaders—Downfall of the sacred city of Anuradhapura and the establishment of a new capital—The journey to Polonnaruwa—Ancient irrigation systems—The Minneria Tank—Remains of seventh to twelfth century buildings at Polonnaruwa—The Rock Temples of Dambulla—The Aluwihari at Matale—A glimpse at modern Ceylon.

8. *Earthquakes and Sea-Waves.* *By* Professor JOHN MILNE, *F.R.S.*

TUESDAY, SEPTEMBER 22.

The following Papers and Report were read:—

1. *The Southern Alps of New Zealand; and a proposed Ascent of Aconcagua.* *By* A. E. FITZGERALD.

The New Zealand Alps have in past years been much neglected by travellers. Few people realise that there exists in our antipodean colony a chain of Alps unsurpassed by anything in Switzerland, while the glaciers that roll down from these great mountains exceed in length and area any of those we know in Europe.

The Southern Alps, which were explored by the author and Mr. C. G. Barrow in 1894–95, lie close to the west coast of the South Island. Mount Cook, the monarch of the range, rises to a height of 12,349 feet, and is situated at not more than fifteen miles from the sea-coast. The author's work was confined to the Mount Cook district, between Mount McKerrow and the Whymper Glacier. His object was to find a pass feasible for tourist traffic during the summer months between The Hermitage, a small inn in the Tasman Valley, at the foot of the Hooker and Müller Glaciers, and the country of Westland, so beautiful in its luxuriant subtropical vegetation and its great glaciers that roll down amidst lianas and tree ferns to within 600 feet of the sea level. The part of Canterbury situated near these ranges is extremely bare and rugged. A great plateau or table land, called the McKenzie country, reaches up towards the Tasman Valley, and in this are two great glacier-fed lakes, Pukaki and Tekapo. All up and along this great plain, some 2,000 feet above sea level, can be seen traces of ancient glacier action. Huge mounds of moraine matter are strewed about, while a low species of snow grass covers the whole, rendering it all a dreary brown colour.

Mount Sealy, 8,631 feet; Mount Tasman, second highest in the Colony, 11,475 feet; Mount Haidinger, 10,107 feet; the Silberhorn, 10,250 feet; and Mount Sefton, 10,359 feet, were ascended. In these ascents much trouble was given by the rotten condition of the rocks, and by the huge overhanging glaciers, caused no doubt by the enormous rainfall, and therefore snowfall, in high altitudes. The snow line is very low, not more than 6,000 feet. This, combined with the fact that one had to commence operations from almost sea-level, renders ascents far more difficult than in Switzerland. When on the top of Mount Sefton the author was fortunate enough to see how a pass could be effected to the Karangarua River in Westland, and accordingly ten days later he set out with his guide Zurbriggen to cross the ranges, and accomplished this journey in three days, after many difficulties and hardships, over a saddle 7,180 feet above sea-level, which the New Zealand Government have named the Fitzgerald Pass. This passage could be rendered easy for tourists by a path being made, and it is only twenty-two miles in length. He came back over some of the largest glaciers in the Colony, and several high Alpine passes, when four consecutive nights were spent in the open. Mr. Harper, one of the New Zealand Government Surveyors, accompanied the expedition on its return.

In a few weeks the author proposes to leave for South America to try and climb the mountain Aconcagua, which rises to a height of about 23,000 feet, and is the highest mountain in South America—in fact, outside of the Himalayan range it is the highest mountain in the world. His plan is to proceed from Buenos Ayres to Mendoza, and thence towards the Cordilleras de los Andes. The party will consist of Mr. C. L. Barrow, who was with the author in New Zealand; Mr. de Trafford; Mr. Stewart Vines; Mr. Philip Gosse, who will be charged with the natural history collections which will be made; and Zurbriggen, with three other guides and a porter from Switzerland.

The author intends to cover as much of the country as possible; to ascend several peaks; and to bring back natural history and geological specimens. He hopes to ascend Aconcagua gradually, moving slowly upwards and establishing several camps; and by leaving one of the party at each camp he expects to keep up communication and to facilitate the supply of provisions, while at the same time he hopes to report the ascent to London immediately on reaching the summit if he should be successful.

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2. *The Egyptian Sudan.*
By General Sir Charles Wilson, *K.C.B.*, *F.R S.*

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3. *The Teaching of Geography in Relation to History.* *By* A. W. Andrews.

The study of the physical geography of a country should proceed and be co-extensive with that of its history.

The ideal of history teaching in English schools.

A lack of perspective in the teaching of English history, owing to the neglect of physical geography.

Teachers and writers of school histories may be themselves geographers, but usually fail to appreciate the standpoint of the student.

As a consequence, physical geography, or the physical side of history is relegated to special text-books and special lessons, not taught in conjunction with history.

A study of physical geography would give the student a firm standpoint for the appreciation of the events of history, and prevent much of the present confusion.

At present the teaching of geography in connection with history is chiefly confined to the use of topographical maps.

Teachers, however, forget that a topographical map is merely a diagrammatic method of learning statistics relating to the distribution of names.

The danger of both history and geography being taught as a mere *verbal* record of statistics.

The different branches that make up history, such as geography, social life, literature, parliament, &c., must not be studied in complete isolation.

There must always in the study of history be comparison and contrast, and this would be gained in English history by a more detailed study of some half-dozen periods, *e.g.*

(1) The present physical geography of Great Britain in connection with the *main and essential* ideas of the history of to-day.

(2) Some few epochs of history studied in sufficient detail for a similarly comprehensive view of the life of the time, as in (1) *e.g.*:—

The *Times of Chaucer*, 1350–1400.

A. Physical geography of British Isles at that date compared with—

- I. Causes which led population to centralise at different points; physical changes (Cinque Ports); [population in E. & S.]; coal and iron manufactures, &c.
- II. *Means of Communication*—Ocean routes, sailing vessels, roads, railways, steam, canals, &c.
- III. The widening of the horizon of thought coextensive with the expansion of geographical knowledge.
- IV. Influence of geographical conditions on the ideas of the time.

B. A knowledge of the main factors that made up life in England at that date grouped round some prominent figure like Chaucer, *e.g.*: literature, social life, trade, religion, &c., considered not merely as independent streams of knowledge, but as they affected the life of an average person at that date.

Threefold advantages of studying geography and history together.

(1) It provides a standard of comparison with the past.

(2) It assists a student to visualise history, *i.e.* to think of it not merely as a series of isolated branches of knowledge, but as the different manifestations of a *living* people at different epochs.

(3) It is the one factor of history of which it is impossible to limit the influence. It is invaluable for teaching the student to think.

4. *The Border-land of British Columbia and Alaska.* *By* E. Odlum.

In this paper it is shown how the building of the transcontinental railway by the Canadian Pacific Company opened British Columbia, how the rapid influx of population into the fishing, mining, and lumbering centres led to the study of the boundaries, and how, especially the goldfields of the Yukon River, which is partly in Canada and partly in Alaska, forced the question of delimitation on both countries.

The southern cause of dispute—viz., the Portland Channel claim, with the adjacent islands of Mary, Revilla Gegido, Annette, and Gravina, with the Oolachan fisheries, the Tsimpsen Indians, who removed from Canada to Annette Island, and other matters in this area of over 5,000 square miles—was referred to first in order. Then followed the central or great gold-bearing strip, in which, or adjacent to which, are the mines of silver, Bow Basin, the Junean, and the Treadwell, the latter being one of the largest in the world.

Lastly, the northern portion was considered. This includes the Lynn channel and the Chilcat and Chilcoot inlets, the whole giving the only waterway from the Pacific into the north of British Columbia and that portion of Canada north of lat. 60°.

The author in the paper gives an account of the excellent climate and the vast resources of that part of Western Canada. The value of the Chinook winds and the 'Kuro Siwa' or Japanese current in modifying the coast and the Canadian prairies was indicated.

The paper sets forth that all matters relating to what is called the disputed territory are being handled by the two governments in the most friendly spirit.

Reference was made to the inadequate nature of the British school maps and geographies in relation to Western and Central Canada, and the speaker affirmed that this central and western part of the Dominion will yet contain scores of millions of loyal British people.

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5. *Some Remarks on Dr. Nansen and the Results of his Recent Arctic Expedition.* *By* J. Scott Keltie.

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6. *An Apparatus to Illustrate Map Projections.*
By Andrew J. Herbertson, *F.R.S.E., F.R.G.S.*

Every teacher of geography experiences a difficulty in trying to give his pupils a vivid idea of the various map projections. This is in part overcome by using a candle and a skeleton hemisphere formed of a wire network of meridians and parallels, and, if possible, with an outline of the continents, such as the author has recently devised, and Messrs. Philip make. By altering the position of the lighted candle, different projections of the network can be thrown on a flat screen, and the pupils can see the different distortions of the network that result for themselves. By using half a cylinder or half a cone, various cylindrical and conical projections can be illustrated in the same graphic way.

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7. *A New Population Map of the South Wales Coal District.*
By B. V. Darbishire, *M.A.*

The population maps one sees in atlases are mostly on a comparatively small scale, and of course are much generalised. The usual method is to show by different depth of colouring the approximate number of inhabitants to the square mile. This, of course, is the only method possible when large areas are under consideration. In representing the distribution of population within a small area we shall be able to do without generalisation, and to deal with, and to show on our map, the actual facts on which the generalisations for larger areas should be based, and—most important of all—to make clear the connection between the physiography and the anthropogeography of a region.

The map shown is an attempt in this direction.

It is reduced from the One-inch Ordnance Map (1 : 63360) to the scale of 1 : 100000, with contours at intervals of 200 feet. On it are inserted all detached houses, and all villages and towns shown on the Ordnance Map. Of course a map of this kind does not show the actual number of persons living on a given area. But it does show clearly various facts which are much more interesting to the geographer than mere numerical strength.

It shows the distribution of human settlements, and it shows how that distribution has been influenced by physical features. It shows the different nature of the settlements in industrial districts and in agricultural districts. It brings out clearly the facts that go to make a great seaport. It even enables us by a study of the shape of villages and towns to get an idea of the circumstances to which they owe their origin, and makes clear many other facts which are masked by the amount of detail shown on the Ordnance Map.

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8. *Report on Geographical Teaching.*—See Reports, p. 494.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION.—The Right Hon. LEONARD COURTNEY, M.A., M.P.

THURSDAY, SEPTEMBER 17.

The following Address by the PRESIDENT was read by Professor Gonner:—

WHEN the British Association revisits a town or city, it is the laudable custom of the President of a Section to refer to what was said by his predecessor in the same chair on the former occasion. I should in any case be disposed to follow this practice, but I could not choose to do otherwise when I find it was my honoured friend Professor Jevons who occupied this place in Liverpool in 1870. He was one of a group which passed away in quick succession, to the great loss of the study of Economics in this country, since each had much promise of further usefulness, and left us with labours unfulfilled. Bagehot, Cairnes, Cliffe Leslie, Fawcett, Jevons, occupied a large space in the field of economic study, and no one among them excelled Professor Jevons in the vigour and clearness of his analysis or in the sincerity and range of his speculations. His first work which arrested public attention was perhaps not so much understood as misunderstood. This busy, bustling, hurrying world cannot afford time to pause and examine the consecutive stages of a drawn-out argument, and too many caught up and repeated to one another the notion that Jevons predicted a speedy exhaustion of our coalfields, and they and their successors have since been congratulating themselves on their cleverness in disbelieving the prophecy. No such prophecy was in truth ever uttered. The grave warning that was given was of the impossibility of continuing the rate of development of coal production to which we had been accustomed, of slackening, and even arrested growth, and of the increasing difficulty of maintaining a prosperity based on the relative advantages we possessed in the low cost of production of coal; and this warning has been amply verified in the years that have since passed, as will be at once admitted by all who are competent to read and understand the significance of our subsequent experience. But I must not dwell on this branch of Jevons's work nor on the many other contributions he made to the study of our economic life. I am concerned with what he said here twenty-six years since.

At first sight the address of my predecessor may seem loose and discursive; but viewed in due perspective, it appears a serious inquiry into the apparent failure of economic teaching to change the course and elevate the standard of our social life, and an earnest endeavour to impress these principles more strongly on the public mind so that the future might better the history he reviewed. He referred to the repeal of the Corn Laws, and owned with regret that the condition of the people was little changed, that pauperism had scarcely abated, that little forethought was shown by the industrial classes in preparing for the chances of the future; and he dwelt on the mischievous influence of the unthinking benevolence of the wealthy in undermining providence by its constant and increasing activity in mitigating the evils of improvidence. Jevons was not content to condemn the doles of past testators; he wanted the reorganisation of the Hospital service of our towns, so that as far, at least, as the ordinary and inevitable casualties of sickness and accident are concerned, they might be met by the co-operation of workers inspired by motives of self-reliance instead of by ever open gratuitous service making forethought unnecessary and even foolish. In this connection it may be noticed that while giving a hearty welcome to Mr. Forster's Education Act, passed in the same year that he spoke, he noted with satisfaction that primary education had not been made gratuitous so as to take away another support of prudence. It is strange, too, in the light of our recent experience, to find him regretting that the task of remodelling local taxation had not been undertaken, so that local wants might be met by a just apportionment of their charge and the principles of association of the members of local communities placed on a firmer basis.

It will be seen that what really occupied the mind of my predecessor was the apparent slow success of Economic thinkers in influencing political action, and we, looking back over the intervening twenty-six years, have certainly no more cause of congratulation than he felt; we are forced to ask ourselves the same question what is the reason of our apparent failure; we are driven to examine anew whether our principles are faulty and incomplete or whether the difficulties in their acceptance, they being sound, lie in the prejudices of popular feeling which politicians are more ready to gratify than to correct.

I do not pause to meet the charges of inhumanity or immorality which have in other times been brought against Economists. Jevons pleaded for the benevolence of Malthus, who might indeed be presumed, as an English clergyman, to be not altogether inhuman or immoral. In truth everyone who has ever had any thought about social or fiscal legislation—and we have had such laws among ourselves for five centuries—everyone who has ever tried to influence the currents of foreign trade—and such attempts date from an equally remote past—has been moved by some train of economic reasoning, and must strictly be classified as an Economist; and the only difference between such men and those who are more usually recognised by the name is that the latter have attempted to carry their thoughts a little further, and have been more busy to examine the links of their own reasoning and the soundness of their conclusions. The men who attempted to fix wages, to limit the numbers in special trades, to prohibit or to compel certain specific exports, all had some notion that they were engaged in doing something to strengthen if not to improve the better organisation of communities. Even the aims which appear to us most selfish were disguised as embodying social necessities. But by the beginning of the present reign it may be said that the study of Political Economy in this country had worked itself free from earlier errors, and it had come to be believed that the secret of social regeneration lay in the utmost allowance of freedom of action to every individual of the community, so far at least as that action affected himself, coupled with the most complete development of the principle of self-reliance, so as to bring home to every member, freed from legal restraint on his liberty of action, the moral responsibility of self-support and of discharging the duties, present and to come, of his special position. With this education of the individual in self-reliance, and with this liberation of the same individual in the conduct of life, it was held that by certain, if slow, stages the condition of the community would be improved, and a wholesome reorganisation naturally effected.

Whatever view we may now hold of this belief, whether we must discard it as incomplete or even erroneous, or whether we remain strong in the conviction of its intrinsic soundness and in the possibility of realising the hopes it offered, it must still be evident that those who professed it were imbued with the deepest interest in the well-being of their fellow creatures, and that the aim of all their speculations was the purification of social life, and its healthy and abundant development.

Such was the theory more or less openly expressed by Economic thinkers when the British Association was founded, and the same theory, as I conceive, lay at the base of Jevons's address in 1870. Can we hold it now, or must it be recast?

Since 1870 Primary Education has practically been made gratuitous. The

Legislature had an opportunity for abolishing the mischief of doles, but showed no inclination to make use of it, and there were even traces of a feeling of favour for the maintenance of these bequests of the past. The indiscriminate multiplication of so-called charitable institutions has in no way been reformed, and there is as great activity as ever in the zeal of those who would mitigate or relieve the effects of improvidence without touching improvidence itself. As far as the course of legislation is concerned, it may be feared that it has been directed to diminish rather than to increase the spirit of self-reliance. Codes of regulations have been framed for the supervision of the conduct of special industries, and their sphere has been extended so as to embrace at no distant period, if not now, the whole industrial community. The reformed Poor Law, which was regarded as a great step in the education of the workman, especially of the agricultural labourer, in independence, stands again upon its trial, and proposals are at least in the air for assuring to the aged poor a minimum measure of support without any regard to the circumstances of their past lives, or to the inevitableness of their condition. The suggestions made by responsible statesmen have indeed been more limited and cautious, but it will be acknowledged of those, as of the German system, from which they may be said to be in some measure borrowed, that they involve a great departure from that ideal of individual development to which I have referred. Add to this that there is a movement, which has become practical in many large cities and towns, for the community itself to engross some forms of industrial activity, and to undertake in respect of them to meet the wants of their inhabitants. All these developments and more may be summed up as illustrations of Collectivity—an ideal which has its advocates and professors, and which looks in the future for regulated civic and national monopolies instead of unrestricted freedom of individual activity, and for the supervision and control of those industries which may remain unabsorbed by state or town. In pursuit of this last conception there have been put forward not only requirements as to hours and conditions of labour, but a demand also for a Living Wage or a minimum, below which no workman shall be paid; and this principle has been already adopted by some municipalities in respect of their monopolised industries. The State itself indeed has, through the popular branch of the legislature, declared more or less clearly in favour of the same principle in respect of the industries which are conducted in its service.

We have not only to acknowledge the continued slowness of politicians to adopt and enforce the teaching of Economists such as Jevons contemplated, but also the rise of another school of Economic thought which competes for, and in some measure successfully obtains, the attention of the makers of laws. The question which has already been suggested thus becomes inevitable. We must inquire whether the failure of former teaching has not been due to errors in itself rather than to the indocility of those who have neglected it.

The greatest difficulty which the teachers of the past have to overcome when put upon their self-defence lies in the suspicion, or more than suspicion, of an occupied multitude that their promises have failed. It is thought of them, if it is not openly said, that they had the ear of legislators for a generation, that the course and conduct of successive administrations were governed by their principles, and yet society, as we know it, presents much the same features, and the lifting up of the poor out of the mire is as much as ever a promise of the future. Some quicker method of introducing a new order is called for, and any scheme offering an assurance of it is welcomed. A ready answer can be given to much of the suspicion of failure that is entertained. That freedom of industrial action, which is the first postulate of the Economists, has never been secured. We are so much accustomed to the conditions of our own life that this declaration may seem strange to many, who will say that at least in England labour and trade are free; but it must be admitted, on reflection, that in one great sphere of action the liberty so postulated has, for good or bad reasons, never been conceded. The limitations and restrictions necessarily consequent upon the system of land laws established among us are not commonly understood, but although much has been done to liberate agriculture from their fetters, its perfect freedom has not been attained. There may be free trade in the United Kingdom and free land in the United States, but the country is yet to be found in which both are realised, and even if both these requisites were attained the sores of social life would not be removed unless the spirit of self-reliance were fully developed: and how little has been done to secure this essential condition of progress! nay, how much has been done by law, and still more by usage, to weaken and destroy its power! The Economist of whom I have been speaking may boldly claim that so far as he has had a free hand, his promises have been realised; there has been a larger population with increased means of subsistence and diminished necessity of toil, a people better housed, better fed, better clothed, with fewer relative failures of self-support; and if the teaching which has been partially adopted has brought about so much, everything it promised would have been secured had it been fully followed. If the teaching had been fully followed? This raises the question whether there are inherent difficulties in the nature of man preventing such a consummation, and many will be ready with the answer that such difficulties exist, are permanent and cannot be surmounted. As long as human nature is what it is —so runs the current phrase—men will not see misery without relieving it, they will not wait to inquire into its cause and whether it could have been prevented, and it is claimed that this instinct is one of the best attributes of humanity, which we should not attempt to eradicate. This kind of reply easily catches the popular ear. It seems generous, sympathetic, humane. But it is based on a view of human nature being incapable of education which has been and will long be the excuse for acquiescence in all imperfections and even iniquity; nor can that be said to be truly generous, sympathetic, or humane which refuses to inquire into the possibility of curing disease, and prefers the selfishness of self-relief to the patient endeavour to probe and remove the causes of the sufferings of others. The Economist of the past generation would, I think, be justified in repudiating with warmth the feeble temper which recoils from the strenuousness of endeavouring to deal with social evils at their origin, and in reprobating the acceptance as inevitable of vices we take no pains to prevent. This, however, does not conclude the whole matter. Even if we did attain the ideal of bringing home to all the members of the community the fatal consequences of improvidence and vice, should we find improvidence and vice ever narrowing into smaller and smaller circles, or should we be confronted with their existence as before, with this difference, that past attempts to alleviate their miserable consequences would be discredited and abandoned? I fear I must here confess to a somewhat faltering faith. That a vigorous enforcement of the penalties of improvidence would diminish it, is a conclusion justified by experience as well as suggested by theory; but that it and its consequences would not still remain gross and palpable facts is a conclusion I have not the courage to gainsay. At all events, I cannot refuse to consider the question whether something more than the complete freedom of the individual is not necessary for the reformation of society, and to examine with an open mind any supplementary or alternative proposals that may be made to reach this end. Yet one thing must be said, and said with emphasis, of the theory of the Economist. It was a working theory. No theory can be accepted even for examination which does not show a working organisation of society, and the theory we have had under review has this necessary characteristic, even if it does not open up a certain way to a perfect reconstruction of our social system.

It will be conceded by the most fearless and thorough-going advocates of the liberty of individual development, that it must be supported by large measures of co-operative action. No individual can by any amount of forethought protect himself by himself against the chances and accidents of the future. No one can tell beforehand what is in store for himself in respect of sickness, or accident, or those changes of circumstances which may arise from the default of others; and mutual aid is necessary to meet such contingencies. The freedom and activity of association thus indicated are in no way inconsistent with the fullest theory of individual responsibility. Nor is there any departure from it in the voluntary combination among themselves of persons, individually weak, to supervise and safeguard the economic conditions into which they may enter with others relatively stronger. A single workman may be powerless to induce his employer to modify in any particular the terms of his employment, but when workmen band together they may meet employers as equal powers. Such liberty of combination is a development and not a limitation of individual liberty. Another step is taken when the parties to such an arrangement as has been suggested seek to make its provisions compulsory on others, be they workmen or employers, who may enter into similar relations; and the principles of former Economists would generally prompt them to condemn such attempts at compulsion. The Factory Acts were opposed in this way, although they rested upon different grounds; for, though in their consequences they affected the labour of adults, they were propounded for the defence of young persons and children unable to protect themselves or to be the parties to free contracts. Legislation has, however, been extended to control directly the employment of fully responsible persons, and this has been defended by three lines of argument. It is urged that when the unchecked liberty of individuals destroys in fact the liberty of action of larger multitudes, it is in defence of liberty of action that those individuals are controlled. If a sea wall is necessary to prevent a large tract from being periodically inundated, it cannot be permitted to the owner of a small patch along the coast to leave the wall unbuilt along his border, and thus threaten the lands of his neighbours with inundation. Again, it is urged that when the overwhelming majority of persons engaged in a particular industry, employers and employed, are agreed upon the necessity of certain rules to govern the industry, it is not merely a convenience, but is a fulfilment of their liberty, to clothe with the sanction of law the regulations upon which they are agreed. Lastly, it is submitted that there are individuals in whom the sense of responsibility is so weak and whose development of forethought is so hopeless, that it is necessary the law should regulate their conduct as it may regulate the conduct of children. I do not propose to examine in detail these real or apparent limitations of individual liberty. The first plea appears to me to be sound in principle, though it may often have been applied to cases not properly coming within it. As to the second, the convenience of giving to an all but universal custom the force of law is incontestable, but it is at least doubtful whether this is sufficient to deprive individuals who deliberately wish to put themselves outside it of the liberty of doing so. Unless their action could be brought within the first line of argument, sufficient reason for restraint does not appear. As for the hopeless class whose existence is made a plea for restrictive legislation, the Economist may forcibly argue that they have never been left to learn the full force of the lessons of experience, and it is the impatient interference of thoughtless men and thoughtless laws which allows this class to be perpetually recruited.

The limitations of individual liberty, to which I have referred, are familiar to us, and have obtained a firm hold in our legislation; but we enter upon comparatively new ground when we turn to the proposals that an increasing number of industries should be undertaken and directed by State or Municipality, and that a minimum and not inadequate subsistence should be assured to all those engaged in such industries, if indeed the principle be not presently extended outside the monopolies so established. The ideas which are clothed in the phrases 'The socialisation of the instruments of industry,' and 'The guarantee of a minimum wage to all workmen,' appear to involve a complete reorganisation of society, and an absolute abandonment of the theories of the past. This is not enough to justify their immediate rejection or their immediate acceptance. The past has not been so good that we can refuse to look at any proposals, however strange in appearance, offering a better promise for the future. It has not been so bad that we must abandon its methods in despair, as if no change could be for the worse, if not for the better. A patient inquirer, feeling his way along the movement of his time, may even be constrained to accept a patchwork covering of life instead of the ideal garment woven without seam throughout; or he may be led to see that the harmony of society, like the harmony of the physical universe, must be the result of divers forces, out of which is developed a perfect curve.

No one could now be found to deny the possibility, and few to question the utility, of the socialisation of some services. The post office is in all civilised countries organised as a national institution, and the complaints that are sometimes heard as to defects in its administration never extend to a demand for its abolition. Jevons, in a careful paper, showed that the same financial success which marks our present postal system, must not be expected from the nationalisation of the telegraph service, and he dismissed even suggestions for the nationalisation of railways. His predictions have been amply verified with respect to the telegraph account; but telegraphs are a national service amongst ourselves, and railways are largely nationalised in many continental countries, and in some of our own colonies and dependencies. Some of our largest municipalities have undertaken the supply of water and of gas, or even of electric light, to the inhabitants, and a movement has begun, which seems likely to be extended, of undertaking the service of tramways. Demands have also been made for the municipalisation or nationalisation of the telephone service.

It may be said of all the industries thus described as taken over, or likely to be taken over, by the nation and local communities, that when they are not so taken over they require for their exercise special powers and privileges conceded by the State or community, and the conditions of such concessions are settled by agreement between the community and the body or bodies exercising such industries. These conditions may involve the payment of a fixed sum, or of a rent for the concession, or the terms upon which the services are to be rendered may be prescribed in a stipulated tariff of charges, or the amount of profit to be realised by the concessionaires may be limited with provisions for reduction of charge when such limit is reached, or it may be required that in working such industries certain limits of wages shall be observed as the minima to be paid to the workmen employed upon them. Speaking very broadly, it may be said that the community delegates or leases the right of practising the industry, and there is no impassable gulf between prescribing the terms on which a lease shall be worked and assuming the conduct of the industry leased. There may be difficulties in the management by a community of a cumbrous and unwieldy undertaking, but there is no difficulty affecting the organisation of society when the undertaking must be created and shaped by the community in the first place. The arguments against the assumption of such monopolies by State or Local Authorities are those of expediency, founded on a comparison of gain and loss. It may be urged that there are more forcible motives of economy on the part of a concessionaire than on the part of a community working the undertaking itself; that improvements of method and reductions of cost will be more carefully sought; and although such improvements and reductions might in theory be realised by the workmen and agents of a community, which would thus secure all the savings effected by them, yet private interest is quicker in discovery and more fertile in suggestion, and it is more profitable in the end for the community to allow a concessionnaire to secure such profits, subject to a stipulation that some part of them should return to the community in the way either of increased money payment, or of reduced rates of charge for the services performed. It may be urged that when a community works an industry itself, it may do so at a loss, thus benefiting those who specially require its services at the cost of the whole body; but this objection is not peculiar to undertakings so directly worked. It is a matter of common experience for State or Municipality to grant important subventions to persons willing to undertake such works on stipulated terms of service, and such subventions involve a levy from the whole community for the benefit of those availing themselves of the services.

New considerations of great difficulty arise when we pass to the suggestion of the undertaking by local authorities of productive industries not in the nature of monopolies. In monopolies direct competition, often competition in any shape, is practically impossible; in other industries competition is a general rule; and it is by virtue of such competition that the members of the community do in the long run obtain their wants supplied in the most economical manner. When commodities are easily carried without serious deterioration, the constantly changing conditions of production and of transport induce a constant variation in the sources of cheapest supply—that is of supply under conditions of least toil and effort—

and any arrest of this mobility involves a corresponding set-back in the advancement of the economic condition of mankind. It is a necessary consequence of this process that the local production of special commodities should be subject to diminution and extinction, and that the labours hitherto engaged in such local production should become gradually worthless. Quite as much labour as before might be expended in achieving the result, but it would be misapplied; it ought not to command the same return; it should cease. It is at least difficult to foresee how far the production of commodities exposed to free competition could be maintained by communities themselves in face of the movement we have described. There would be a danger of pressure to do away with invasive competition—action which, in my judgment, would be destructive of the most powerful cause of improvement in the condition of the people. There would be an allied danger of a refusal to recognise the possibility of a diminished worth of work which remains as toilsome as ever, and of an increasing congestion of labour when the great movement of the world demands its dispersion. It may be that those evils are not inevitable, but they would require to be faced if any serious attempt were made to increase the range of national or municipal industries, and I have not yet seen any attempt at their serious investigation.

The position thus taken may be illustrated by an experience to which I have elsewhere referred, but so pregnant with suggestion that I need not apologise for recalling it. My native county, Cornwall, was in my boyhood the scene of widespread activity in copper and tin mining. There had not been wanting warnings that the competition of richer deposits in far countries would put an end to these industries in the county, but the warnings had not been realised and remained unheeded. In the years that have since passed they have been gradually and almost completely fulfilled. There are no copper mines now in Cornwall, and the tin mines, which were scattered far and wide throughout the county, are reduced to two or three within one limited area. It is not the case that the ores have been exhausted; they could still be raised, but at a cost of production making the process unprofitable. The mines were abandoned one by one, and the population of the county has steadily diminished in every recent census. What would the experience have been had the mines been a county or national property worked by county or nation? I do not stop to comment on the difficulty of expropriating present owners, which, however, must not be forgotten. If the collective owner had leased the mines to companies of adventurers (to use the local phrase), the lessees would have gradually relinquished their concessions, as they have done when taking them from private owners. Nor would the case have been materially different even if the collective owner had introduced the novel stipulation into his leases that the working miners should be paid according to prescribed rates of wages. The process of relinquishment might have been precipitated and accelerated by insisting on such a condition, but otherwise the experience would have been the same. The shrinkage of industry would go on without a check, and it is to be hoped that the workmen who found their work failing would, with the fine courage and enterprise they have in fact shown, have betaken themselves to the fields of mining industry displacing their own in all parts of the world. Can one think that the same process would have been maintained had the collective owner worked the mines directly, and the working men looked to county or nation for the continuance of work and wages? The attachment which all men have for the homes of themselves and their fathers would have stimulated a demand for a recurrence to the other resources of the collective owner for the maintenance of an industry that was dying. Some demand might even be made for a repression or prohibition of that competition which was the undoing of the local industry. These possibilities may be regarded as fanciful, and it is true that forces might be kept under control that operated within an area and affected a population relatively so limited. But what if the warnings of Jevons respecting coal in England proved like the warnings of the men who foresaw the cessation of tin mining in Cornwall, and the community had to deal with the problem of the dwindling coal industry in face of nationalised coal mines and armies of workmen employed by the nation? The initial difficulties of the nationalisation of that which for centuries has been the subject of private property are formidable, but they could doubtless be overcome by the short and simple process of confiscation. This transformation is theoretically conceivable. It is in the subsequent development of the scheme of nationalised and municipalised industries that we are confronted with tasks not so easy of solution. How is its working to be reconciled with that opening up of more and more productive fields which is one of the prime factors of social progress? How is the allotment of men to be directed so that they may be shifted about as new centres open and old centres close? What checks or commands can be invoked to restrain the growth of population in a district when it should be dwindling? These are questions that can scarcely be put aside, and it may even be acknowledged that they gain fresh force when viewed in the light of another experience. Agricultural industry has recently been subjected to severe trials through a great breadth of this country. This has been due to cheaper importations from other lands, and though the competition has in my judgment been aggravated by causes into which I will not now digress (which aggravation however might and should be dealt with), the importation of food at less cost is a result no Economist will regard as otherwise than beneficial to the community as a whole. It is well that bread and flesh and the sustenance of life should be procured with as little toil as possible, however severe the trial for those who have been engaged hitherto in the production of those necessaries. We know that it has been so severe that demands for relief and assistance have been loudly made, and their power has been such as to have been in some measure successful; but had land been nationalised and farms held from the State or from county, town, or parish, they would have assumed a different shape, have been urged with greater purpose, and have received larger treatment. The difficulties of such a nationalised industry, passing into what may be described as a water-logged condition, would test beyond the straining point such statesmanship as our experience warrants us to believe possible.

However much we may contemplate the reconstruction of an industrial system, it must, if it is to be a living social organism, be constantly responsive to the ever-changing conditions of growth; some parts must wax whilst others wane, extending here and contracting there, and manifesting at every moment those phenomena of vigour and decline which characterise life. In the development of industry new and easier ways are constantly being invented of doing old things; places are being discovered better suited for old industries than those to which resort had been made; there is a continuous supersession of the worth of known processes and of the utility of old forms of work involving a supersession, or at least a transfer, of the labour hitherto devoted to them. All these things compel a perpetual shifting of seats of industry and of the settlements of man, and no organisation can be entertained as practicable which does not lend itself to those necessities. They are the pre-requisites of a diminution of the toil of humanity. As I have said before, the theory of individual liberty, however guarded, afforded a working plan; society could and did march under it. The scheme of collective action gives no such promise of practicability; it seems to lack the provision of the forces which should bring about that movement upon which growth depends. The Economist of the past generation still holds his ground, and our best hope lies in the fuller acceptance of his ideas. Such, at least, appears to me to be the result of a dispassionate inquiry; but what may be wanting is something more than a dispassionate temper—a certain fervour of faith. The Economist must feel, if he is to animate multitudes and inspire legislatures, that he, too, has a religion. Beneath the calmness of his analysis must be felt the throb of humanity. Slow in any case must be the secular progress of any branch of the human family; but if we take our stand upon facts, if our eyes are open to distinguish illusions from truth, if we are animated by the single purpose of subordinating our investigations and our actions to the lifting up of the standard of living, we may possess our souls in patience, waiting upon the promise of the future.

The following Papers were read:—

1. *Some Economic Issues in regard to Charitable or Philanthropic Trading.* *By* C. S. Loch.

Philanthropic trading is, for the purposes of this paper, defined as trading undertaken, in the case of a municipality, to provide, not the common wants of the community, but those of its individual members. The definition thus excludes trading in gas or water, but includes, for instance, the supply of artisans' dwellings or municipal common lodging houses. In the case of institutions philanthropic trading is defined as trading undertaken to supply the general market, whether with the object primarily of reforming or occupying inmates or dependents, or solely with the purpose of raising funds.

Of the relation of philanthropic trading to the use of capital and credit three examples are given: the provision of dwellings for artisans and labourers by the municipality, and the methods adopted, one by the Salvation Army, and one by a philanthropic home, in order to raise capital.

By detailed reference to the Goldsmith's Row and Boundary Road schemes of the London County Council, it is shown that, in accordance with the general evidence on the subject, there is loss on the purchase of land when it is utilised for artisans' dwellings in the centre of London; that those displaced by a scheme do not return to occupy the new buildings; and that the system competes with private agencies, who, if they take the land at all for artisans' dwellings, will only do so at such specially reduced rates as will enable them to make a profit.

The one economic result of this philanthropic trading is to undersell the capital and credit of the ordinary trader, who practically pays in diminished business for the advantage which the community receive—namely, the difference between the 2½ or 3 per cent. at which the London County Council, with the credit of the community behind it, can raise money and the 4½ or 5 per cent. that the private capitalist would require. Other results are to cause waste, consisting (1) of the difference between the value of the land in the market and its value when reserved for artisans' dwellings; (2) of the continuing loss on the site, for though rateable value will increase when the dwellings are built, it will increase at a lesser rate than it would if the site were used for commercial purposes; (3) of the loss due to misdirection, since, after all, the dwellings do not as a rule provide for the very poor, but for the better class, who secure a better article at the usual rates of rental prevailing in the neighbourhood. For all these forms of waste the ratepayer has to pay. Socially, the system is wrong, as it tends to increase the density of the population instead of spreading it over a larger area. And the supply of house accommodation does not, in fact, demand State or municipal intervention more than the supply of food or clothing. In the former case the market lies at hand or the goods are brought to the house; in the latter the market, the cheaper accommodation, has to be sought (always a difficult matter with the poor) in the cheaper districts in the outskirts of the town.

'General' Booth's loans at 4½ per cent. are next referred to. In this case spiritual credit is used for the philanthropic trading of the Salvation Army, which undertakes to 'supply shopkeepers at wholesale prices,' &c. The parallel is drawn between the conditions of municipal trading and of such philanthropic trading as this.

Of philanthropic retail trading four instances are given: the supply of common lodging houses, the Salvation Army tea trade, the depôts of the Church Extension Association, and the free or part-pay supply of medicine and medical advice in out-patient departments.

In the philanthropic supply of common lodging houses by the municipality the ratepayer pays twice over—first to meet waste of the kind referred to above in connection with the capital expenditure, and next in order to maintain the persons who resort to these institutions, and immediately or soon after apply for relief from the rates. This is shown in detail in the case of the Blackfriars shelter of the Salvation Army and from evidence from Manchester and Whitechapel.

The Salvation Army tea trade is lucrative. They supply (with a philanthropic capital) 'the best possible teas at the lowest price at which they can be purchased elsewhere.' But those who pledge themselves (as they are asked to do) to buy their teas do not thereby themselves pay towards the support of the Army. Those who actually pay are the merchants and others who are engaged in the tea trade, whose business is philanthropically diverted, and who are thus made to contribute to the funds of the Salvation Army not merely without their consent but to their detriment.

In regard to the philanthropic employment of labour in institutions, instances are given showing the economic and social results of such interference upon unskilled labour, and the principles that should limit and guide its introduction are stated.

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2. *Trade Combinations and Prices.* *By* H. J. Falk, *M.A.*

Definitions. Trade Combination an ambiguous term; Combinations of Capital and Combinations of Labour. Misuse of word Trust for former. A distinctive terminology suggested.

Trade Combination in general. Its general effect.

Combinations of Capital primarily Trusts for Partners or Shareholders and not Public Trusts. Their Formation and Constitution actual and ultimate or ideal. *Brief history of Combinations of Capital.* Distinction between old monopolies created by law and voluntary combinations. *Purpose of Combinations.* Professed and Actual:—Reduction of cost; advance of price. Indirect effect of premium-hunting, and of Stock-Exchange value of shares in a business upon management of combinations and prices.

Effect on prices.—Difference between effect of combinations of capital and combinations of labour. Actual effect and ideal or ultimate effect. Four stages. First, monopoly complete or tentative. Second, competition with tacit combination of competitors. Third, thorough competition. Fourth, survival of fittest by ultimate economy. (A) Effect upon cost. Economy of material. Concentration of work. Elaboration of new methods from larger views. Better synthesis and organisation. (B) Effect upon distribution. Larger production tends to better arrangement of sales. Its various effects upon prices. Wider acquaintance with consumers and demand. Economy in handling. Direction of channels of distribution. Indirect effect through reaction upon cost of knowledge gained in distribution. Collateral effects on prices of allied products.

Remedies for evils of primitive stages of combination.—General remedies are better statistics and more knowledge of economics in industrial world. Education of commercial men as industrial trustees. Growing experience of public, both as shareholders and consumers. Mistrust of uneducated plutocrats and their methods. Methods of inducing ultimate economies of combination. Example of railways and banks.

Ultimate effect on prices.—Progress towards a rational ideal of profit and industrial methods accelerated by combination. Law of average operates. Forces tending to produce result. Trade of individuals menaced, selfish instincts tend to economy; trade of country attacked, patriotic instincts add to effort. Increase of education and the new industrial religion. The artist's view of production. The worthy product and its price.

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3. *Les Crises Commerciales.* *By* Monsieur Clément Juglar.

Statistics indicative of commercial activity during long periods of time exhibit an ebb and flow extending over a variable number of years, and due to some powerful force acting continuously in the same direction for a considerable time. The movement so observed is more or less uniform in all countries at the same time. The circulation of banks in England, France, and America, since 1800 affords an example. The cyclical period is not constant, but the credit-movement shows a succession of stages of expansion, shock (or crisis), contraction (or liquidation), stagnation, and renewed expansion. The crash of the Copper Syndicate, of the Panama Canal Company and the Baring crisis fit in with a movement of this kind.

The International Institute of Statistics had propounded the question, What is the best measure of the economic condition of a nation? The consumption of coal, iron, and corn, had been suggested as the measure; but these are partial at best. The credit circulation, on the contrary, embraces the whole industrial and commercial activity of the country, cash and credit alike, for the second carries with it the first.

A remarkable confirmation of the pervading power of credit is afforded by diagrams showing the number of marriages and births in London and Paris, in France, England, Germany, Prussia, Austria, Italy, Belgium, Switzerland. These expand and contract with striking similarity, increasing in good times when credit is active, contracting in bad times when credit is diminishing or sluggish. Similar diagrams of the number of deaths show no such concordance with the movements of credit, because, unlike credit, they are largely determined independently of human volition, though the minimum on this curve usually occurs in a period of prosperity.

FRIDAY, SEPTEMBER 18.

The following Papers were read:—

1. *That Ability is not the Proper Basis of Local Taxation.* *By* EDWIN CANNAN, *M.A.*

The assessment of the poor rate, to which nearly all other English rates are now mere additions, was originally founded on the principle of ability to pay, and that principle has never been expressly repudiated. But the successive steps by which it has been practically abandoned have been called for by public opinion, and, in spite of complaints, loud rather than deep, the present system is generally approved.

A portion of public expenditure on what are really national objects is still raised by local taxation, in order to secure economy and efficiency of administration. The making of this expenditure a local charge is in itself a negation of the principle of taxation according to ability, and the only question is whether an attempt should be made to re-establish in each locality a principle which has been abandoned as regards the nation as a whole. The answer is in the negative. Most people migrate before reaching the prime of life, and the effect of their consideration where to settle is to equalise the advantages and disadvantages of different localities as places of business and residence. Local taxation is a disadvantage duly taken into account, and consequently, no matter what it is laid upon in the first instance, it tends to reduce the value of the land and other fixed property of the locality. This being the case, it is expedient to levy it directly in respect of such property. Even, therefore, if all local expenditure were of this class, ability would not be the proper basis of local taxation.

But by far the greater portion of modern local expenditure is of a class to which it would be unjust as well as inexpedient to apply the principle of taxation according to ability, either locally or nationally. The principle is approved in the case of national taxation, because the benefits produced by the national expenditure are of such a kind that their distribution cannot be traced and their amount measured. The ideal commonly held is practically equal distribution modified by differences of need, and this communistic principle has its natural counterpart in payment according to ability. But the greater portion of modern local expenditure is calculated (owing to the competition between localities) to produce commensurable pecuniary benefits to the owners of land and other fixed property.

The proper principle of contribution is therefore not the communistic one of payment according to ability, but the joint-stock principle of payment according to share or interest.

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2. *Some Observations on the Distribution and Incidence of Rates and Taxes; with special reference to the transfer of charges from the former to the latter.* *By* G. H. Blunden.

Expenses of kinds formerly provided for by the levy of rates are now met by the imposition of Imperial taxation to the amount of 8,000,000*l.* (including 1,000,000*l.* transferred by the Agricultural Rates Act, 1896). Who gains by the consequent reduction of the rates, and who loses by the corresponding imposition of taxes?

Calculations have been made which show that the payers of Income Tax contribute 29 per cent. of the rates as occupiers of houses, and 31 per cent. as property-owners and consumers; or 60 per cent. in all. Non-payers of Income Tax are shown to pay 32 per cent. of the rates as occupiers of houses, and 8 per cent. as property-owners and consumers; or 40 per cent. in all. Of the rates levied, 12·6 per cent. are borne by certain kinds of real property, 12·1 per cent. by some forms of personal property, and 75·3 per cent. by the community as occupiers and consumers. Much of both real and personal property does not contribute.

Of the Imperial taxes levied, 3 per cent. is borne by real property, 10·4 per cent. by other rateable property, 16·2 per cent. by non-rateable property, 5·5 falls on the earnings of personal exertion, as such; and 64·9 on the consumers of taxed commodities. One-half of the Imperial taxes are contributed by the classes who fall below the Income Tax standard.

The transferred charges prior to 1896 are held to have fallen equally on the payers of Income Tax and the consumers of tea, coffee, cocoa, and dried fruits. As between those who pay Income Tax and those who do not, the shares of the burden remain practically unaltered. But those of the former class who own rate-bearing property gain largely at the expense of those who do not; and the share of the latter class is less evenly distributed among its members, to the disadvantage of the poorer of them.

The Agricultural Rates Act reduces the quota of the rates borne by real property from 12·6 per cent. to 7·5 per cent. The cost of the transfer falls upon the whole community.

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3. *Proposed Modifications of the Rating System.* *By* W. H. Smith.

The changes in local taxation usually proposed involve financial questions that are matters of controversy; but the rating system ought to continue in some form the main source of local revenue, and it is probable that many grievances alleged against it can be mitigated by modifications of the system which may be viewed as the development, rather than the supersession, of the broader principles upon which it rests. Thus, it should be observed that the primary question arising is one between the persons interested in competing properties, and not between those who are variously interested in a single property. Changes, mostly unforeseen, occur in the relative values of properties put to similar uses. These changes, which necessitated 'reassessment,' speedy in their operation, demand that reassessment be associated, not with 'an equal £ rate,' but with a rate which, *cæteris paribus*, would vary more widely than the rateable value varies. To the grievance of the ratepayer as tradesman, there is added his complaint as private householder. As such, he occupies property whose value depends much on the building as distinguished from the site. Moreover, as one descends socially, the demand for house accommodation becomes ineffectual more rapidly than the demand for other comparative necessaries. It is to be considered whether this is in any measure a result of the present distribution of local taxation. A question also arises as to the effect, as regards the individual ratepayer, of the subsidies received by local authorities in the shape of profits from undertakings.

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4. *Farm Labour Colonies and Poor Law Guardians.* *By* Harold E. Moore, *F.S.I.*

With the experience now gained it is possible to divide Farm Labour Colonies into two distinct classes. The first may be considered to be colonies for the reception of well-conducted men of the working classes temporarily out of employment. These colonies can be made self-supporting if managed under proper conditions, as appears from the evidence collected by Mr. W. Mather, then M.P. for the Gorton division of Lancashire, and placed before the Parliamentary Committee on the Unemployed, in the scheme which that gentleman advocated for the foundation of colonies for this class from national resources.

The second class of colonies may be considered to be those for the reception of men who would otherwise be in the casual wards or inmates of workhouses. This kind of colony must be worked either by Boards of Guardians or in close connection with the same. The advantages claimed for such colonies are the reduction in cost of Poor Law Relief, and the giving of more hope to those engaged than if they were employed in other classes of forced labour. Old enactments not yet repealed give Boards of Guardians power to take land not exceeding fifty acres for each parish and to pay wages for working the same. At the time of passing the Poor Law Act of 1834 many such farms were in operation. To continue this class of work was, however, contrary to the spirit of that Act, and has been discouraged. In 1894, however, the Local Government Board consented to consider any schemes submitted by Guardians for providing employment on land. The proposals made by various Boards seem to have been either (*a*) to allow part of the cost of men sent to colonies under private control to be paid by Guardians; or (*b*) to sanction acquirement of land to be worked by paid labour; or (*c*) to permit the acquirement of small areas mainly for purposes of test work. The first-named proposition has been approved, the second rejected, and the third has received favourable consideration.

These decisions of the Local Government Board seem to have been generally prudent, for if land is to be worked for the class named it must be (*a*) largely waste land, to admit of the employment of intermittent and unskilled labour; (*b*) not of such a size as to involve usual farm risks; (*c*) used only for growth of such crops as can be consumed in the workhouses or by the men employed; (*d*) managed on a system giving a reward for labour on the basis of piece-work. The experience quoted showed if these considerations were adhered to the cost of Poor Relief would be lessened with benefit to the men helped. More especially has this been the case where assistance of Guardians has been in the nature of a subsidy to colonies carried on by voluntary committees. An extension of this system can therefore be recommended, especially in view of the recommendations of the Parliamentary Report on the Unemployed, published in July 1896.

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5. *Raffeisen Village Banks in Germany.* *By* Professor W. B. Bottomley.

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6. *The Decay of British Agriculture: its Causes and Cure.* *By* Charles Rintoul.

The decay of agriculture may be attributed to the abolition of the Corn Laws in 1846, which Act was a security to the farmer for the safe investment of his capital and labour in producing food for the nation. This did not immediately follow, as trade and manufacture, which were languishing under the Corn Laws, became very prosperous, together with several other reasons, but as soon as the prairie lands of virgin soil abroad were broken up and reaped with the labour-saving string-binder, and produce sent into this country at very low freights, the exhausted and clay lands, which then could not compete, began to become derelict. Large tracts are thrown out of cultivation, and labourers who formerly produced food supplies are driven into towns to compete with wage-earners there, or to emigrate, and thus their services are lost to the country. Three important remedies:—First: That rents should be adjusted in accordance with the prices, and that permanent improvements executed by the tenantry should be secured to them. Second: That all city refuse be returned to the soil to restore fertility. This is being done in Glasgow at a profit, details of which are given in the paper. Government ought to assist in making this universal. The fertilising matter at present cremated, or thrown into the sea, is a national loss, and could be turned into a national gain. Third: A national system of reclamation of all suitable tidal wastes, to provide virgin soil and marsh pastures, so that the *raw material* now necessary for successful agriculture be kept up. Some details of what has been accomplished in Scotland and Holland are given. In the event of war, the limited supply of home produce and steady increase of population in this country are regarded as serious, and ought to be provided for.

SATURDAY, SEPTEMBER 19.

The following Papers were read:—

1. *Metric Measures and our Old System. By* F. Toms.

The metric system of weights and measures will doubtless be legalised in this country before long. But, admirable as this system is for scientific purposes and large commercial transactions, the decimal divisions are not well adapted to the small dealings which prevail among the less educated portion of the community, who form the great mass of the British nation. In legalising the new code, however, there is no need to sweep away the method now in force, as the two systems may be combined, and the retention of old forms will make our untaught population familiar with new principles.

Our English measures may be made to accord with the French by dividing the metre into eleven equal parts and taking ten of those parts as the basis of our yard. The divisions and multiples of our old system could be retained as heretofore, the only difference being that inches, feet, yards, furlongs, &c., would all be reduced by a small fraction (·006). This done, the metres would be exactly converted into yards when multiplied by 1·1, and yards would be converted into metres when divided by 1·1. At the same time, the complications of our present land measures would be simplified.

A somewhat similar course might be taken with weights and measures of capacity—old names being applied to new equivalents. If half a kilogramme be taken as the new pound, and half a dekalitre as the new gallon, their divisions and multiples would follow the same course as that now in vogue, and retain the same nomenclature.

2. *Comparison of the Age-Distribution of Town and Country Population in Different Lands. By* A. W. Flux, *M.A.*

MONDAY, SEPTEMBER 21.

The following Papers were read:—

1. *Mercantile Markets for 'Futures.' By* Elijah Helm.

Origin and purpose of dealings in 'Futures' in the commercial markets—Utility of the system to industry and commerce—It constitutes a method of insurance to producers and distributors against the risks of fluctuating prices—Its effect upon prices examined in the light of the law of supply and demand—Its influence in rising and falling markets respectively—It has accentuated the fall of prices of commodities within the last twenty years—Its development assisted by the telegraph and the telephone—Why it is confined to the markets for raw materials—Its indirect effect in the markets for manufactures—Its connection with speculative operations—How far these can be differentiated from pure gambling—The system, properly organised and controlled, is, on the whole, economically beneficial—The demand for legislative suppression not justifiable.

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2. *Grain Futures, their Effects and Tendencies.* *By* H. R. Rathbone.

Futures trading, or 'options' as they are generally called, has been of recent growth in the grain trade, and has only during the last ten years exercised a paramount influence on the trade. Its introduction has increased the tendency already in operation to reduce the margin of profit in distribution to a minimum. Owing to the tendency of speculators to overtrade the margin is generally against the importer, and, except under rather unusual circumstances, the cost of distribution is borne chiefly by the speculators. In America, where the system has reached a perfection unknown elsewhere, the option-market is the invariable basis of trading both for the farmer, the distributor, and the miller. In fact, the option-market is looked upon by the trader as a sort of insurance system. The rapidity with which the trade can be executed in these speculative markets has invited operators from all parts of the world, and undoubtedly during the great fall in prices since 1891, the world used the American markets in which to insure their holdings. But it is quite impossible to prove that this fall in values was brought about by option-trading, although a natural fall is accentuated just as a rise is by the existence of the option-market. On the other hand, it may easily be shown that much of the shrinkage in values is due to a fall in freight both ocean and inland.

It is evident that this speculative trading by reducing margins and by making large operations less risky and dangerous is steadily concentrating the grain trade of England into fewer and fewer hands. There are unmistakeable signs that this concentration may eventually take the form of large trusts or syndicates for the distribution of our breadstuffs. As long as England follows her Free Trade principles, it is unlikely that any such abuse of their powers will be possible as we are familiar with in protectionist America. And the hope of the Fabian, that such trusts are only the stepping-stones to the nationalisation of commerce, if not brought about by abuse, is still less likely to be brought about on the ground of economy. For, as long as mankind remains what it is, with an inherent, insatiable passion for speculation, I can imagine no cheaper means for distribution than that in which option-trading plays so important a part.

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3. *Cotton Futures, what they are, and how they operate in Practice.* *By* Charles Stewart.

Avoiding trade technicalities where possible, and explaining them where unavoidable, the paper commences by a description of what a Cotton Futures contract is, its method of working as a contract in suspense and at maturity, and how differences in value are adjusted through the medium of the Clearing House of the Liverpool Cotton Association.

The subject is afterwards separated into two divisions: the utility of Cotton Futures as 'Hedges,' first as sales, second as purchases. The sales are again divided: 1st. As sales by planters in order to secure a favourable current price while the crop is growing, the feature dwelt upon being that such a sale can always be immediately effected, and a ruling good or fair price instantaneously secured. 2nd. The sales of Futures by importers as a hedge against shipments, this operation fully protecting the value interest not only of the importer while the cotton is in transit or in the warehouse, but also the interest of the banker.

financing the bills of exchange drawn for the value of the shipment. This feature is specially emphasised as an insurance against loss in value in a declining market, it being pointed out that without such protection cotton importing would be a sheer gamble and speculation. 3rd. The sales of Futures by spinners, manufacturers, and their agents against accumulated and accumulating stocks of yarn and cloth in times when from temporary and local causes production is ahead of demand.

The purchase of Cotton Futures as a hedge is divided into two sections: 1st. As purchases by shippers against contracts made for forward delivery, during such time as their agents, spread over the cotton belt, can lay their hands upon the actual specialties required. 2nd. As purchases by spinners against contracts made for forward delivery of yarn, by manufacturers against contracts made for forward delivery of cloth, and their agents, it being pointed out that after a sale is effected on a recognised basis a cover-purchase of practically equivalent value can be made immediately, the question of selection being a matter of detail and convenience.

The fidelity of contracts is explained, also the rapidity and facility of effecting either sale or purchase, Cotton Futures being designated as the consols of produce. It is claimed that the system of dealing in Futures is the natural outcome of the expansion of trade, particularly the feature of the development of such by telegraphy. The increase in the size of the crops, the small margin of present-day profits, the greater speed in transit, the increased magnitude of producing concerns, the necessarily greater increase in the capital for their requirements, are all demonstrated. Throughout the paper ignores theory or fallacy, and is devoted to a simple explanation of practice.

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4. *The Influence of Business in Futures on Trade and Agriculture.* *By* J. SILVERBERG.

Agitation against the system of dealing in produce for future delivery in America, England, and Germany. The opponents allege that—

1. The system of selling fictitious produce is the cause of the decline and of constant low prices.
2. That the system overrules the law of supply and demand.
3. That statistical figures prove this contention.
4. They stigmatise the magnitude of these transactions, which they brand as gambling.
5. They produce evidence from their supporters.

As against these it is argued that the system operates as part of the law of supply and demand.

The statistics are unreliable.

The magnitude of the transactions in futures is immense.

Futures may be classed as follows:—

1. Speculation pure and simple is only a comparatively small part. It is difficult to trace and to distinguish it from other business; it is impossible to legislate against it and to stop it.
2. Selling against imports, called 'hedging,' quite legitimate and supremely non-speculative.
3. 'Jobbing' transactions, balancing one another mostly on the same day, and not to be deprecated, having the advantage of creating a broad market.
4. 'Straddling' transactions not altering the position, being identical with transposing quantities from one side of an arithmetical equation to the other, by changing the signs.

Evidence given by opponents mostly biassed and contradictory; they plead their own cause, while pretending to pose as public benefactors.

Dealers and importers of the old school are speculators, while the importer nowadays finds in the system the means of eliminating the element of speculation. The system moves the crops with ease and safety, draws them to our ports, and makes these the centres of distribution, which is a great benefit.

The influence of the system on *agriculture* is salutary:—

1. It furnishes buyers at a time when supplies are enormous and a congestion likely to occur.
2. It increases the number of buyers, which is always an advantage to sellers.
3. It brings consumers into closer contact with producers, and the saving hereby effected benefits producers.
4. It engenders speculative investments by capitalists.
5. It ensures banking facilities to the small shippers, and thus increases competition.
6. It gives producers the cardinal advantage of making produce at all times a readily saleable commodity.
7. It has a decidedly levelling effect on prices, while the *abuses*, such as artificial depression or artificial inflation, are only rare occurrences, and have only a *temporary* effect.

The low price of produce is due to natural causes, ruled by the inexorable law of supply and demand, and the trading in futures *has nothing to do with it.*

'Bear' selling is too sweepingly condemned by the opponents; on the contrary, it very frequently acts beneficially.

In summing up, the conclusion is reached that the system of dealing in futures is a branch of business with which, under modern conditions of trade, we cannot dispense; and that the excrescences and abuses are insignificant compared with the advantages which it confers on trade and agriculture.

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5. *The Course of Average General Prices.* *By* Henry Binns.

TUESDAY, SEPTEMBER 22.

The following Papers were read:—

1. *The Currency Question in the United States and its bearing on British Interests.* *By* Arthur Lee.

Recent developments of the currency question in the United States have rudely dispelled many illusions. Both great parties bimetallist: the Republicans declare for international bimetallism; the Democrats for national bimetallism. No proper gold monometallist party now in the United States. The attitude of England towards international bimetallism a potent factor in the development of strength of the free silver party.

In whatever way struggle results it will vitally affect British interests: 1. If the Republicans win, by operation of a new McKinley tariff especially hostile to British trade; by non-settlement of silver question and four years of continual agitation; by prospect of free silver victory in 1900 and consequent uncertainty as to future. 2. If Democrats win, by reduction in exchangeable value of gold; by increase in exchangeable value of silver; by a violent change in relative values of gold and silver, and consequently of the three standards of value now in existence in British Empire.

Can the United States alone make a coinage ratio of 16 *to* 1 *effective?* Opinion generally held in this country that they cannot do so. Not supported on any definite scientific ground. *Factors in the problem*: Amount of gold now in the States; how much of this can be absorbed by gold-standard countries; how much silver will probably rise and gold will probably fall. Argument of those who maintain that ratio cannot be made effective. Effect of throwing one-seventh of the total stock of gold in the world on the gold-standard countries. Effect of a demand for one-seventh of the total silver money in existence. Gregory King's law. Professor Thorold Rogers on Gregory King's law. No reason why law should not apply in present case. United States cannot exchange one-ninth of total world's stock of gold for silver without bringing market ratio of precious metals below 16 to 1. Probability that the United States will retain large proportion of her present holding of gold. In that case coinage ratio of 16 to 1 will be effective. Effect on the various currencies of the British Empire. Interest of the British Empire in stability of ratio between gold and silver money. But sudden change will work terrible disturbance. Will affect British Empire more than any other. Effect of turning a deaf ear to proposals with respect to international agreement.

Appreciation of gold has been of advantage to certain classes in this country although injurious to producing classes. But this class benefit dependent on action taken by foreign powers. Settlement of the question an important British interest. One for trained political economists, not for popular vote. Should be result of calm deliberation and conference between wisest heads of principal trading nations. Strength of Republican position the hope that international agreement may be brought about. If this hope definitely abandoned free silver agitation will become irresistible.

England's responsibility. *Present British attitude*: Gives strength to present free silver agitation; may result in abandonment of any attempt at international settlement. But question will be settled. *Alternative settlement*: Violent change as a consequence of a popular vote after appeals to popular passion and prejudice. Scant consideration of British interests. Wild revolution instead of wise reform.

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2. *Standard of Value and Price.* *By* William Fowler.

Low Prices Origin of Contest of Standards.—Is it a monetary question? No lack of gold or of standard money (state of banks, treasuries, &c.). Standard money less and less used in trade. Increased output of gold.

What is Price?—The fundamental question. It is the record in money of a bargain depending on markets, not on supplies of money. Prices may affect money, not money prices (Giffen). Money a measure and not creator of price. Price affected by money supply only in case of alarm. If credit maintained, prices not so affected, *e.g.*, dear money and high prices 1864–67. At present time cheap money and low prices. (This true, though word money often used in different senses.) Supply and demand of goods real source of changes of price.

Low Prices chiefly due to Excess of Supplies—caused by (1) inventions, cheap carriage, cheap production. (2) Increase of capital applied to production by (*a*) limited liability, (*b*) capital set free by changes in trade (telegraphs, &c.). (*c*) Accumulations. (3) Special case of silver—great supplies—lessened demands owing to demonetisation caused by great supplies. Fall in prices irregular, but if caused by want of gold should act on all alike, *e.g.*, minerals and wheat fallen much and meat little. The causes affecting them must be contrasted. Wages have risen though labour is a commodity. Gold depreciated as against labour.

Allegation that Low Price of Silver affects (*a*) *Prices,* (*b*) *Trade.*—(1) It affects exports from silver-using countries, *e.g.*, imports of wheat from India. Russia and Argentine (paper) and U.S A. (gold) now rule our markets as to grain. (2) Cheap silver discourages our exports to silver countries (silver prices). But our exports to gold countries have fallen in twenty years far more than our exports to silver countries (Whitehead). Our real rival in the East as to our exports—local manufacture—cheap labour—cheap materials. Discoveries of gold may cause speculative demands for goods—*Query* any recent evidence of this affecting prices?

Bimetallism. What is it?—What is a standard? Is a double standard conceivable? Objections to change of standard. Bimetallism attempts to create a price by law. It says gold worth so many times silver—market or no market. Is this possible? 'Fixed price' impossible (Giffen), *e.g.*, France in 1873—Sherman Act of 1890—France before and after 1850—Fall in silver from 1890 to 1893 (58*d.* to 38*d.*). Can legislation secure circulation? *e.g.*, silver holding of America and France. Law as to circulation of two metals as legal tender money; cheaper remains, dearer goes, *e.g.*, America all silver '92–'34, all gold '34–'73. Demand for gold outside nations agreeing on ratio for (*a*) hoarding; (*b*) war treasure. Danger if not certainty of silver monometallism (Giffen). Danger of panic and hoarding if free coinage of silver as legal tender seriously entertained—United States in '93, and now. Permanent and unconditional agreement of all great nations impossible. What is the ratio approved. No agreement (Cernuschi in France). May not silver suit some and gold others? Danger of agreements in giving power over us to others. Danger of loss of position—what is a pound? Is it honest to pay gold debt in silver? Desiderata—permanence and stability. No proof of probable gain—certainty of dangers if standard made uncertain.

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3. *The Monetary Standard.* *By* Major L. Darwin.

In this paper the author discusses the law which it is desirable that a metallic standard of value should follow with reference to the price of commodities. Taking the case of stagnant trade, when the production of commodities is neither increasing nor diminishing, he shows that objectionable results will arise if the standard is one which either tends to raise or to depress prices. Taking the case of progressive trades, there are two standards to be considered, one which tends to keep the price of the output per man per day constant, and the other which tends to keep the price of the commodities produced constant. These standards are compared under certain hypothetical conditions (also assumed in the case of stagnant trade), and it is shown that both have merits, but that the standard of constant price of output is on the whole the best. But in considering the various facts of real life, omitted in such hypothetical discussions—such as the variations in prices due to causes other than currency causes, the effect of charges of the nature of mining royalties, and the influences which tend to revive trade in periods of depression—all these circumstances show the desirability of keeping up prices at a higher level than these theoretical discussions would indicate as advisable. Thus in times of progressive trade it would seem best that the standard should tend to keep prices between the two extremes above mentioned—that it should make the price of commodities fall, and the price of the average output of human labour rise, the latter perhaps more than the former.

Section G.—MECHANICAL SCIENCE.

President of the Section—Sir Douglas Fox, Vice-President of the Institution of Civil Engineers.

THURSDAY, SEPTEMBER 17.

The President delivered the following address:—

It is rather over a quarter of a century since the British Association last held its meeting in the hospitable city of Liverpool. The intervening period has been one of unparalleled progress, both generally and locally, in the many branches of knowledge and of practical application covered by Civil and Mechanical Engineering, and therefore rightly coming within the limits for discussion in the important Section of the Association in which we are specially interested.

During these twenty-five years the railway system of the British Isles, which saw one of its earliest developments in this neighbourhood, has extended from 15,376 miles, at a capital cost of 552,680,000*l.*, to 21,174 miles, at a capital cost of 1,001,000,000*l.* The railway system of the United States has more than trebled in the same period, and now represents a total mileage of 181,082, with a capital cost of $11,565,000,000.

The Forth and Brooklyn, amongst bridges, the Severn and St. Gothard, amongst tunnels, the gigantic works for the water-supply of towns, are some of the larger triumphs of the civil engineer; the substitution of steel for iron for so many purposes, the perfecting of the locomotive, of the marine engine, of hydraulic machinery, of gas and electric plant, those of the mechanical branch of the profession.

The city of Liverpool and its sister town of Birkenhead have witnessed wonderful changes during the period under review. Great and successful efforts have been made to improve the watergate to the noble estuary, which forms the key to the city's greatness and prosperity; constant additions have been made to the docks, which are by far the finest and most extensive in the world. The docks on the two sides of the river have been amalgamated into one great trust. In order properly to serve the vast and growing passenger and goods traffic of the port, the great railway companies have expended vast sums on the connections with the dock lines and on the provision of station accommodation, and there have been introduced, in order to facilitate intercommunication, the Mersey Railway, crossing under the river, and carrying annually nearly 10 millions of passengers, and the Liverpool Overhead Railway, traversing for six miles the whole line of docks, and already showing a traffic of 7½ millions of passengers per annum. A very complete waterside station connected with the landing-stage has been lately opened by the Dock Board in connection with the London and North-Western Railway. In addition to this, the water-supply from Rivington and Vyrnwy has now been made one of the finest in the world.

The following comparative figures, kindly supplied by Mr. K. Miles Burton, may be of interest :—

	1871	1895
Population of Liverpool	493,405	641,000 (Estimated)
„ Birkenhead	65,971	109,000 „
Area of docks, Liverpool, about	236 acres	362½ acres
„ „ Birkenhead, about	147 „	160 „
	383	522½
Number of steamers using the port	7,448	18,429
Average tonnage of six largest vessels entering the port	2,890	6,822

The following figures show the importance of the local railway traffic :—

Number of passenger stations within the boroughs	—	58
Number of goods stations	—	50
Number of passengers crossing the Mersey in the twelve months (Woodside Ferry)	—	7,143,088
Number of passengers crossing the Mersey in the twelve months (Mersey Railway)	—	6,976,299

To the hydraulic engineer there are few rivers of more interest, and presenting more complicated problems, than the Mersey and its neighbours, the Dee and the Ribble. They all possess vast areas of sand covered at high water, but laid dry as the tide falls, and in each case the maintenance of equilibrium between the silting and scouring forces is of the greatest importance to the welfare of the trading communities upon their banks. The enclosure of portions of the areas of the respective estuaries for the purposes of the reclamation of land, or for railway or canal embankments, may thus have far-reaching effects, diminishing the volume of the tidal flow and reducing the height of tide in the upper reaches of the rivers. Some idea of the magnitude of these considerations may be derived from the fact that a spring tide in the Mersey brings in through the narrows between Birkenhead and Liverpool 710 millions of cubic yards of water to form a scouring force upon the ebb. The tidal water is heavily laden with silt, which is deposited in the docks, and, at slack water, upon the sandbanks. The former is removed by dredging, and amounts to some 1,100,000 cubic yards per annum; the latter is gradually fretted down into the channels and carried out to sea before the ebb. Whilst a considerable portion of the narrows is kept scoured, in some places right down to the sandstone rock, there is a tendency, on the Liverpool side, near the landing-stage, to silt up, a difficulty counteracted, to some extent, by the extensive sluicing arrangements introduced by Mr. George Fosbery Lyster, the engineer of the Mersey Docks and Harbour Board.

Very extensive and interesting operations have been carried on by the Board in connection with the bar at the mouth of the river. Dredgers specially designed for the purpose have been employed for some six years, with the result that 15,142,600 tons of sand and other dredged matter have been removed, and the available depth of water at low-water increased from 11 to 24 feet in a channel 1,500 feet in width.

Those who have made the transatlantic passage in former years can more readily appreciate the very great advantage accruing from this great improvement.

Formerly vessels arriving off the port on a low tide had to wait for some hours for the water-level to rise sufficiently to enable them to cross the bar; the result of a large vessel lying outside, rolling in the trough of the sea with her engines stopped, was that not infrequently this proved to be the worst part of the voyage between New York and Liverpool, and passengers who had escaped the malady of sea-sickness throughout the voyage were driven to their cabins and berths within three or four hours of landing.

Owing to the very successful dredging operations, ships of largest size can now enter or depart from the Mersey at any state of the tide, and they are also able to run alongside the landing-stage without the intervention of a tender.

Such vessels as the 'Teutonic' or 'Majestic,' of nearly 10,000 registered tonnage, 566 feet in length, 57 feet wide, and 37 feet deep; or the still larger vessels, the 'Campania' or 'Lucania,' of nearly 13,000 tons register, 601 feet in length, 65 feet in width, and 38 feet in depth, can be seen, on mail days, lying alongside.

Whilst the estuary of the Mersey presents a narrow entrance with a wide internal estuary, the Dee, owing to extensive reclamation of land in the upper reaches, has a wide external estuary leading to an embanked river of very limited width, up which the tide rushes with great velocity laden with silt, rising in some two hours, then, during a short time of slack water, depositing the silt, which is not removed by the ebb-tide, spread over some ten hours, and therefore having comparatively little velocity. In this case, also, the outer estuary shows a great tendency to silt up beyond the reach of any but the highest spring tides.

The reclamation of the Ribble has not yet proceeded so far as to so seriously affect the general conditions of the estuary; but here, also, there is a constant tendency in the channels to shift, and the erosion which takes place when a high tide and wind combine is very remarkable.

A most important improvement was introduced in 1886, by Mr. G. F. Lyster, when it was decided to raise the water-level in certain of the docks by pumping, the wharves being heightened in proportion, and half-tide basins, or locks, made use of to compensate for the difference of level.

The area of the docks so treated in Liverpool is 73 acres, whilst at Birkenhead the whole area of the docks on that side of the river, amounting to 160 acres, is so raised.

The hydraulic power used in the docks is very large, the indicated horse-power of the engines amounting to 1,673 in the case of Liverpool, and 874 in that of Birkenhead; whilst the Hydraulic Power Company are supplying some 1,000 h.p. to railways and private firms.

The direct-acting hydraulic lifts of the Mersey Railway have now been at work for ten years, and through these, at St. James's Station, no less than 75,000,000 to 80,000,000 of passengers have passed with regularity and safety.

It is remarkable that, whilst Great Britain led the van in the introduction of steam locomotion, she has lagged in the rear as regards electric and other mechanical traction. This arose in the first instance from mistaken legislation, which strangled electrical enterprise, which is still much hampered by the reluctance of public authorities to permit the introduction of the necessary poles and wires into towns.

At the date of the latest published returns there were at work in the United States no less than 12,133 miles of electric, in addition to 599 miles of cable, tramway. Hardly a large village but has its installation, and vast have been the advantages derived from these facilities. In Brooklyn one company alone owns and works 260 miles of overhead trolley lines. With the exception of some small tramways at Portrush, Brighton, Blackpool, South Staffordshire, Hartlepool, &c., the only examples in this country of serious attempts to apply electro-motive force to the carriage of passengers are the City and South London Railway and the Liverpool Overhead Railway, the latter being the latest constructed, and having, therefore, benefited by the experience gained upon the London line.

This railway is over six miles long, a double line of the normal, or 4 ft. 8½ in. gauge, running on an iron viaduct for the whole length of the docks; the installation is placed for convenience of coal supply about one-third of the distance from the northern end. Particulars of this interesting work will be placed before the Section, but suffice it to say that a train service of three minutes each way is readily maintained, with trains carrying 112 passengers each, at an average speed of twelve miles per hour, including stoppages at fourteen intermediate stations.

During the last year, as before stated, $7\frac{1}{2}$ million passengers were carried, the cost of traction per train mile being 3·4*d.*

The Hartlepool Tramway is proving successful, overhead trollies and electric traction having taken the place of a horse tramroad, which was a failure from a traffic point of view.

Careful researches are being prosecuted, and experiments made, with the intention of reducing the excessive weight of storage batteries. If this can be effected, they should prove very efficient auxiliaries, especially where, in passing through towns, underground conductors are dangerous, and overhead wires objectionable.

In connection with electric traction, it is very important to reduce, if possible, the initial force required for starting from rest. Whether this will be best attained by the improvement of bearings and their better lubrication, or by the storage, for starting purposes, of a portion at least of the force absorbed by the brakes, remains to be seen, but it is a fruitful field for research and experiment.

In the United States there is a very general and rapid displacement of the cable tramways by the overhead wire electric system. The latter has many opponents, owing, probably, to causes which are preventable.

Many accidents were caused by the adoption of very high tension currents, which, on the breakage of a wire, were uncontrollable, producing lamentable results.

The overhead wires were placed in the middle of the street, causing interference with the passage of fire-escapes.

The speed of the cars was excessive, resulting in many persons being run over.

The cable system, therefore, found many advocates, but the result of experience is in favour of electrical traction under proper safeguards.

The cable system can only compete with the electric system when a three-minute or quicker service is possible, or, say, when the receipts average 20*l.* per mile per day; it is impossible to make up lost time in running, and the cars cannot be 'backed.' If anything goes wrong with the cable the whole of the traffic is disorganised. The cost of installation is much greater than in the case of electricity, and extensions are difficult.

On the other hand, electricity lends itself to the demands of a growing district, and extensions are easily effected; it satisfies more easily the growing demands on the part of the public for luxury in service and car appointment. It is less expensive in installation, and works with greater economy. By placing the wire at the side of the street, and using a current of low voltage, the objections are greatly minimised, and the cars are much more easily controlled and manipulated. In cases of breakdown these are limited to the half-mile section, and do not completely disorganise the service. Electric cars have been worked successfully on gradients of 1 in 7.

The conduit slot system can be adopted with good results, provided care is taken in the design of the conduit, and allowance made for ample depth and clearance; a width of $\frac{3}{4}$-inch is now proved to be sufficient. Where, however, there are frequent turnouts, junctions, and intersecting lines, the difficulties are great, and the cost excessive.

The following figures represent the cost of a tramway, on this system, in America:—

	£	
Cost of track and conduit	5,600	(per mile of single track)
Insulator, boxer, and double conductor .	480	
Asphalte paving on 6 inches of concrete to 2 feet outside double track . .	1,500	
	£7,580	

Complete cost of operating 4 miles of double track for 24 hours per day with $2\frac{1}{2}$-minute service, 4·55*d.* per train mile (exclusive of interest, taxes, &c.).

One train consists of one motor car and one trailer.

The trains make a round trip of eight miles in one hour, with three minutes lay-off at each end.

The cost of keeping the slot clean comes to about 40*l.* per quarter, and the repairs to each plough conductor about 50*s.* per quarter.

Attempts have been made to obviate the necessity of the slot by what is known as the closed conduit: but at present the results are not encouraging.

The following figures will help to convey to the mind the great development which is taking place in America, as regards the earnings upon lines electrically equipped. They are derived from the Report of the State Board of Railroad Commissioners for Massachusetts.

	1888	1894	Increase
Net earnings per passenger carried	·48	·78	62·5 per cent.
Net earning per car mile	2·78	4·83	73·56 ,,
Net earning per mile of road	£484	£762	57 ,,

In addition to the application of electricity for illuminating purposes, and for the driving of tram cars and railways, it has also been applied successfully to the driving of machinery, cranes, lifts, tools, pumps, &c., in large factories and works. This has proved of the greatest convenience, abolishing as it does the shafting of factories, and applying to each machine the necessary power by its own separate motor; the economy resulting from this can hardly be over-estimated.

It is also successfully employed in the refining of copper, and in the manufacture of phosphorus, aluminium, and other metals, which, before its application, were beyond the reach of commercial application.

The extent of its development for chemical purposes in the future no one can foresee.

It is hardly necessary to call attention to the successful manner in which the Falls of Niagara, and the large Falls of Switzerland, and elsewhere, are being harnessed and controlled for the use of man, and in which horse-power by thousands is being obtained.

At Niagara, single units of electrical plant are installed equal to about 5,000 horse-power output. These units are destined to be utilised for any of the purposes previously suggested, and it is computed that one horse-power can be obtained from the river, and sold for the entire year day and night continuously, for the sum of 3*l.* 2*s.* 6*d.* per annum.

Electric head lights are being adopted for locomotives in the United States.

The use of compressed air and compressed gas for tractive purposes is at present in an experimental stage in this country. The latter is claimed to be the cheapest for tramway purposes, the figures given being—

	d
Single horse cars	$5\frac{3}{4}$
Electrical cars, with overhead wires	$4\frac{1}{4}$
Gas cars	$3\frac{1}{4}$

Combination steam and electric locomotives, gazoline, compressed air, and hot-water motors are all being tried in the United States, but definitive results are not yet published.

The first electric locomotive practically applied to hauling heavy trains was put into service on the Baltimore and Ohio Railway in 1895 to conduct the traffic through the Belt Line Tunnel.

It is stated that, not only was the guaranteed speed of 30 miles per hour attained, but, with the locomotive running light, it reached double that speed.

On the gradient of 8 per cent. a composite train of forty-four cars, loaded with coal and lumber, and three ordinary locomotives—weighing altogether over 1,800 tons—was started easily and gradually to a speed of 12 miles an hour without slipping a wheel. The voltage was 625. The current recorded was, at starting, about 2,200 ampères, and, when the train was up to speed, it settled down to about 1,800 ampères. The drawbar pull was about 63,000 lbs.

The actual working expense of this locomotive is stated to be about the same as for an ordinary goods locomotive—viz., 23 cents per engine mile.

The rapid extension of tunnel construction for railway purposes, both in towns and elsewhere, is one of the remarkable features of the period under review, and has been greatly assisted by the use of shields, with and without compressed air. This brings into considerable importance the question of mechanical ventilation. Amongst English tunnels, ventilation by fan has been applied to those under the Severn and the Mersey. The machinery for the latter is, probably, the most complete and most scientific application up to the present time.

There are five ventilating fans, two of which are 40 feet in diameter, and 12 feet wide on the blades; two of 30 feet, and 10 feet wide; and one quick-running fan of 16 feet in diameter, all of which were ably installed by Messrs. Walker Brothers of Wigan. They are arranged, when in full work, to throw 800,000 cubic feet of air per minute, and to empty the tunnel between Woodside and St. James's Street in eight minutes; but, unfortunately, it is found necessary, for financial reasons, not to work the machinery to its full capacity.

The intended extension of electrical underground railways will render it necessary for those still employing steam traction either to ventilate by machinery or to substitute electro-motive force.

Great improvements have been lately made in the details of mechanical ventilators, especially by the introduction of anti-vibration shutters, and the driving by belts or ropes instead of direct from the engine. The duties now usually required for mining purposes are about 300,000 cubic feet of air per minute with a water-gauge of about 4 inches; but one installation is in hand for 500,000 cubic feet of air per minute, with a water-gauge of 6 inches. Water-gauge up to 10 inches can now be obtained with fans of 15 feet diameter only.

An interesting installation has been made at the Pracchia Tunnel on the Florence and Bologna Railway.

The length of the tunnel is 1,900 metres, or about 2,060 yards; it is for a single line, and is on a gradient of 1 in 40. When the wind was blowing in at the lower end, the steam and smoke of an ascending train travelled concurrently with the train, thus producing a state of affairs almost unimaginable except to those engaged in working the traffic.

Owing to the height of the Apennines above the tunnel, ventilating shafts are impracticable; but it occurred to Signor Saccardo that, by blowing air by means of a fan into the mouth of the tunnel, through the annular space which exists between the inside of the tunnel arch and the outside of the traffic gauge, a sufficient current might be produced to greatly ameliorate the state of things.

The results have been most satisfactory, the tunnel, which was formerly almost dangerous, under certain conditions of weather, being now kept cool and fresh, with but a small expenditure of power.

In an age when, fortunately, more attention is paid than formerly to the well-being of the men, the precautions necessary to be observed in driving long tunnels, and especially in the use of compressed air, are receiving the consideration of engineers. In the case of the intended Simplon Tunnel, which will pierce the Alps at a point requiring a length of no less than 12½ miles, a foreign commission of engineers was entrusted by the Federal Government of Switzerland with an investigation of this amongst other questions.

During the construction of the St. Gothard Tunnel, which is about 10 miles in length, the difficulties encountered were, of necessity, very great; the question of ventilation was not fully understood, nor was sanitary science sufficiently advanced to induce those engaged in the work to give it much attention. The results were lamentable, upwards of 600 men having lost their lives, chiefly from an insidious internal malady not then understood. But the great financial success of this international tunnel has been so marked, as to justify the proposed construction of a still longer tunnel under the Simplon.

The arrangements which are to be adopted for securing the health of the employés are admirable, and will surely not only result in reducing the death rate to a minimum, but also tend to shorten the time necessary for the execution of the undertaking to one-half.

The quantity of air to be forced into the workings will be twenty times greater than in previous works. Special arrangements are devised for reducing the temperature of the air by many degrees, suitable houses are to be provided for the men, with excellent arrangements for enabling them to change their mining clothes, wet with the water of the tunnel, before coming in contact with the Alpine cold; every man will have a bath on leaving; his wet clothes will be taken care of by a custodian, and dried ready for his return to work; suitable meals of wholesome food will be provided, and he will be compelled to rest for half-an-hour on emerging from the tunnel, in pleasant rooms furnished with books and papers. This may appear to some as excessive care; but kind and humane treatment of men results, not only in benefit to them, but also in substantial gain to those employing them, and the endeavour of our own authorities, and of Parliament, to secure for our own work-people the necessary protection for their lives and limbs in carrying out hazardous trades and employments, is worthy of admiration.

The great improvements in sub-aqueous tunnelling can be clearly recognised from the fact that the Thames Tunnel cost 1,150*l.* per lineal yard, whilst the Blackwall Tunnel, consisting of iron lined with concrete, and of 25 feet internal diameter, has, by means of Greathead's shield and grouting machine, been driven from shaft to shaft a distance of 754 yards for 375*l.* per yard.

Tunnels have now been successfully constructed through the most difficult strata, such as waterbearing silt, sand, and gravel, and, by the use of grouting under pressure, subsidence can almost entirely be avoided, thus rendering the piercing of the substrata of towns, underneath property without damaging it, a simple operation: and opening up to practical consideration many most important lines of communication hitherto considered out of the question.

On the other hand, very little improvement has taken place in the mode of constructing tunnels in ordinary ground, since the early days of railways. The engineers and contractors of those days adopted systems of timbering and construction which have not been surpassed. The modern engineer is, however, greatly assisted by the possibility of using Brindle bricks of great strength to resist pressure, combined with quick-setting Portland cement, by the great improvements which have taken place in pumping machinery, and by the use of the electric light during construction.

A question which is forcing itself upon the somewhat unwilling attention of our great railway companies, in consequence of the continual great increase of the population of our cities, is the pressing necessity for a substantial increase in the size of the terminal stations in the great centres of population.

Many of our large terminal stations are not of sufficient capacity to be worked properly, either with regard to the welfare of the staff or to the convenience of the travelling public.

Speak to station-masters and inspectors on duty, when the holiday season is on, and they will tell you of the great physical strain that is produced upon them and their subordinates, in endeavouring to cope with the difficulty.

This, if nothing else, is a justification for the enterprise of the Manchester, Sheffield and Lincolnshire Railway Company in providing an entirely new terminus for London.

It is thirty years since the last, that of St. Pancras, was added, and during that period the population of London has increased by no less than two millions.

The discussion, both in and out of Parliament, of the proposals for light railways has developed a considerable amount of interest in the question. Experience only can prove whether they will fulfil the popular expectations. If the intended branch lines are to be of the standard gauge, with such gradients and curves as will render them suitable for the ordinary rolling-stock, they will, in many cases, not be constructed at such low mileage costs as to be likely to be remunerative at rates that would attract agricultural traffic. The public roads of this country (very different from the wide and level military roads of Northern Italy and other parts of the Continent) do not usually present facilities for their utilisation, and, once admitted, the necessity for expropriating private property, the time-honoured questions of frontage severances and interference with amenities will force their way to the front, fencing will be necessary, and, even if level crossings be allowed at public roads, special precautions will have to be taken.

Much must then depend upon the regulations insisted upon by the Board of Trade. If, in consideration of a reduction in speed, relaxation of existing safeguards are permitted, much may, no doubt, be effected by way of feeders to existing main lines.

If, on the other hand, the branches are of narrower gauge, separate equipment will be necessary, and transhipment at junctions will involve both expense and delay. It is very doubtful whether the British farmer would benefit much from short railways of other than standard gauge. He must keep horses for other purposes, and he will probably still prefer to utilise them for carting his produce to the nearest railway station of the main line, or to the market town.

The powers granted by the Light Railways Act, in the hands of the able Commissioners appointed under the Act, cannot, however, fail to be a public boon.

Special Acts of Parliament will be unnecessary, facilities will be granted, procedure simplified, some Government aid rendered, and probably the heavy burden of a Parliamentary deposit will be removed.

It would seem quite probable, that motor cars may offer one practical solution of the problem how best to place the farms of the country in commercial touch with the trunk railways, seaports, and market towns. They could use existing roads, could run to the farmyard or field, and receive or deliver produce at first hand.

Such means of locomotion were frequently proposed towards the end of the last century, and in the early part of the present one, and it was not until the year 1840, that the victory of the railway over steam upon common roads was assured, the tractive force required being then shown to be relatively as 1 to 7.

The passing of the Act of 1896, superseding those of 1861 and 1865, will undoubtedly mark the commencement of a new era in mechanical road traction. The cars, at present constructed chiefly by German and French engineers, are certainly of crude design, and leave much to be desired. They are ugly in appearance, noisy, difficult to steer, and vibrate very much with the revolutions of their engines, rising as they do to 400 per minute; those driven by oil give out offensive odours, and cannot be readily started, so that the engine runs on during short stops. There would seem to be arising here an even more important opening for the skill of our mechanical engineers than in the case of bicycles, in which wonderful industry the early steps appear also to have been foreign.

It is claimed for a motor car that it costs no more than carriage, horse, and harness, that the repairs are about the same, and that, whilst a horse, travelling 20 miles per day, represents for fodder a cost of 2*d.* per mile, a motor car of 2½ horse-power will run the same distance at ½d. per mile.

The highway authorities should certainly welcome the new comer, for it is estimated that two-thirds of the present wear and tear of roads is caused by horses, and one-third only by wheels.

Perhaps no invention has had so widespreading an influence on the construction of railways as the adoption of the Bessemer process for the manufacture of steel rails. This has substituted a homogeneous crystalline structure, of great strength and uniformity, for the iron rails of former years, built up by bundles of bars, and therefore liable to lamination and defective welds. The price has been reduced from the 13*l.* per ton, which iron rails once reached, to 3*l.* 15*s.* as a minimum for steel. There are, however, not infrequently occurring, in the experience of railway companies, the cracking, and even fracture of steel rails, and the Government has lately appointed a Board of Trade Committee for the investigation, incidentally of this subject, but specially of the important question of the effect of fatigue upon the crystallisation, structure, and strength, of the rail. Experience proves, at any rate, that it is of great importance to remove an ample length of crop end, as fractures more frequently take place near the ends, aided by the weakening caused by bolt holes. Frequent examination by tapping, as in the case of tyres, seems, at present, the most effective safeguard.

It is open to serious question, whether the great rigidity of the permanent way of the leading railways of this country is an advantage. Certainly the noise is very great, more so than in other countries, and this points to severe shocks, heavy wear and tear of rails and tyres, and—especially when two heavy locomotives are run with the same train—liability to fracture. Whilst the tendency in this country, and in the United States, has been to gradually increase the weight of rails from 40 lb. up to 100 lb. per lineal yard, there are engineers who think that to decrease the rigidity of rail and fishplate, and weight of chair, and to increase the sleepers, so as to arrive as nearly as possible at a continuous bearing, would result in softness and smoothness of running.

The average and maximum speeds now attained by express trains would appear to have reached the limit of safety, at any rate under the existing conditions of junctions, cross-over roads, and other interferences with the continuity of the rail. If higher speeds are to be sought, it would seem to be necessary to have isolated trunk lines, specially arranged in all their details, free from sharp curve and severe gradient, and probably worked electrically, although a speed of 100 miles per hour is claimed to have been reached by a steam locomotive in the United States.

The grain trade of the port of Liverpool has assumed very large proportions, and the system of storage in large silos has been adopted, with great advantage, both as regards capital, outlay, and the cost of working, per ton of grain.

The Liverpool Grain Storage Warehouses at Bootle will be open to Members of the Association, and there can be seen the latest development of the mechanical unloading, storing and distribution of grain in bulk; the capacity is large, being:—

Warehouse No. 1,	56,000 tons	or 4,240,000 bushels,
" " 2,	30,000 "	
Quay Stores	20,000 "	

thus constituting this granary as one of the largest, if not the largest, in the world.

The question of the pressure of grain is a very difficult one, and, in constructing the brick silos, which are 12 feet across at the top, by nearly 80 feet in depth, large allowance has been made both for ordinary pressure, and for possible swelling of the grain.

The grain is unloaded by elevators, and then transported on bands, the result being its cooling and cleansing, as well as its storage and distribution.

The question of the early adoption in England of the metric system is of importance not only to the engineering profession, but also to the country at large. The recommendation of the recent Royal Commission, appointed for the consideration of the subject, was, that it should be taught at once in all schools, and that, in two years' time, its adoption should be compulsory; but it is much to be regretted that, up to the present time, nothing has been done.

The slight and temporary inconvenience of having to learn the system is of no moment compared to the great assistance it would prove to the commercial and trading world; the simplification of calculations and of accounts would be hailed with delight by all so soon as they realised the advantages. England is suffering greatly in her trade with the Continent for want of it.

Our foreign customers, who have now used it for many years, will not tolerate the inconvenience of the endless variety of weights and measures in use in England, and they consequently purchase their goods, to a great extent, from Germany, rather than use our antiquated English system. It is no exaggeration to say that, with their knowledge of the metric system, they regard ours as completely obsolete and unworkable, just in the same way as we should were we to buy our corn, our wine, our steel and iron, by the hin, the ephah, or the homer, or to compute our measurements by cubit, stadium, or parasang.

It behoves all who desire to see England regain her trade to use all their influence in favour of the adoption of this system, as its absence is, doubtless, one of the contributory causes for the loss that has taken, and is taking, place.

An important argument in favour of the metric system of weights and measures is that it is adopted all over the civilised world by physicists and chemists; and it may be stated with confidence, that the present international character of these sciences is largely due to this.

It is interesting also to notice, that the metric system is being gradually introduced into other branches of science. Anthropometric measurements made by the Committees of the British Association in this country and in Canada are invariably given in metres, and a comparison with measurements made in other countries can be at once made.

The period of twenty-five years under review has indeed witnessed great advances, both in scientific knowledge and practical application. This progress has led to powerful yet peaceful competition between the leading nations. Both from among our cousins of the United States, and from our nearer neighbours of Europe, have we, at this Meeting, the pleasure of welcoming most respected representatives. But their presence, and the knowledge of the great discoveries made, and colossal works carried out, by them and their brother scientists and engineers, must make us of Great Britain face with increased earnestness the problem of maintaining our national position, at any rate, in the forefront of all that tends towards the 'utilisation of the great sources of power in Nature for the use and convenience of man.' Those English engineers who have been brought in contact with engineering thought and action in America and abroad have been impressed with the thoroughness of much of the work, the great power of organisation, and the careful reliance upon scientific principles constantly kept in view, and upon chemical and mechanical experiments, carried out often upon a much more elaborate scale than in this country. This is not the place from which to discuss the questions of bounties and tariffs, which have rendered possible powerful competition for the supply of machinery and railway plant from the Continent to our own Colonies; but there is certainly need for advance all along the line of mechanical science and practice, if we are to hold our own—need especially to study the mechanical requirements of the world, ever widening and advancing, and to be ready to meet them, by inventive faculty first, but also by rigid adherence to sound principles of construction, to the use of materials and workmanship of the highest class, to simplicity of design and detail, and to careful adaptation of our productions to the special circumstances of the various markets.

It is impossible to forecast in what direction the great advances since 1871 will be equalled and exceeded in the coming quarter of a century. Progress there will and must be, probably in increased ratio; and some, at the end of that period, may be able to look back upon our gathering here in Liverpool in 1896 as dealing with subjects then long since left behind in the race towards perfection.

The mechanical engineer may fairly hope for still greater results in the perfection of machinery, the reduction of friction, the economical use of fuel, the substitution of oil for coal as fuel in many cases, and the mechanical treatment of many processes still dependent upon the human hand.

The electrical engineer (hampered as he has been in this country by unwise and retrograde legislation) may surely look forward to a wonderful expansion in the use of that mysterious force, which he has already learned so wonderfully to control, especially in the direction of traction.

The civil engineer has still great channels to bridge or tunnel, vast communities to supply with water and illuminating power, and (most probably with the assistance of the electrician) far higher speeds of locomotion to attain. He has before him vast and ever-increasing problems for the sanitary benefit of the world, and it will be for him to deal from time to time with the amazing internal traffic of great cities. China lies before him, Japan welcomes all advance, and Africa is great with opportunities for the coming engineers.

Let us see to it, then, that our rising engineers are carefully educated and prepared for these responsibilities of the future, and that our scientific brethren may be ever ready to open up for them by their researches fresh vistas of possibilities, fresh discoveries of those wonderful powers and facts of Nature which man to all time will never exhaust.

The Mechanical Section of the British Association has done good work in this direction in the past, and we may look forward with confidence to our younger brethren to maintain these traditions in the future.

The following Papers were read:—

1. *Physical and Engineering Features of the River Mersey and the Port of Liverpool.*

This Paper was ordered by the General Committee to be printed *in extenso.*—See Reports, p. 548.

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2. *The Cause of Fracture of Railway Rails.*
By W. WORBY BEAUMONT, *M.Inst.C.E.*

In this paper the author gives an explanation of the apparently anomalous fractures of railway rails. Attention is first directed to the leading features in the history and characteristics of fractured rails, and from these the conclusion is drawn that the failure of any rail, however perfect, is chiefly a question of the number and weight of the trains passing over it. The effect of the rolling of the heavily loaded wheels of engines and vehicles[1] is the gradual compression of the upper part of the rails and the production thereby of internal stresses which are cumulative and reach great magnitude. That which takes place in the material of a rail head under the action of very heavy rolling loads at high speed, is precisely that which is purposely brought into use every day in our ironworks. The effect is, however, obscured by the slowness of the growth and transmission of the forces which are ultimately destructive.

When a piece of iron or steel is subjected to pressures exceeding the limit of elastic compression, by a rolling or hammering action, or by both these combined, the result is spreading of the material and general change of the dimensions. This is equally the case with a plate pane hammered on one side or rolled on one side while resting on a flat surface, or with a rivet when hammered over. In all these cases and many others, the hammering or rolling work done upon the surfaces tends to compress the material beneath it, but being nearly incompressible and unchangeable in density, the material flows, and change of form results.

Generally the material thus changed in form suffers permanently no greater stresses than those within its elastic limit of compression or extension. When, however, the material is not free to flow or to change its form in the directions in which the stresses set up would act, the effect of continued work done on the surface is the growth of compressive stress exceeding elastic resistance.

In the case of railway rails the freedom for the flow of the material is very limited, especially when considered with reference to the rolling and hammering media and the surface contact between rails and wheels. Hardening of the surface takes place and destructive compression of the surface material is set up. If the material be cast iron, the destructive compression causes crumbling of the superficial parts and the consequent relief of the material immediately below it from stress beyond that of elastic compression; but when the material is that of steel rails, the stress accumulates, the upper part near the surface being under intense compression, differentiating from a maximum at the surface.

This compression gives rise to molecular stresses analogous to those which, on the compression side or inner curve of a bar bent on itself, originate traverse flaws on that side.

This condition of compression exists along the whole length of a rail, so that when its magnitude is sufficient to originate crumbling or minute flaws, any unusual impact stress, or a stress in the direction opposite to that brought about by the usual rolling load, the rail may break into two or into numerous pieces. Stresses originating in the same manner explain the fracture of railway tyres as described fully by the author in the 'Proceedings of the Institution of Civil Engineers,' 1876, vol. xlvii.

[1] The static pressure per square inch of surface contact between wheel and rail with locomotive weights now common is considerably more than 30 tons, and the pressure under heavily balance-weighted locomotive wheels at high speed is much greater than this.

FRIDAY, SEPTEMBER 18.

The following Papers were read:—

1. *Report on the Effect of Wind and Atmospheric Pressure on the Tides.*
See Reports, p. 503.

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2. *Report on the Calibration of Instruments in Engineering Laboratories.*
See Reports, p. 538.

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3. *Description of General Features and Dimensions of the Tower Bridge. By* J. WOLFE BARRY, *C.B., F.R.S.*

London Bridge built in 1280.—Its dimensions.—The houses upon it.—Its improvement in 1758.

New London Bridge built in 1824 to 1831.—Its approaches.—Only one bridge for metropolis till 1729, when Putney Bridge was built in spite of opposition of Corporation of London.

Eight more bridges built between 1730 and 1830.—Development of South London and distribution of population.—Reference to Thames Tunnel and Tower Subway.

Metropolitan Board of Works proposed Bridge in 1879.—Proposal by private company for Subway in 1883.—Subway of Metropolitan Board of Works in 1884, and duplex bridge.—Proposal for *bascule bridge.*—Description and views of original design by Sir Horace Jones.

Corporation of London apply for permission to build present Tower Bridge in 1885.—Description of Upper and Lower Pool of Thames.—Temporary works for constructing the Bridge.—Action of Government authorities and approval of the Queen.—Detailed description of piers and bascule chamber.—Mode of construction of substructure of piers.—The Caissons.—Mode of sinking Caissons.—Construction of pier within Caissons.—The Abutments.—The opening span.—Its dimensions.—Mode of construction and weight.—Mode by which it is actuated.—The hydraulic machinery.—Pumping engines and accumulators.—Estimated wind pressure.—Requirements of Board of Trade and actual wind pressure.—Lifts for foot passengers.—The fixed superstructure.—The masonry of the towers and differences of opinion as to employment of stone round the steel pillars of the tower.—The rollers carrying the chains.—Description of the chains and anchorages.—Total weight of steel and iron in the bridge.—Erection of superstructure.—Temporary bridge—expedients adopted.—The approaches.—Opening of the bridge in June 1894.—Estimates of river traffic as compared with actual traffic.—The vehicular and foot traffic across bridge.—Cost of the bridge defrayed by Bridge House Estates Committee.—Acknowledgments of assistance rendered by various persons.

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4. *On the Liverpool Waterworks. By* J. PARRY.

Early history of the Liverpool water supply—Engineering and chemical ideals of a century ago—Private enterprise and public spirit—Competition and its consequences—Bootle Company's works—Harrington Company's works—Purchase by Corporation—Schemes of 1846—Rivington scheme and its lessons—Investigations for additional supplies 1866–1880—Joint schemes for Manchester and Liverpool—Vyrnwy works—Filtration: Rivington and Vyrnwy—Experiences of introducing a new supply—Consumption of water—Supply of towns and villages on the lines of aqueduct.

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5. *The Present Position of the British North Atlantic Mail Service. By* A. J. MAGINNIS.

SATURDAY, SEPTEMBER 19.

The Section did not meet.

MONDAY, SEPTEMBER 21.

The following Report and Papers were read :—

1. *Report on Small Screw Gauges.*—See Reports, p. 527.

2. *Test of Glow Lamps. By* W. H. PREECE, *C.B., F.R.S.*

3. *The Liverpool Overhead Railway and the Southern Extension of it. By* S. B. COTTRELL.

4. *Notes on Electric Cranes. By* E. W. ANDERSON.

After some introductory remarks, the author states that his object is to give an account of the experience gained during the last eight years at the Erith Iron Works, where two electric travelling cranes have been in constant use for about that period.

No actual experiments are, however, given, as a paper with all such information is to be read by Mr. Ravenshaw at the Institution of Civil Engineers, and it is not considered advisable to forestall this in any way.

A brief description of a 20-ton crane in the foundry is given, to which electricity was applied as a motive power early in 1888, and of which a full account was written in a paper read before the British Association in the same year by Dr. W. Anderson, C.B., F.R.S.

This crane is driven by one single motor which actuates all the different motions, and the paper describes some of the difficulties at first experienced with it, and the way in which they were overcome.

A self-contained steam crane was shortly afterwards placed in the foundry of the same size, and enabled a comparison to be made of the practical advantages of each, and of the amount of repairs required by them, resulting in the practical proof of the superiority of the electric one, by the fact that early prejudice against it had been quite overcome, and that now it was greatly preferred to the other.

Not only are the repairs required less, but in several other ways the electric crane is both more convenient and less costly.

Attention is called to the first motion gearing of the electric crane, which though satisfactory was very noisy, and the means whereby it was much improved are mentioned, though from the necessities of the particular circumstances it cannot be made quite as noiseless as it should be.

A description then follows of a second crane in the turnery to which electricity was applied shortly after the first was started, but which had to be dealt with in a different manner, namely, by applying a separate motor for each motion, the first motion gear consisting of short belts with jockey pulleys. The motions were therefore controlled by three reversing switches, and a brake for lowering.

The method of collecting the current was different from that used in the foundry, and is fully described.

This crane has also proved very successful, and has given very little trouble. The belt reduction gear is quite noiseless.

The author sums up the experience with these cranes by stating that in his opinion electricity applied to this purpose has proved itself to be remarkably efficient, even in the somewhat trying atmosphere of a foundry.

Various practical points are then discussed relating to efficiency, cost, and general convenience.

A comparison is made of the relative merits of the single motor system as used in the foundry, and the three-motor arrangement as in the turnery.

Several methods of reducing the comparatively high speed of the motor to the slow speed of the gearing shafts, as required in cranes and similar machines, are described and commented upon.

The paper concludes with a brief comparison of the merits of hydraulic and electric transmission as applied to cranes, pointing out that the adaptability of one or the other must depend entirely on the circumstances of the case, but at the same time showing that for travelling cranes the difficulty of conveying the pressure-water to the crane practically precludes its adoption, while in this respect electricity stands foremost, especially where there is a long travel.

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5. *Experiments on the Hysteresis of Iron in Revolving Magnetic Fields. By* Professor J. A. Fleming, *F.R.S.*, R. Beattie, *and* R. C. Clinker.

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6. *Street Lighting by Electric Incandescent Lamps. By* William George Walker, *M.Inst.M.E., A.M.Inst.C.E.*

Great difference exists between the quality of the illumination required for the various streets of a large town. Arc lamps are undoubtedly the right thing for busy streets, but would prove an extravagant illumination for ordinary bye-streets or roads of country towns.

It may roughly be taken that the quality of the illumination necessary is of two kinds—firstly, where a flood of light is necessary on account of the nature of the traffic; secondly, where the light is necessary for the demarcation of the roads. At present very little street lighting by glow lamps has been carried out in this country. It has, however, been tried with success on a fairly large scale in America and on the Continent. There are many objections to taking the current off the ordinary low pressure mains that serve for house lighting. Estimates show that the parallel system is generally impracticable on account of the great cost of the copper mains required for the proper distribution of small incandescent lamps in streets.

The parallel system becomes practical in congested districts, and where natural water power can be obtained. It has been felt that a way out of the adoption of a 'series system' of distribution. The main difficulty against this system is that the failure of a lamp filament is liable to put out all the lamps on the circuit.

In the town of Temesvar in Hungary, nearly ten years ago, 750 16-candle-power lamps on the multiple series system were installed, with satisfactory results, the wires being overhead.

The series system has been installed in the parishes of Kingswood and Keynsham, near Bristol, with considerable success during the four and a half years which it has been at work.

At Kingswood, about seven miles of roads are lighted by circuits of 2, 2½ and 3 miles respectively from the central station. The lamps are spaced at 60 yards apart, and are elevated at from 14 to 16 feet from the level of the road on wooden poles, which also carry the overhead wires.

There are 150 street lamps of candle power varying from 100 to 25. The indicated horse-power of the engine at full load is 32.

The revenue from street lighting at 2½*d.* per unit is 650*l.* per annum, leaving a clear profit of 100*l.*, after allowing for depreciation and all expenses. Lighting hours, 4,250 per annum. Total cost of plant, about 3,500*l.* The chief feature of this installation is the automatic cut out, so that the failure of one lamp does not affect the lamps in series with it. Each circuit is divided into two branches, taking equal amounts of current. Each lamp has in series with it an electro-magnet. A resistance is placed as a shunt to the lamp. The normal current will not lift the armature of the electro-magnet, but when a lamp breaks, double the current passes through the allied lamp, and lifts the armature, completing the circuit through the shunt, the resistance of which is equal to the lamp.

A series system with overhead wires is suitable for scattered districts, and is as cheap as gas.

Now that it is possible to obtain lamps suitable for working at 250 volts, and when used in conjunction with a three-wire system, it may be worth while to pay for the extra copper.

An alternating system might be considered with a small transformer for each lamp, reducing the voltage in the primary mains from, say, 2,000 to 250 in the secondary wire, on which the glow lamp would be placed.

TUESDAY, SEPTEMBER 22.

The following Papers were read:—

1. *Armour and Heavy Ordnance—Recent Developments and Standards. By* Captain W. H. JAQUES, *of the United States of America.*

When I picked up the last issue of Brassey's 'Naval Annual' (1896), and upon the title-page read—

'No system of conduct, however correct in principle, can protect Neutral Powers from injury from any party. A defenceless position and a distinguished love of peace are the surest invitations to war.'—THOMAS JEFFERSON.

it occurred to me how little our legislators are influenced by the words of the eminent statesman which have been selected by the editor of a British Annual of the record of the naval events of the year as a warning to Great Britain, the first naval power of the world, that its preparations for defence must be liberal and continuous.

The situation and policy of the United States could not be more accurately described than by these words of Jefferson, '*A defenceless position and a distinguished love of peace*,' yet little heed is given to his warning that these conditions '*are the surest invitations to war*.'

In fact our engineers and manufacturers are the only ones who have awakened to the situation, and this awakening will no doubt be attributed to the hope of pecuniary gain. They have, however, no matter whatever the incentive, attained the highest standards in the production of armour, heavy ordnance, and projectiles. All we need in the United States are adequate budgets and well-planned ship-building programmes. That we are gradually reaching out in the right direction is shown by the following table of estimates for 1896–7, taken from Brassey's 'Annual' for 1896:—

	£
England	21,823,000
France	10,637,096
Russia	6,440,666
United States	5,862,228
Germany	4,372,068
Italy	3,641,324

although in the table of effective fighting ships, built and building, the United States is left out, England, France, Russia, Italy, and Germany only being included.

The progress in armour-making referred to in my last public pamphlet (1894) has been continuous, and the United States (The Carnegie Steel Co., Ltd.) and Germany (Krupp) have produced armour fully 15% if not 20% better than the best plain steel Harveyed armour that Great Britain has placed upon her battleships; although one is handicapped in making thorough comparison so long as England continues to determine the value of her battleship armour by firing 6-inch soft Holtzer shells against 6-inch plates at velocities below 2,000 ft. sec.

In making a comparison of the tests I have cited, we must not lose sight of the fact that the German and French plates were *experimental*, and made to secure the greatest resistance possible, whereas those of the United States were *service* plates representing hundreds of tons of armour from which the inspectors had selected what they considered were the poorest of the lot.

A summary of recent advances will include the cheapening and more extensive use of nickel; the substitution of the hydraulic forging-press for hammers and rolls; better means of removing scale; simplification of the methods, and more uniform results of supercarburisation; utilisation of the valuable sub-forging process (now required for all United States armour); improved facilities for hardening, and improvements in the machines and tools for shaping and finishing.

While in the United States the increased resistance of armour has determined the authorities to retain the higher calibres of heavy ordnance, the Navy Department having ordered 13-inch B.L. rifles for battleships, and the War Department having commenced a type gun of 16-inch calibre (both adhering to the forged-hooped type), Great Britain still keeps the 12-inch as her limit, and continues the radical departure to wire construction made by Dr. Anderson when he became Director-General, and so successfully carried out by him.

France adheres to types containing too many parts, and Germany is satisfied to possess a large number of comparatively low ballistic power.

No matter which type, hooped or wire, is adhered to, improved armour and projectiles must be met by greater energies, which involve higher pressures, shorter guns (for utility), and stronger material. That this last is to be obtained in the United States is evident from the following requisites in a 3-inch test piece for *nickel* steel tubes for cannon of 8-inch calibre and over:—

Tensile Strength	90,000 lb. per sq. in.
Elastic Limit	56,000 " " " "
Elongation	20 per cent.
Contraction of Area	40 " "

Equally favourable progress has been made with projectiles, but as yet very few truly competitive results are at hand. The uncertainty of their relative value still causes a very large unknown quantity in the valuation of armour comparisons.

In conclusion we may count, at least in the United States, as commercial commodities, armour having a resistance 10% better than the best of last year; heavy ordnance giving *service* velocities of 200 ft. sec. higher, and armour-piercing projectiles, that to be accepted must perforate a thickness of nickel-steel carburised armour equal to their calibre. Truly an excellent record!

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2. *A new Spherical Balanced Valve for all Pressures. By* James Casey, *Consulting Marine Engineer.*

In this paper the author deals with the avoidable loss of life and damage to property caused through explosions of defective valves, whether from steam, water, or other fluid, where extreme pressures were used. Having described the valves generally in use, he points out that in many cases water that had passed into the valve-box and steam-pipes from the boilers had caused danger and even fatal results, often attributed to defective steam-pipes, whereas both valve-box and pipes were charged with water from the steam leaking and passing into the main steam-pipe and getting condensed into water. No means were afforded under the present valve system of draining this water, and hence it happened that the moment the stop-valves were opened on the boilers full to the engines a hammering took place, the explosion immediately following. From the design of these valves he did not see how it was possible for a satisfactory drainage to be applied that could be always available and keep the steam-pipes free of water and of the danger to which he referred.

The importance of having reliable valves under extreme pressure, whether for steam, water, or other fluid, could not be overestimated. Having regard to this, he had designed a valve of globe form which, he might say with perfect confidence, was balanced under all or any pressures. The valve formed a complete sphere, with openings in the same at right angles to each other, with spindle cast on, working in a fixed and adjustable seating, and so arranged that the pressures were balanced or equalised, and friction was reduced to a minimum. This sphere was fitted into a valve-box, sometimes made in two parts for convenience in adjusting the sphere and its seatings, such being adopted to allow for contraction and expansion under pressure. Suitable openings were formed in the valve-box corresponding with those in the globe, so that when the globe was turned by its spindle to the required position the same might be turned off or on. The openings in the valve-box and in the sphere respectively were arranged to correspond with the full supply of steam, water, or other fluid. The globe or ball was perforated with a small passage corresponding to a similar passage in the valve casing, and when opposite to each other any condensed steam or water escaped from the steam-pipes or valves either to the condenser or ran to waste, thereby effectually clearing the pipe of water and preventing any chance of explosion.

As showing some of the defects arising from the existing system in connection with boilers, steam-pipes, and heating-apparatus in mills, on board ship, in public buildings and places of business, the author gave particulars derived from Board of Trade reports of official inquiries under Act of Parliament. These clearly pointed to the necessity of a new departure in the valve system if the present destruction of life and property was to be obviated.

For hydraulic purposes the author claims that with the new valve no grit or sandy matter could get between the valve and seatings, for the simple reason that it worked in and on the seatings, and no foreign matter could be introduced. A valve on this principle has now been at work close upon eighteen months, and it had been found upon examination that it was as good now as on the first day it was put in place, and had not cost a penny for repairs or even adjustment, although in daily work at a pressure of 750 lb. per square inch. In the use of higher pressures the limit of its working was the cohesive strength of the material of which it might be constructed, and being balanced it was manipulated by a small lever which a boy could work. The system which the author had advocated possessed equal advantages in connection with fire hydrants and water supply generally owing to its simplicity and the ease with which it could be worked. Briefly what the author claimed was that by the adoption of his valve system the following, amongst other advantages, would be attained:—

1. The substitution of a perfectly balanced spherical valve under all pressure for one on the old principle of lifting, which is liable to get out of order or to cause explosion, consequent on faulty construction and the absence of proper means of draining steam-pipes and other connections therewith.

2. The valve can be worked easily and instantaneously, and is not affected where dirty or gritty water is used.

3. The valve can be adopted for steam, hydraulic, gas, mining, and all other purposes for which valves are in daily use, and made of cast iron or gun metal.

4. The valve drains itself and the connections of boilers, &c., of all water created by condensation of steam, thereby preventing dangerous hammering in the pipes and obviating, under certain conditions, the bursting or freezing of pipes and concomitant dangers.

3. *Engineering Laboratory Apparatus.*
By Professor H. S. Hele-Shaw, *M.Inst.C.E.*

At the Liverpool Meeting of the Institution of Mechanical Engineers in 1891 an account was given of the chief appliances in the Walker Engineering Laboratories at Liverpool.

A description of the Triple-Expansion steam engine and boiler, and the alternative centre 100 ton testing Machine will be found illustrated in the Proceedings of the Institution of Mechanical Engineers for 1891.

The first intention of the author on the present occasion was to give a description of certain appliances which are of a novel character and which were to be shown in operation together with other experimental arrangements at the Walker Engineering Laboratories after the reading of the paper.

These appliances might be conveniently arranged under the three following heads, which constituted in fact the three divisions of Laboratory teaching, viz.:—

1. The steam engine.
2. Hydraulics.
3. Testing the strength and properties of materials.

The apparatus to be mentioned under the first head were as follows:—

1. Hydraulic brake and integrator.
2. Spring dynamometer.
3. Arrangement for drawing crank-effort diagrams.
4. Arrangement in connection with steam-engine indicators.
5. General arrangements in connection with the experimental courses of instruction.

Under the head of Hydraulics:—

1. Hydraulic tank, valve-boxes and sump.

Under the third head:—

1. An extensometer of novel design.
2. Arrangement for testing the torsion of shafts.
3. A convenient gauge in connection with crushing and bending experiments.

When, however, the author came to actually prepare the paper and diagrams, he found that it would be impossible to deal in a satisfactory manner with all these subjects, many of which were entirely new, all possessing novel features, representing the hitherto unpublished work of some years. He therefore limited himself to the experimental steam engine and the hydraulic tank, merely indicating by means of diagrams various matters without attempting to describe them fully, which might be seen in operation at the laboratories, where actual trials would be conducted by the students in the same way as during the work of the college classes.[1]

In the above-mentioned paper the brake which was described was of the ordinary friction type, except that the flywheel rim was hollow through which

[1] The following demonstrations were given:—

1. Full trial of experimental steam engine by third year students.

Conditions:—Triple expansion, unjacketed, condensing. Boiler pressure 100 lb. per square inch. Natural draught.

2. Testing various specimens of wrought iron, and taking their stress-strain diagrams, in the 100-ton testing machine.
3. Finding the deflection of beams, and value of E.
4. Experiments on the angle of torsion, and value of coefficient of rigidity.
5. Finding modulus of rupture and strength of cast-iron bars.
6. Gauging and cement testing.
7. Experiments on the flow of water through orifices with the hydraulic tank.
8. Drawing crank-effort diagrams by a new apparatus.
9. Experiments on the whirling and vibration of shafts.

water circulated, a weight of 1,500 lb. being required to take the power of the engine.

This brake never worked satisfactorily, and though every expedient was tried, it was found impossible to conduct a trial with any regularity beyond 30 indicated horse-power. Moreover, owing to the flywheel being overhung, and a weight hanging upon it, during a long trial, the bearing nearest the wheel almost invariably became heated. Beyond this, it was found that for practical purposes a 3-ton wheel was unnecessarily large for any trials. A brake, of which a descriptive diagram was shown, was therefore designed, the weight of the fly-wheel being about 15 cwt., instead of 3 tons, and the framing being so arranged that the load was taken off the bearing. This brake at once removed the difficulty of heating, and a regular series of trials were made up to about 60 horse-power, which during one session served quite satisfactorily for the work of the students. Beyond this, however, it was impossible to get regular runnings with the brake. The loads were taken by a hemp cable, five coils of which passed round the wheel, which is in the form of a broad pulley, and acted by taking advantage of the power of coil friction. To get steady runnings it was found necessary to keep the rope wet, a stream of water flowing upon it.

It had been originally intended to have the form of Froude hydraulic brake, as modified by Professor Osborne Reynolds, and it became evident that nothing but a hydraulic brake would solve the problem of taking up continuously 150 horse-power. The question of cost had prevented this form of brake from being obtained originally from Messrs. Mather and Platt, and the same reason led to a modified design of the hydraulic brake, in which the chief cause of expense in the Reynolds type was avoided, viz. by doing away with the considerable amount of coring for air and water passages in the castings, and also in constructing the main part in cast iron instead of gun-metal, and further, in having it single acting. For this, and other apparatus, funds were provided through the kindness of Mr. Charles W. Jones (of Messrs. Lamport and Holt) and Mr. R. R. Heap.

The author then proceeded to explain by means of models the action of the brake, and the features which were peculiar in the new brake, which were as follows :—

(1) The vortex is artificially produced.
(2) The brake is single acting.
(3) The pressure is downwards, so as to take the weight of the brake off; in fact, practically not to take off the weight of the brake only, but also of the flywheel.
(4) Autographic recording and registering arrangements are employed.
(5) Special arrangements are adopted by which automatic action is secured.

These various points were considered in detail and described by means of drawings, but it was pointed out that as far as the actual work of the trials for the students were concerned, none of the refinements mentioned were necessary. An extremely simple form of brake was quite sufficient to maintain the engine running perfectly steady under the highest steam pressures

The various features in which the engine itself has been improved were then mentioned, and may be summarised as follows :—

(1) A series of drain tanks, so as to measure the water condensed in the steam jackets.
(2) A separate tank has been provided, into which the water from these drain tanks is thereby checked.
(3) A new special tank for the exact calibration of feed-water supply has been provided, which works in connection with the injector by which the boiler is supplied.
(4) A special arrangement has been devised by which the indicator diagrams can be conveniently and rapidly taken by students.
(5) A system of checking and graduating the indicator springs, which has been found most valuable in operation by means of a duplex standard steam gauge.

(6) An arrangement was shown in operation for obtaining the diagrams of crank effort, by means of a special apparatus which is done on smoked glass. These can either be printed off, or used direct in the lantern for illustration upon the screen.

The dynamometer coupling was then described and illustrated, after which a diagram giving a complete table of the results of several trials of the experimental engine was shown, and copies were distributed amongst members of the Section.[1] The various conditions of the trials were as follows:—

Triple unjacketed condensing.
Triple jacketed condensing.
Compound unjacketed condensing. (I. and II.)
Compound jacketed condensing. (I. and II.)
Compound unjacketed condensing. (II. and III.)
Compound unjacketed non-condensing. (II. and III.)
Single unjacketed condensing. (II.)
Single jacketed condensing. (II.).

These tables showed at a glance the method adopted for tabulating the results of the trials which had been carried out by the senior lecturer, Mr. Dunkerley.

The hydraulic tank and sump was next alluded to, and the new form of valves for rapidly operating with the jet under pressure was mentioned; a brief description of the other laboratory apparatus illustrated on the diagrams then concluded the paper.

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4. *Development of the Art of Printing in Colours.* *By* T. Cond.

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5. *Expanded Metal.* *By* H. B. Tarry.

WEDNESDAY, SEPTEMBER 23.

The following Papers were read:—

1. *Wreck Raising.* *By* J. Bell.

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2. *Horseless Road Locomotion.* *By* A. R. Sennett.

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[1] Since published in *Engineering*, October 9, 1896.

SECTION H.—ANTHROPOLOGY.

PRESIDENT OF THE SECTION.—ARTHUR J. EVANS, M.A., F.S.A.

THURSDAY, SEPTEMBER 17.

The PRESIDENT delivered the following Address:—

'*The Eastern Question*' *in Anthropology.*

TRAVELLERS have ceased to seek for the 'Terrestrial Paradise,' but, in a broader sense, the area in which lay the cradle of civilised mankind is becoming generally recognised. The plateaux of Central Asia have receded from our view. Anthropological researches may be said to have established the fact that the White Race, in the widest acceptation of the term, including, that is, the darker-complexioned section of the South and West, is the true product of the region in which the earliest historic records find it concentrated. Its 'Area of Characterisation' is conterminous, in fact, with certain vast physical barriers due to the distribution of sea and land in the latest geological period. The continent in which it rose, shut in between the Atlantic and the Indian Oceans, between the Libyan Desert, and what is now Sahara, and an icier Baltic stretching its vast arms to the Ponto-Caspian basin, embraced, together with a part of anterior Asia, the greater part of Europe, and the whole of Northern Africa. The Mediterranean itself—divided into smaller separate basins, with land bridges at the Straits of Gibraltar, and from Sicily and Malta to Tunis—did not seriously break the continuity of the whole. The English Channel, as we know, did not exist, and the old sea-coast of what are now the British Islands, stretching far to the west, is, as Professor Boyd Dawkins has shown, approximately represented by the hundred-fathom line. To this great continent Dr. Brinton, who has so ably illustrated the predominant part played by it in isolating the white from the African black and the yellow races of mankind, has proposed to give the useful and appropriate name of 'Eurafrica.' In 'Eurafrica,' in its widest sense, we find the birthplace of the highest civilisations that the world has yet produced, and the mother country of its dominant peoples.

It is true that later geological changes have made this continental division no longer applicable. The vast land area has been opened to the east, as if to invite the Mongolian nomads of the Steppes and Tundras to mingle with the European population; the Mediterranean bridges, on the other hand, have been swept away. Asia has advanced, Africa has receded. Yet the old underlying connexion of the peoples to the north and south of the Mediterranean basin seems never to have been entirely broken. Their inter-relations affect many of the most interesting phenomena of archæology and ancient history, and the old geographical unity of 'Eurafrica' was throughout a great extent of its area revived in the great political system which still forms the basis of civilised society, the Roman Empire. The Mediterranean was a Roman lake. A single fact brings home to us the extent to which the earlier continuity of Europe and North Africa asserted itself in the imperial economy. At one time, what is now Morocco and what is now Northumberland, with all that lay between them on both sides of the Pyrenees, found their administrative centre on the Mosel.

It is not for me to dwell on the many important questions affecting the physiological sides of ethnography that are bound up with these old geographical relations. I will, however, at least call attention to the interesting, and in many ways original, theory put forward by Professor Sergi in his recent work on the 'Mediterranean Race.'

Professor Sergi is not content with the ordinary use of the term 'White Race.' He distinguishes a distinct 'brown' or 'brunette' branch, whose swarthier complexion, however, and dark hair bear no negroid affinities, and are not due to any intermixture on that side. This race, with dolichocephalic skulls, amongst which certain clearly defined types constantly repeat themselves, he traces throughout the Mediterranean basin, from Egypt, Syria, and Asia Minor, through a large part of Southern Europe, including Greece, Italy, and the Iberic peninsula, to the British islands. It is distributed along the whole of North Africa, and, according to the theory propounded, finds its original centre of diffusion somewhere in the parts of Somaliland.

It may be said at once that this grouping together into a consistent system of ethnic factors spread over this vast yet inter-related area—the heart of 'Eurafrica'—presents many attractive aspects. The ancient Greek might not have accepted kinship even with 'the blameless Ethiopian,' but those of us who may happen to combine a British origin with a Mediterranean complexion may derive a certain ancestral pride from remote consanguinity with Pharaoh. They may even be willing to admit that 'the Ethiopian' in the course of his migrations has done much to 'change his skin.'

In part, at least, the new theory is little more than a re-statement of an ethnographic grouping that commands a general consensus of opinion. From Thurnam's time onwards we have been accustomed to regard the dolichocephalic type found in the early Long Barrows, and what seem to have been the later survivals of the same stock in our islands, as fitting on to the Iberian element in South-western Europe. The extensive new materials accumulated by Dr. Garson have only served to corroborate these views, while further researches have shown that the characteristic features of the skeletons found in the Ligurian caves, at Cro Magnon and elsewhere in France, are common to those of a large part of Italy, Sicily, and Sardinia, and extend not only to the Iberic group, but to the Guanche interments of the Canary Islands.

The newly correlated data unquestionably extend the field of comparison; but the theories as to the original home of this 'Mediterranean race' and the course of its diffusion may be thought to be still somewhat lacking in documentary evidence. They remind us rather too closely of the old 'Aryan' hypothesis, in which we were almost instructed as to the halting places of the different detachments as they passed on their way from their Central Asian cradle to rearrange themselves with military precision, and exactly in the order of their relationship, in their distant European homes. The existing geological conditions are made the basis of this migratory expansion from Ethiopia to Ireland; parallel streams move through North Africa and from Anatolia to Southern Europe. One cardinal fact has certainly not received attention, and that is, that the existing evidence of this Mediterranean type dates much further back on European soil than even in ancient Egypt.

Professor Sergi himself has recognised the extraordinary continuity of the cranial type of the Ligurian caves among the modern population of that coast.

But this continuity involves an extreme antiquity for the settlement of the 'Mediterranean Race' in North-western Italy and Southern France. The cave interments, such as those of the Finalese, carry back the type well into Neolithic times. But the skeletons of the Baoussé Roussé caves, between Mentone and Ventimiglia, which reproduce the same characteristic forms, take us back far behind any stage of culture to which the name of Neolithic can be properly applied.

The importance of this series of interments is so unique, and the fulness of the evidence so far surpasses any other records immediately associated with the earliest remains of man, that even in this brief survey they seem to demand more than a passing notice.

So much, at least, must be admitted on all hands: an earlier stage of culture is exhibited in these deposits than that which has hitherto been regarded as the minimum equipment of the men of the later Stone Age. The complete absence of pottery, of polished implements, of domesticated animals—all the more striking from the absolute contrast presented by the rich Neolithic cave burials a little further up the same coast—how is it to be explained? The long flint knives, the bone and shell ornaments, might, indeed, find partial parallels among Neolithic remains; but does not, after all, the balance of comparison incline to that more ancient group belonging to the 'Reindeer Period' in the South of France, as illustrated by the caves of La Madeleine, Les Eyzies and Solutré?

It is true that, in an account of the interments found in 1892 in the Barma Grande Cave, given by me to the Anthropological Institute, I was myself so prepossessed by the still dominant doctrine that the usage of burial was unknown to Palæolithic man, and so overpowered by the vision of the yawning hiatus between him and his Neolithic successor, that I failed to realise the full import of the evidence. On that occasion I took refuge in the suggestion that we had here to deal with an earlier Neolithic stratum than any hitherto recorded. 'Neolithic,' that is, without the Neolithic.

But the accumulation of fresh data, and especially the critical observations of M. d'Acy and Professor Issel, have convinced me that this intermediate position is untenable. From the great depth below the original surface, of what in all cases seem to have been homogeneous quaternary deposits, at which the human remains were found, it is necessary to suppose, if the interments took place at a later period, that pits in many cases from 30 to 40 feet deep must have been excavated in the cave earth. But nothing of the kind has been detected, nor any intrusion of extraneous materials. On the other hand, the gnawed or defective condition of the extremities in several cases points clearly to superficial and imperfect interment of the body; and in one case parts of the same core from which flints found with the skeleton had been chipped were found some metres distant on the same floor level. Are we, then, to imagine that another pit was expressly dug to bury these?

In the case of a more recently discovered and as yet unpublished interment, at the excavation of which I was so fortunate as to assist, the superficial character of the deposit struck the eye. The skeleton, with flint knife and ochre near, decked out with the usual shell and deer's tooth ornaments, lay as if in the attitude of sleep, somewhat on the left side. The middle of the body was covered with a large flat stone, with two smaller ones lying by it, while another large stone was laid over the feet. The left arm was bent under the head as if to pillow it, but the extremities of the right arm and the toes were suggestively deficient: the surface covering of big stones had not sufficiently protected them. The stones themselves seem in turn to have served as a kind of hearth, for a stratum of charred and burned bones about 45 cm. thick lay about them.

Is it reasonable to suppose that a deposit of this kind took place at the bottom of a pit over 20 feet deep, left open an indefinite time for the convenience of roasting venison at the bottom?

A rational survey of the evidence in this as in the other cases leads to the conclusion that we have to deal with surface burial, or, if that word seems too strong, with simple 'seposition'—the imperfect covering with handy stones of the dead bodies as they lay in the attitude of sleep on the then floor of the cavern. In other words, they are *in situ* in a late quaternary deposit, for which Professor Issel has proposed the name of 'Meiolithic.'

But if this conclusion is to hold good, we have here on the northern coast of the Mediterranean evidence of the existence of a late Palæolithic race, the essential features of which, in the opinion of most competent osteological inquirers, reappear in the Neolithic skeletons of the same Ligurian coast, and still remain characteristic of the historical Ligurian type. In other words, the 'Mediterranean Race' finds its first record in the West; and its diffusion, so far from having necessarily followed the lines of later geographical divisions, may well have begun at a time when the land bridges of 'Eurafrica' were still unbroken.

There is nothing, indeed, in all this to exclude the hypothesis that the original expansion took place from the East African side. That the earliest homes of primæval man lay in a warm region can hardly be doubted, and the abundant discovery by Mr. Seton Karr in Somaliland of Palæolithic implements reproducing many of the most characteristic forms of those of the grottoes of the Dordogne affords a new link of connexion between the Red Sea and the Atlantic littoral.

When we recall the spontaneous artistic qualities of the ancient race which has left its records in the carvings on bone and ivory in the caves of the 'Reindeer Period,' this evidence of at least partial continuity on the northern shores of the Mediterranean suggests speculations of the deepest interest. Overlaid with new elements, swamped in the dull, though materially higher, Neolithic civilisation, may not the old æsthetic faculties which made Europe the earliest-known home of anything that can be called human art, as opposed to mere tools and mechanical contrivances, have finally emancipated themselves once more in the Southern regions, where the old stock most survived? In the extraordinary manifestations of artistic genius to which, at widely remote periods, and under the most diverse political conditions, the later populations of Greece and Italy have given birth, may we not be allowed to trace the re-emergence, as it were, after long underground meanderings, of streams whose upper waters had seen the daylight of that earlier world?

But the vast gulf of time beyond which it is necessary to carry back our gaze in order to establish such connexions will hardly permit us to arrive at more than vague probabilities. The practical problems that concern the later culture of Europe from Neolithic times onwards connect themselves rather with its relation to that of the older civilisations on the southern and eastern Mediterranean shores.

Anthropology, too, has its 'Eternal Eastern Question.' Till within quite recent years, the glamour of the Orient pervaded all inquiries as to the genesis of European civilisation. The Biblical training of the northern nations prepared the ground. The imperfect realisation of the antiquity of European arts; on the other hand, the imposing chronology of Egypt and Babylonia; the abiding force of classical tradition, which found in the Phœnician a *deus ex machinâ* for exotic importations; finally, the 'Aryan Hypothesis,' which brought in the dominant European races as immigrant wanderers from Central Asia, with a ready-made stock of culture in their wallets—these and other causes combined to create an exaggerated estimate of the part played by the East as the illuminator of the benighted West.

More recent investigations have resulted in a natural reaction. The primitive 'Aryan' can be no longer invoked as a kind of patriarchal missionary of Central Asian culture. From d'Halloy and Latham onwards to Penka and Schrader an array of eminent names has assigned to him an European origin. The means by which a kindred tongue diffused itself among the most heterogeneous ethnic factors still remain obscure; but the stricter application of phonetic laws and the increased detection of loan-words has cut down the original 'Aryan' stock of culture to very narrow limits, and entirely stripped the members of this linguistic family of any trace of a common Pantheon.

Whatever the character of the original 'Aryan' stage, we may be very sure that it lies far back in the mists of the European Stone Age. The supposed common names for metals prove to be either a vanishing quantity or strikingly irrelevant. It may be interesting to learn on unimpeachable authority that the Celtic words for 'gold' are due to comparatively recent borrowing from the Latin; but nothing is more certain than that gold was one of the earliest metals known to the Celtic races, its knowledge going back to the limits of the pure Stone Age. We are told that the Latin 'ensis,' 'a sword,' is identical with the Sanskrit 'asi' and Iranian 'ahi,' but the gradual evolution of the sword from the dagger, only completed at a late period of the Bronze Age, is a commonplace of prehistoric archæology. If 'ensis,' then, in historical times an iron sword, originally meant a bronze dagger, may not the bronze dagger in its turn resolve itself into a flint knife?

The truth is that the attempts to father on a common Aryan stock the beginnings of metallurgy argue an astonishing inability to realise the vast antiquity of languages and their groups. Yet we know that, as far back as we have any written records, the leading branches of the Aryan family of speech stood almost as far apart as they do to-day, and the example of the Egyptian and Semitic groups, which Maspero and others consider to have been originally connected, leads to still more striking results. From the earliest Egyptian stela to the latest Coptic liturgy we find the main outlines of what is substantially the same language preserved for a period of some six thousand years. The Semitic languages in their characteristic shape show a continuous history almost as extensive. For the date of the diverging point of the two groups we must have recourse to a chronology more familiar to the geologist than the antiquary.

As importer of exotic arts into primitive Europe the Phœnician has met the fate of the immigrants from the Central Asian 'Arya.' The days are gone past when it could be seriously maintained that the Phœnician merchant landed on the coast of Cornwall, or built the dolmens of the North and West. A truer view of primitive trade as passing on by inter-tribal barter has superseded the idea of a direct commerce between remote localities. The science of prehistoric archæology, following the lead of the Scandinavian School, has established the existence in every province of local centres of early metallurgy, and it is no longer believed that the implements and utensils of the European Bronze Age were imported wholesale by Semites or 'Etruscans.'

It is, however, the less necessary for me to trace in detail the course of this reaction against the exaggerated claims of Eastern influence that the case for the independent position of primitive Europe has been recently summed up with fresh arguments, and in his usual brilliant and incisive style, by M. Salomon Reinach, in his 'Mirage Orientale.' For many ancient prejudices as to the early relations of East and West it is the trumpet sound before the walls of Jericho. It may, indeed, be doubted whether, in the impetuousness of his attack, M. Reinach, though he has rapidly brought up his reserves in his more recent work on primitive European sculpture, has not been tempted to occupy outlying positions in the enemy's country which will hardly be found tenable in the long run. I cannot myself, for instance, be brought to believe that the rude marble 'idols' of the primitive Ægean population were copied on Chaldæan cylinders. I may have occasion to point out that the oriental elements in the typical higher cultures of primitive Europe, such as those of Mycenæ, of Hallstatt, and La Tène, are more deeply rooted than M. Reinach will admit. But the very considerable extent to which the early European civilisation was of independent evolution has been nowhere so skilfully focussed into light as in these comprehensive essays of M. Reinach. It is always a great gain to have the extreme European claims so clearly formulated, but we must still remember that the 'Sick Man' is not dead.

The proofs of a highly developed metallurgic industry of home growth accumulated by prehistoric students *pari passu* over the greater part of Europe, and the considerable cultural equipment of its early population—illustrated, for example, in the Swiss Lake settlements—had already prepared the way for the more startling revelations as to the prehistoric civilisation of the Ægean world which have resulted from Dr. Schliemann's diggings at Troy, Tiryns, and Mycenæ, so admirably followed up by Dr. Tsountas.

This later civilisation, to which the general name of 'Ægean' has been given, shows several stages, marked in succession by typical groups of finds, such as those from the Second City of Troy, from the cist-graves of Amorgos, from beneath the volcanic stratum of Thera, from the shaft-graves of Mycenæ, and again from the tombs of the lower town. Roughly, it falls into two divisions, for the earlier of which the culture illustrated by the remains of Amorgos may be taken as the culminating point, while the later is inseparably connected with the name of Mycenæ.

The early 'Ægean' culture rises in the midst of a vast province extending from

Switzerland and Northern Italy through the Danubian basin and the Balkan peninsula, and continued through a large part of Anatolia, till it finally reaches Cyprus. It should never be left out of sight that, so far as the earliest historical tradition and geographical nomenclature reach back, a great tract of Asia Minor is found in the occupation of men of European race, of whom the Phrygians and their kin—closely allied to the Thracians on the other side of the Bosphorus—stand forth as the leading representatives. On the other hand, the great antiquity of the Armenoid type in Lycia and other easterly parts of Asia Minor, and its priority to the Semites in these regions, has been demonstrated by the craniological researches of Dr. von Luschan. This ethnographic connexion with the European stock, the antiquity of which is carried back by Egyptian records to the second millennium before our era, is fully borne out by the archæological evidence. Very similar examples of ceramic manufactures recur over the whole of this vast region. The resemblances extend even to minutiæ of ornament, as is well shown by the examples compared by Dr. Much from the Mondsee, in Upper Austria, from the earliest stratum of Hissarlik, and from Cyprus. It is in the same Anatolo-Danubian area—as M. Reinach has well pointed out—that we find the original centre of diffusion of the 'Svastika' motive in the Old World. Copper implements, and weapons too, of primitive types, some reproducing Neolithic forms, are also a common characteristic, though it must always be remembered that the mere fact that an implement is of copper does not of itself necessitate its belonging to the earliest metal age, and that the freedom from alloy was often simply due to a temporary deficiency of tin. Cyprus, the land of copper, played, no doubt, a leading part in the dissemination of this early metallurgy, and certain typical pins and other objects found in the Alpine and Danubian regions have been traced back by Dr. Naue and others to Cypriote prototypes. The same parallelism throughout this vast area comes out again in the appearance of a class of primitive 'idols' of clay, marble, and other materials, extending from Cyprus to the Troad and the Ægean islands, and thence to the pile settlements of the Alps and the Danubian basin, while kindred forms can be traced beyond the Carpathians to a vast northern Neolithic province that stretches to the shores of Lake Ladoga.

It is from the centre of this old Anatolo-Danubian area of primitive culture, in which Asia Minor appears as a part of Europe, that the new Ægean civilisation rises from the sea. 'Life was stirring in the waters.' The notion that the maritime enterprise of the Eastern Mediterranean began on the exposed and comparatively harbourless coast of Syria and Palestine can no longer be maintained. The island world of the Ægean was the natural home of primitive navigation. The early sea-trade of the inhabitants gave them a start over their neighbours, and produced a higher form of culture, which was destined to react on that of a vast European zone—nay, even upon that of the older civilisations of Egypt and Asia.

The earlier stage of this Ægean culture culminates in what may conveniently be called the Period of Amorgos from the abundant tombs explored by Dr. Dümmler and others in that island. Here we already see the proofs of a widespread commerce. The ivory ornaments point to the South; the abundance of silver may even suggest an intercourse along the Libyan coast with the rich silver-producing region of South-eastern Spain, the very ancient exploitation of which has been so splendidly illustrated by the researches of the brothers Siret. Additional weight is lent to this presumption by the recurrence in these Spanish deposits of pots with rude indications of eyes and eyebrows, recalling Schliemann's owl-faced urns; of stone 'idols,' practically identical with those of Troy and the Ægean islands, here too associated with marble cups of the same simple forms; of triangular daggers of copper and bronze, and of bronze swords which seem to stand in a filial relation to an 'Amorgan' type of dagger. In a former communication to this Section I ventured to see in the so-called 'Cabiri' of Malta—very far removed from any Phœnician sculpture—an intermediate link between the Iberian group and that of the Ægean, and to trace on the fern-like ornaments of the altar-stone a comparison with the naturalistic motives of proto-Mycenæan art, as seen, for instance, on the early vases of Thera and Therasia.

A Chaldæan influence cannot certainly be excluded from this early Ægean art. It reveals itself, for instance, in indigenous imitations of Babylonian cylinders. My own conclusion that the small marble figures of the Ægean deposits, though of indigenous European lineage, were in their more developed types influenced by Istar models from the East, has since been independently arrived at by the Danish archæologist, Dr. Blinkenburg, in his study on præ-Mycenæan art.

More especially the returning-spiral decoration, which in the 'Amorgan Period' appears upon seals, rings, bowls, and caskets of steatite, leads us to a very interesting field of comparison. This motive, destined to play such an important part in the history of European ornament, is absent from the earlier products of the great Anatolo-Danubian province. As a European design it is first found on these insular fabrics, and it is important to observe that it first shows itself in the form of reliefs on stone. The generally accepted idea, put forward by Dr. Milchhöfer, that it originated here from applied spirals on metal work is thus seen to be bereft of historical justification. At a somewhat later date we find this spiraliform motive communicating itself to the ceramic products of the Danubian region, though from the bold relief in which it sometimes appears, a reminiscence of the earlier steatite reliefs seems still traceable. In the late Neolithic pile-station of Butmir, in Bosnia, this spiral decoration appears in great perfection on the pottery, and is here associated with clay images of very advanced fabric. At Lengyel, in Hungary, and elsewhere, we see it applied to primitive painted pottery. Finally, in the later Hungarian Bronze Age it is transferred to metal work.

But this connexion—every link of which can be made out—of the lower Danubian Bronze Age decoration with the Ægean spiral system—itself much earlier in origin—has a very important bearing on the history of ornament in the North and West. The close relation of the Bronze Age culture of Scandinavia and North-western Germany with that of Hungary is clearly established, and of the many valuable contributions made by Dr. Montelius to prehistoric archæology, none is more brilliant than his demonstration that this parallelism of culture between the North-west and South-east owes its origin to the most ancient course of the amber trade from the North Sea shores of Jutland by the valley of the Elbe and Moldau to the Danubian Basin. As Dr. Montelius has also shown, there was, besides, a western extension of this trade to our own islands. If Scandinavia and its borderlands were the source of amber, Ireland was the land of gold. The wealth of the precious metal there is illustrated by the fact that, even as late as 1796, the gold washings of County Wicklow amounted to 10,000*l*. A variety of evidence shows a direct connexion between Great Britain and Scandinavia from the end of the Stone Age onwards. Gold diadems of unquestionably British—probably Irish—fabric have been found in Seeland and Fünen, and from the analysis of early gold ornaments it clearly results that it was from Ireland rather than the Ural that Northern and Central Europe was supplied. Mr. Coffey, who has made an exhaustive study of the early Irish monuments, has recently illustrated this early connexion by other comparisons, notably the appearance of a design which he identifies with the early carvings of boats on the rocks of Scandinavia.

This prolongation of the Bronze Age trade route—already traced from the Middle Danube—from Scandinavia to Ireland, ought it to be regarded as the historic clue to the contemporary appearance of the spiral motive in the British Islands? Is it to this earlier intercourse with the land of the Vikings that we must ascribe the spiral scrolls on the slabs of the great chambered barrows of the Irish Bronze Age—best seen in the most imposing of them all, before the portal and on the inner chambers of New Grange?

The possibility of such a connexion must be admitted; the probability is great that the contemporary appearance of the spiraliform ornament in Ireland and on the Continent of Europe is due to direct derivation. It is, of course, conceivable that such a simple motive as the returning spiral may have originated independently in various parts of Europe, as it did originate in other parts of the world. But anthropology has ceased to content itself with the mere accumulation of sporadic coincidences. It has become a historic study. It is not sufficient to know how such and such phenomena *may* have originated, but how, as a matter of fact, they *did*. Hence in the investigation of origins and evolution the special value of the European field where the evidence has been more perfectly correlated and the continuous records go further back. An isolated example of the simple volute design belonging to the 'Reindeer Period' has been found in the grotto of Arudy. But the earliest cultural strata of Europe, from the beginning of the Neolithic period onwards, betray an entire absence of the returning spiral motive. When we find it later propagating itself as a definite ornamental system in a regular chronological succession throughout an otherwise inter-related European zone, we have every right to trace it to a common source.

But it does not therefore follow that the only alternative is to believe that the spiral decoration of the Irish monuments necessarily connects itself with the ancient stream of intercourse flowing from Scandinavia.

We have to remember that the Western lands of gold and tin were the goals of other prehistoric routes. Especially must we bear in mind the early evidence of intercourse between the British Isles and the old Iberic region of the opposite shores of the Continent. The derivation of certain forms of Bronze Age types in Britain and Ireland from this side has already been demonstrated by my father, and British or Irish bronze flat axes with their characteristic ornamentation have in their turn been found in Spain as well as in Denmark. The peculiar technique of certain Irish flint arrowheads of the same period, in which chipping and grinding are combined, is also characteristic of the Iberian province, and seems to lead to very extended comparisons on the Libyan side, recurring as it does in the exquisite handiwork of the non-Egyptian race whose relics Mr. Petrie has brought to light at Nagada. In prehistoric Spanish deposits, again, are found the actual wallet-like baskets with in-curving sides, the prototypes of a class of clay food-vessels which (together with a much wider distribution) are of specially frequent occurrence in the British Isles as well as the old Iberian area.

If the spiral decoration had been also a feature of the Scandinavian rock carvings, the argument for derivation from that side would have been strong. But they are not found in them, and, on the other hand, the sculptures on the dolmens of the Morbihan equally show certain features common to the Irish stone chambers, including the primitive ship figure. The spiral itself does not appear on these; but the more the common elements between the Megalithic piles, not only of the old Iberian tract on the mainland, including Brittany, but in the islands of the West Mediterranean basin, are realised, the more probable it becomes that the impulse came from this side. The prehistoric buildings of Malta, hitherto spoken of as 'Phœnician temples,' which show in their primitive conception a great affinity to the Megalithic chambers of the earliest British barrows, bear witness on this side to the extension of the Ægean spiral system in a somewhat advanced stage, and accompanied, as at New Grange, with intermediate lozenges. In Sardinia, as I hope to show, there is evidence of the former existence of monuments of Mycenæan architecture in which the chevron, the lozenge, and the spiral might have been seen associated as in Ireland. It is on this line, rather than on the Danube and the Elbe, that we find in a continuous zone that Cyclopean tradition of domed chambers which is equally illustrated at Mycenæ and at New Grange.

These are not more than indications, but they gain additional force from the converging evidence to which attention has already been called of an ancient line of intercourse, mainly, we may believe, connected with the tin trade between the East Mediterranean basin and the Iberian West. A further corroboration of the view that an Ægean impulse propagated itself as far as our own islands from that side is perhaps afforded by a very remarkable find in a British barrow.

I refer to the Bronze Age interment excavated by Canon Greenwell on Folkton Wold, in Yorkshire, in which, beside the body of a child, were found three carved chalk objects resembling round boxes with bossed lids. On one of these lids were grouped together, with a lozenge-shaped space between them, two partly spiraliform partly concentric circular ornaments, which exhibit before our eyes the degeneration of two pairs of returning spiral ornaments. Upon the sides of two of these chalk caskets, associated with chevrons, saltires, and lozenges, were rude indications of faces—eyes and nose of bird-like character—curiously recalling the early Ægean and Trojan types of Dr. Schliemann. These, as M. Reinach has pointed out, also find an almost exact parallel in the rude indications of the human face seen on the sculptured menhirs of the Marne and the Gard valleys. To this may be added the interesting comparisons supplied by certain clay vessels, of rounded form, somewhat resembling the chalk 'caskets' discovered by MM. Siret in Spanish interments of the early metal age, in which eyes and eyebrows of a primitive style are inserted, as on the British relics, in the inter-spaces of linear ornamentation. The third chalk disc exhibits, in place of the human face, a butterfly with volute antennæ, reminding us of the appearance of butterflies as a decorative motive on the gold roundels from the shaft-graves of Mycenæ, as also on early Mycenæan gems of steatite from Crete; in the latter case with the feelers curving outwards in the same way. The stellate design with central circles on the lid of one of the chalk caskets is itself not impossibly a distant degeneration of the star-flowers on the same Mycenæan plates. Putting all these separate elements of resemblance together—the returning spiral and star, the rude face and butterfly—the suggestion of Ægean reminiscence becomes strong, but the other parallels lead us for the line of its transmission towards the Iberian rather than the Scandinavian route.[1]

So much, at least, results from these various comparisons that, whether we find the spiral motive in the extreme West or North of Europe, everything points to the Ægean world as its first European centre. But have we any right to regard it, even there, as of indigenous evolution?

It had been long my own conviction that the Ægean spiral system must itself be regarded as an offshoot of that of ancient Egypt, which as a decorative motive on scarabs goes back, as Professor Petrie has shown, to the Fourth Dynasty. During the time of the Twelfth Dynasty, which, on general grounds, may be supposed roughly to correspond with the 'Amorgan Period' of Ægean culture, it attained its apogee. The spiral convolutions now often cover the whole field of the scarab, and the motive begins to spread to a class of black bucchero vases the chalk inlaying of whose ornaments suggests widespread European analogies. But the important feature to observe is that here, as in the case of the early Ægean examples, the original material on which the spiral ornament appears is stone, and that, so far from being derived from an advanced type of metal work, it goes back in Egypt to a time when metal was hardly known.

The prevalence of the spiral ornamentation on stone work in the Ægean islands and contemporary Egypt, was it merely to be regarded as a coincidence? To turn one's eyes to the Nile Valley, was it simply another instance of the '*Mirage Orientale*'? For my own part, I ventured to believe that, as in the case of Northern Europe, the spread of this system was connected with many collateral symptoms of commercial inter-connexion, so here, too, the appearance of this early Ægean ornament would be found to lead to the demonstration of a direct intercourse between the Greek islands and Egypt at least a thousand years earlier than any that had hitherto been allowed.

One's thoughts naturally turned to Crete, the central island, with one face on the Libyan Sea—the natural source and seminary of Ægean culture—where fresh light was already being thrown on the Mycenæan civilisation by the researches of Professor Halbherr, but the earlier prehistoric remains of which were still unexplored. Nor were these expectations unfounded. As the result of three expeditions—undertaken in three successive years, from the last of which I returned three months since—it has been my fortune to collect a series of evidences of a very early and intimate contact with Egypt, going back at least to the Twelfth

[1] A further piece of evidence pointing in this direction is supplied by one of the chalk 'caskets.' On the upper disc of this, in the place corresponding with the double-spirals on the other example, appears a degeneration of the same motive in a more compressed form, resembling two sets of concentric horseshoes united at their bases. This recurs at New Grange, and single sets of concentric horseshoes, or semicircles, are found both there and at Gavrinnis. The degeneration of the returning spiral motive extends therefore to Brittany.

Dynasty, and to the earlier half of the third millennium before our era. It is not only that in primitive deposits, like that of Hagios Onuphrios, scarabs, acknowledged by competent archæologists to be of Twelfth Dynasty date, occurred in association with steatite seals presenting the Ægean spiral ornamentation, and with early pottery answering to that of Amorgos and the second city of Troy. This by itself might be regarded by many as convincing. But,—what from the point of view of intercourse and chronology is even more important,—in the same deposit and elsewhere occurred early button-shaped and triangular seals of steatite with undoubted indigenous copies of Egyptian lotos designs characteristic of the same period, while in the case of the three-sided bead-seals it was possible to trace a regular evolution leading down to Mycenæan times. Nor was this all. Throughout the whole of the island there came to light a great variety of primitive stone vases, mostly of steatite, a large proportion of which reproduced the characteristic forms of Egyptian stone vases, in harder materials, going far back into the Ancient Empire. The returning spiral motive is also associated with these, as may be seen from a specimen now in the collection of Dr. Naue, of Munich.

A geological phenomenon which I was able to ascertain in the course of my recent exploration of the eastern part of the island goes far to explain the great importance which these steatite or 'soapstone' fabrics played in the primitive culture of Crete and the Ægean islands. In the valley of the Sarakina stream I came upon vast deposits of this material, the diffusion of which could be further traced along a considerable tract of the southern coast. The abundant presence of this attractive and, at the same time, easily workable stone—then incomparably more valuable, owing to the imperfection of the potter's art—goes far to explain the extent to which these ancient Egyptian forms were imitated, and the consequent spread of the returning spiral motive throughout the Ægean.

In the matter of the spiral motive, Crete may thus be said to be the missing link between prehistoric Ireland and Scandinavia and the Egypt of the Ancient Empire. But the early remains of the island illustrate in many other ways the comparatively high level of culture already reached by the Ægean population in præ-Mycenæan times. Especially are they valuable in supplying the antecedent stages to many characteristic elements of the succeeding Mycenæan civilisation.

This ancestral relationship is nowhere more clearly traceable than in a class of relics which bear out the ancient claim of the islanders that they themselves had invented a system of writing to which the Phœnicians did not do more than add the finishing touches. Already, at the Oxford meeting of the Association, I was able to call attention to the evidence of the existence of a prehistoric Cretan script evolved by gradual simplification and selection from an earlier picture writing. This earlier stage is, roughly speaking, illustrated by a series of primitive seals belonging to the 'Period of Amorgos.' In the succeeding Mycenæan age the script is more conventionalised, often linear, and though developments of the earlier forms of seals are frequently found, they are usually of harder materials, and the system is applied to other objects. As the result of my most recent investigations, I am now able to announce the discovery of an inscribed prehistoric relic, which surpasses in interest and importance all hitherto known objects of this class. It consists of a fragment of what may be described as a steatite 'Table of Offerings,' bearing part of what appears to be a dedication of nine letters of probably syllabic values, answering to the same early Cretan script that is seen on the seals, and with two punctuations. It was obtained from the lowest level of a Mycenæan stratum, containing numerous votive objects, in the great cave of Mount Dikta, which, according to the Greek legend, was the birthplace of Zeus.

This early Cretan script, which precedes by centuries the most ancient records of Phœnician writing, and supplies, at any rate, very close analogies to what may be supposed to have been the pictorial prototypes of several of the Phœnician letters, stands in a direct relation to the syllabic characters used at a later date by the Greeks of Cyprus. The great step in the history of writing implied by the evolution of symbols of phonetic value from primitive pictographs is thus shown to have effected itself on European soil.

In many other ways the culture of Mycenæ—that extraordinary revelation from the soil of prehistoric Greece—can be shown to be rooted in this earlier Ægean stratum. The spiral system, still seen in much of its pure original form on the gold vessels and ornaments from the earlier shaft-graves of Mycenæ, is simply the translation into metal of the pre-existing steatite decoration.[1]

The Mycenæan repoussé work in its most developed stage as applied to human and animal subjects has probably the same origin in stone work. Cretan examples, indeed, give the actual transition in which an intaglio in dark steatite is coated with a thin gold plate impressed into the design. On the other hand, the noblest of all creations of the Mycenæan goldsmith's art, the Vaphio cups, with their bold reliefs, illustrating the hunting and capture of wild bulls, find their nearest analogy in a fragment of a cup, procured by me from Knôsos, of black Cretan steatite, with naturalistic reliefs, exhibiting a fig-tree in a sacred enclosure, an altar, and men in high action, which in all probability was originally coated, like the intaglio, with thin plates of gold.

In view of some still prevalent theories as to the origin of Mycenæan art, it is important to bear in mind these analogies and connexions, which show how deeply set its roots are in Ægean soil. The Vaphio cups, especially, from their superior art, have been widely regarded as of exotic fabric. That the art of an European population in prehistoric times should have risen above that of contemporary Egypt and Babylonia was something beyond the comprehension of the traditional school These most characteristic products of indigenous skill, with their spirited representations of a sport the traditional home of which in later times was the Thessalian plains, have been, therefore, brought from 'Northern Syria'! Yet a whole series of Mycenæan gems exists executed in the same bold naturalistic style, and of local materials, such as lapis Lacedæmonius, the subjects of which are drawn from the same artistic cycle as those of the cups, and not one of these has as yet been found on the Eastern Mediterranean shores. Like the other kindred intaglios, they all come from the Peloponnese, from Crete, from the shores and islands of the Ægean, from the area, that is, where their materials were procured. Their lentoid and almond-shaped forms are altogether foreign to Semitic usage, which clung to the cylinder and cone. The finer products of the Mycenæan glyptic art on harder materials were, in fact, the outcome of long apprentice studies of the earlier Ægean population, of which we have now the record in the primitive Cretan seals, and the explanation in the vast beds of such an easily worked material as steatite.

But the importation of the most characteristic Mycenæan products from 'Northern Syria' has become quite a moderate proposition beside that which we have now before us. In a recent communication to the French Academy of Inscriptions, Dr. Helbig has re-introduced to us a more familiar figure. Driven from his prehistoric haunts on the Atlantic coasts, torn from the Cassiterides, dislodged even from his Thucididean plantations in pre-Hellenic Sicily, the Phœnician has returned, tricked out as the true 'Mycenæan.'

A great part of Dr. Helbig's argument has been answered by anticipation. Regardless of the existence of a regular succession of intermediate glyptic types, such as the 'Melian' gems and the engraved seals of the geometrical deposits of the Greek mainland, like those of Olympia and of the Heræon at Argos, which link the Mycenæan with the classical series, Dr. Helbig takes a verse of Homer to hang from it a theory that seals and engraved stones were unknown to the early Greeks. On this imaginary fact he builds the astounding statement that the engraved gems and seals found with Mycenæan remains must be of foreign and, as he believes, Phœnician importation. The stray diffusion of one or two examples of Mycenæan pots to the coast of Palestine, the partial resemblance of some Hittite bronze figures, executed in a more barbarous Syrian style, to specimens of quite different fabric found at Tiryns, Mycenæ, and, it may be added, in a Cretan cave near Sybrita, the wholly unwarranted attribution to Phœnicia of a bronze vase-handle found in Cyprus, exhibiting the typical lion-headed demons of the Mycenæans—these are only a few salient examples of the

[1] See *Hellenic Journal*, xii. 1892, p. 221.

reasoning by which the whole prehistoric civilisation of the Greek world, so instinct with naturalism and individuality, is handed over to the least original member of the Semitic race. The absence in historic Greece of such arts as that of *intarsia* in metal work, of glass-making (if true) and of porcelain-making, is used as a conclusive argument against their practice by an Ægean population, of uncertain stock, a thousand years earlier, as if in the intervening dark ages between the primitive civilisation of the Greek lands and the Classical Renaissance no arts could have been lost!

Finally, the merchants of Keftô depicted on the Egyptian monuments are once more claimed as Phœnicians, and with them—though this is by no means a necessary conclusion, even from the premise—the precious gifts they bear, including vases of characteristic Mycenæan form and ornament. All this is diametrically opposed to the conclusions of the most careful inquirer into the origins of this mysterious people, Dr. W. Max Müller (to be distinguished from the eminent Professor), who shows that the list of countries in which Keftô occurs places them beyond the limit of Phœnicia or of any Semitic country, and connects them rather with Cilicia and with Cyprus, the scene, as we now know, of important Mycenæan plantations. It is certain that not only do the Keftiu traders bear articles of Mycenæan fabric, but their costume, which is wholly un-Semitic, their leggings and sandals, and the long double locks of hair streaming down below their armpits, identify them with the men of the frescoes of Mycenæ, and of the Vaphio and Knôsian cups.

The truth is that these Syrian and Phœnician theories are largely to be traced to the inability to understand the extent to which the primitive inhabitants of the Ægean shores had been able to assimilate exotic arts without losing their own individuality. The precocious offspring of our Continent, first come to man's estate in the Ægean island world, had acquired cosmopolitan tastes, and already stretched forth his hands to pluck the fruit of knowledge from Oriental boughs. He had adopted foreign fashions of dress and ornament. His artists revelled in lion-hunts and palm-trees. His very worship was infected by the creations of foreign religions.

The great extent to which the Mycenæans had assimilated exotic arts and ideas can only be understood when it is realised that this adaptive process had begun at least a thousand years before, in the earlier period of Ægean culture. New impulses from Egypt and Chaldæa now succeed the old. The connexion with Eighteenth and Nineteenth Dynasty Egypt was of so intimate a kind that it can only be explained by actual settlement from the Ægean side. The abundant relics of Ægean ceramic manufactures found by Professor Petrie on Egyptian sites fully bear out this presumption. The early marks on potsherds discovered by that explorer seem to carry the connexion back to the earlier Ægean period, but the painted pottery belongs to what may broadly be described as Mycenæan times. The earliest relics of this kind found in the rubbish heaps of Kahun, though it can hardly be admitted that they go quite so far back as the Twelfth Dynasty date assigned to them by Mr. Petrie (c. 2500 B.C.), yet correspond with the earliest Mycenæan classes found at Thera and Tiryns, and seem to find their nearest parallels in pottery of the same character from the cave of Kamares on the northern steep of the Cretan Ida, recently described by Mr. J. L. Myres and by Dr. Lucio Mariani. Vases of the more typical Mycenæan class have been found by Mr. Petrie in a series of deposits dated, from the associated Egyptian relics, from the reign of Thothmes III. onwards (1450 B.C.). There is nothing Phœnician about these—with their seaweeds and marine creatures they are the true products of the island world of Greece. The counterpart to these Mycenæan imports in Egypt is seen in the purely Egyptian designs which now invade the northern shores of the Ægean, such as the ceiling of the sepulchral chamber at Orchomenos, or the wall-paintings of the palace at Tiryns—almost exact copies of the ceilings of the Theban tombs—designs distinguished by the later Egyptian combination of the spiral and plant ornament which at this period supersedes the pure returning spiral of the earlier dynasties. The same contemporary evidence of date is seen in the scarabs and porcelain fragments with the cartouches of Queen Tyi and Amenhotep III., found in the Mycenæan deposits. But more than a mere commercial connexion between the Ægean seat of Mycenæan culture and Egypt seems to be indicated by some of the inlaid daggers from the Acropolis tombs. The subject of that representing the ichneumons hunting ducks amidst the lotos thickets beside a stream that can only be the Nile, as much as the intarsia technique, is so purely of Egypt that it can only have been executed by a Mycenæan artificer resident within its borders. The whole cycle of Egyptian Nile-pieces thoroughly penetrated Mycenæan art,—the duck-catcher in his Nile-boat, the water-fowl and butterflies among the river plants, the spotted cows and calves, supplied fertile motives for the Mycenæan goldsmiths and ceramic artists. The griffins of Mycenæ reproduce an elegant creation of the New Empire, in which an influence from the Asiatic side is also traceable.

The assimilation of Babylonian elements was equally extensive. It, too, as we have seen, had begun in the earlier Ægean period, and the religious influence from the Semitic side, of which traces are already seen in the assimilation of the more primitive 'idols' to Eastern models, now forms a singular blend with the Egyptian, as regards, at least, the externals of cult. We see priests, in long folding robes of Asiatic cut, leading griffins, offering doves, holding axes of a type of Egyptian derivation which seems to have been common to the Syrian coast, the Hittite regions of Anatolia, and Mycenæan Greece. Female votaries in flounced Babylonian dresses stand before seated Goddesses, rays suggesting those of Shamas shoot from a Sun-God's shoulders, conjoined figures of moon and star recall the symbols of Sin and Istar, and the worship of a divine pair of male and female divinities is widely traceable, reproducing the relations of a Semitic Bel and Beltis. The cylinder subjects of Chaldæan art continually assert themselves: A Mycenæan hero steps into the place of Gilgames or Eabani, and renews their struggles with wild beasts and demons in the same conventional attitudes, of which Christian art has preserved a reminiscence in its early type of Daniel in the lions' den. The peculiar schemes resulting from, or, at least, brought into continual prominence by the special conditions of cylinder engraving, with the constant tendency to which it is liable of the two ends of the design to overlap, deeply influenced the glyptic style of Mycenæ. Here, too, we see the same animals with crossed bodies, with two bodies and a single head, or simply confronted. These latter affiliations to Babylonian prototypes have a very important bearing on many later offshoots of European culture. The tradition of these heraldic groups preserved by the later Mycenæan art, and communicated by it to the so-called 'Oriental' style of Greece, finds in another direction its unbroken continuity in ornamental products of the Hallstatt province, and that of the late Celtic metal workers.

'But this,' exclaims a friendly critic, 'is the old heresy—the "*Mirage Orientale*" over again. Such heraldic combinations have originated independently elsewhere:—why may they not be of indigenous origin in primitive Europe?'

They certainly may be. Confronted figures occur already in the Dordogne caves. But, in a variety of instances, the historic and geographical connexion of these types with the Mycenæan, and those in turn with the Oriental, is clearly made out. That system which leaves the least call on human efforts at inventiveness seems in anthropology to be the safest.

Let us then fully acknowledge the indebtedness of early Ægean culture to the older civilisations of the East. But this indebtedness must not be allowed to obscure the fact that what was borrowed was also assimilated. On the easternmost coast of the Mediterranean, as in Egypt, it is not in a pauper's guise that the Mycenæan element makes its appearance. It is rather the invasion of a conquering and superior culture. It has already outstripped its instructors. In Cyprus, which had lagged behind the Ægean peoples in the race of progress, the Mycenæan relics make their appearance as imported objects of far superior fabric, side by side with the rude insular products. The final engrafting on Cypriote soil of what may be called a colonial plantation of Mycenæ later reacts on Assyrian art, and justifies the bold theory of Professor Brunn that the sculptures of Nineveh betray Greek handiwork. The concordant Hebrew tradition that the Philistines were immigrants from the Islands of the Sea, the name 'Cherethim,' or Cretans, actually applied to them, and the religious ties which attached 'Minoan' Gaza to the cult of the Cretan Zeus, are so many indications that the Ægean settlements, which in all probability existed in the Delta, extended to the neighbouring coast of Canaan, and that amongst other towns the great staple of the Red Sea trade had passed into the hands of these prehistoric Vikings. The influence of the Mycenæans on the later Phœnicians is abundantly illustrated in their eclectic art. The Cretan evidence tends to show that even the origins of their alphabet receive illustration from the earlier Ægean pictography. It is not the Mycenæans who are Phœnicians. It is the Phœnicians who, in many respects, acted as the depositaries of decadent Mycenæan art.

If there is one thing more characteristic than another of Phœnician art, it is its borrowed nature, and its incongruous collocation of foreign elements. Dr. Helbig himself admits that if Mycenæan art is to be regarded as the older Phœnician, the Phœnician historically known to us must have changed his nature. What the Mycenæans took they made their own. They borrowed from the designs of Babylonian cylinders, but they adapted them to gems and seals of their own fashion, and rejected the cylinders themselves. The influence of Oriental religious types is traceable on their signet rings, but the liveliness of treatment and the dramatic action introduced into the groups separate them, *toto cœlo*, from the conventional schematism of Babylonian cult-scenes. The older element, the sacred trees and pillars which appear as the background of these scenes—on this I hope to say more later on in this Section—there is no reason to regard here as Semitic. It belongs to a religious stage widely represented on primitive European soil, and nowhere more persistent than in the West.

Mycenæan culture was permeated by Oriental elements, but never subdued by them. This independent quality would alone be sufficient to fix its original birthplace in an area removed from immediate contiguity with that of the older civilisations of Egypt and Babylonia. The Ægean island world answers admirably to the conditions of the case. It is near, yet sufficiently removed, combining maritime access with insular security. We see the difference if we compare the civilisation of the Hittites of Anatolia and Northern Syria, in some respects so closely parallel with that of Mycenæ. The native elements were there cramped and trammelled from the beginning by the Oriental contact. No real life and freedom of expression was ever reached; the art is stiff, conventional, becoming more and more Asiatic, till finally crushed out by Assyrian conquest. It is the same with the Phœnicians. But in prehistoric Greece the indigenous element was able to hold its own, and to recast what it took from others in an original mould. Throughout its handiwork there breathes the European spirit of individuality and freedom. Professor Petrie's discoveries at Tell-el-Amarna show the contact of this Ægean element for a moment infusing naturalism and life into the time-honoured conventionalities of Egypt itself.

A variety of evidence, moreover, tends to show that during the Mycenæan period the earlier Ægean stock was reinforced by new race elements coming from north and west. The appearance of the primitive fiddle-bow-shaped *fibula* or safety-pin brings Mycenæan Greece into a suggestive relation with the Danube Valley and the Terremare of Northern Italy. Certain ceramic forms show the same affinities; and it may be noted that the peculiar 'two-storied' structure of the 'Villanova' type of urn which characterises the earliest Iron Age deposits of Italy finds already a close counterpart in a vessel from an Akropolis grave at Mycenæ—a parallelism which may point to a common Illyrian source. The painted pottery of the Mycenæans itself, with its polychrome designs, betrays Northern and Western affinities of a very early character, though the glaze and exquisite technique were doubtless elaborated in the Ægean shores. Examples of spiraliform painted designs on pottery going back to the borders of the Neolithic period have been found in Hungary and Bosnia. In the early rock-tombs of Sicily of the period anterior to that marked by imported products of the fully developed Mycenæan culture are found unglazed painted wares of considerable brilliancy, and allied classes recur in the heel of Italy and in the cave deposits of Liguria of the period transitional between the use of stone and metal. The 'household gods,' if so we may call them, of the Mycenæans also break away from the tradition of the marble Ægean forms. We recognise the coming to the fore again of primitive European clay types in a more advanced technique. Here, too, the range of comparison takes us to the same Northern and Western area. Here, too, in Sicily and Liguria, we see the primitive art of ceramic painting already applied to these at the close of the Stone Age. A rude female clay figure found in the Arene Candide cave near Finalmarina, the upper part of the body of which, armless and rounded, is painted with brown stripes on a pale rose ground, seems to me to stand in a closer relation to the prototype of a well-known Mycenæan class than any known example. A small painted image, with punctuated cross-bands over the breast, from a sepulchral grotto at Villafrati, near Palermo, belongs to the same early family as the *bucchero* types of Butmir, in Bosnia. Unquestionable parallels to the Mycenæan class have been found in early graves in Servia, of which an example copied by me some years since in the museum at Belgrade was found near the site of that later emporium of the Balkan trade, Viminacium, together with a cup attesting the survival of the primitive Ægean spirals. These extensive Italian and Illyrian comparisons, which find, perhaps, their converging point in the North-Western corner of the Balkan peninsula, show, at least approximately, the direction from which this new European impulse reached the Ægean shores.

It is an alluring supposition that this North-Western infusion may connect itself with the spread of the Greek race in the Ægean islands and the Southern part of the Balkan peninsula. There seems, at least, to be a reasonable presumption in favour of this view. The Mycenæan tradition, which underlies so much of the classical Greek art, is alone sufficient to show that a Greek element was at least included in the Mycenæan area of culture. Recent criticism has found in the Mycenæan remains the best parallel to much of the early arts and industries recorded by the Homeric poems. The *megaron* of the palaces at Tiryns and Mycenæ is the hall of Odysseus; the inlaid metal work of the shield of Achilles recalls the Egypto-Mycenæan intarsia of the dagger blades; the cup of Nestor with the feeding doves, the subjects of the ornamental design—the siege-piece, the lion-hunt, the hound with its quivering quarry—all find their parallels in the works of the Mycenæan goldsmiths. The brilliant researches of Dr. Reichel may be said to have resulted in the definite identification of the Homeric body-shield with the most typical Mycenæan form, and have found in the same source the true explanation of the greaves and other arms and accoutrements of the epic heroes.

That a Greek population shared in the civilisation of Mycenæ cannot reasonably be denied, but that is far from saying that this was necessarily the only element, or even the dominant element. Archæological comparisons, the evidence of geographical names and consistent tradition, tend to show that a kindred race, represented later by the Phrygians on the Anatolian side, the race of Pelops and Tantalos, the special votaries of Kybelê, played a leading part. In Crete a non-Hellenic element, the Eteocretes, or 'true Cretans,' the race of Minôs, whose name is bound up with the earliest sea-empire of the Ægean and perhaps identical with that of the Minyans of continental Greece, preserved their own language and nationality to the borders of the classical period. The Labyrinth itself, the double-headed axe as a symbol of the divinity called Zeus by the Greek settlers, the common forms in the characters of the indigenous script, local names and historical traditions, further connect these Mycenæan aborigines of Crete with the primitive population, it, too, of European extraction, in Caria and Pisidia, and with the older elements in Lycia.

It is difficult to exaggerate the part played in this widely ramifying Mycenæan culture on later European arts from prehistoric times onwards. Beyond the limits of its original seats, primitive Greece and its islands, and the colonial plantations thrown out by it to the west coast of Asia Minor to Cyprus, and in all probability to Egypt and the Syrian coast, we can trace the direct diffusion of Mycenæan products, notably the ceramic wares, across the Danube to Transylvania and Moldavia. In the early cemeteries of the Caucasus the fibulas and other objects indicate a late Mycenæan source, though they are here blended with allied elements of a more Danubian character. The Mycenæan impress is very strong in Southern

Italy, and, to take a single instance, the prevailing sword-type of that region is of Mycenæan origin. Along the western Adriatic coast the same influence is traceable to a very late date in the sepulchral stelæ of Pesaro and the tympanum relief of Bologna, and bronze knives of the prehistoric Greek type find their way into the later Terremare. At Orvieto and elsewhere have even been discovered Mycenæan lentoid gems. In Sicily the remarkable excavations of Professor Orsi have brought to light a whole series of Mycenæan relics in the beehive rock-tombs of the south-eastern coast, associated with the later class of Sikel fabrics.

Sardinia, whose name has with great probability been connected with the Shardanas, who, with the Libyan and Ægean races, appear as the early invaders of Egypt, has already produced a Mycenæan gold ornament. An unregarded fact points further to the probability that it formed an important outpost of Mycenæan culture. In 1853 General Lamarmora first printed a MS. account of Sardinian antiquities, written in the latter years of the fifteenth century by a certain Gilj, and accompanied by drawings made in 1497 by Johan Virde, of Sassari. Amongst these latter (which include, it must be said, some gross falsifications) is a capital and part of a shaft of a Mycenæan column in a style approaching that of the façade of the 'Treasury of Atreus.' It seems to have been found at a place near the Sardinian Olbia, and Virde has attached to it the almost prophetic description, '*columna Pelasgica.*' That it is not a fabrication due to some traveller from Greece is shown by a curious detail. Between the chevrons that adorn it are seen rows of eight-rayed stars, a detail unknown to the Mycenæan architectural decoration till it occurred on the painted base of the hearth in the *megaron* of the palace at Mycenæ excavated by the Greek Archæological Society in 1886. In this neglected record, then, we have an indication of the former existence in Sardinia of Mycenæan monuments, perhaps of palaces and royal tombs comparable to those of Mycenæ itself.

More isolated Mycenæan relics have been found still further afield, in Spain, and even the Auvergne, where Dr. Montelius has recognised an evidence of an old trade connexion between the Rhone valley and the Eastern Mediterranean, in the occurrence of two bronze double axes of Ægean form. It is impossible to do more than indicate the influence exercised by the Mycenæan arts on those of the early Iron Age. Here it may be enough to cite the late Mycenæan parallels afforded by the Ægina Treasure to the open-work groups of bird-holding figures and the pendant ornaments of a whole series of characteristic ornaments of the Italo-Hallstatt culture.

In this connexion, what may be called a sub-Mycenæan survival in the North-Western corner of the Balkan peninsula has a special interest for the Celtic West. Among the relics obtained by the fruitful excavations conducted by the Austrian archæologists in Bosnia and Herzegovina, and notably in the great prehistoric cemetery of Glasinatz, a whole series of Early Iron Age types betray distinct Mycenæan affinities. The spiral motive and its degeneration—the concentric circles grouped together with or without tangential lines of connexion—appear on bronze torques, on fibulæ of Mycenæan descent, and the typical finger-rings with the besil at right angles to the ring. On the plates of other 'spectacle fibulæ' are seen triquetral scrolls singularly recalling the gold plates of the Akropolis graves of Mycenæ. These, as well as other parallel survivals of the spiral system in the Late Bronze Age of the neighbouring Hungarian region, I have elsewhere [1] ventured to claim as the true source from which the Alpine Celts, together with many Italo-Illyric elements from the old Venetian province at the head of the Adriatic, drew the most salient features of their later style, known on the Continent as that of La Tène. These Mycenæan survivals and Illyrian forms engrafted on the 'Hallstatt' stock were ultimately spread by the conquering Belgic tribes to our own islands, to remain the root element of the Late Celtic style in Britain—where the older spiral system had long since died a natural death—and in Ireland to live on to supply the earliest decorative motives of its Christian art.

[1] Rhind Lectures, 1895, 'On the Origins of Celtic Art,' summaries of which appeared in the *Scotsman.*

From a Twelfth Dynasty scarab to the book of Durrow or the font of Deerhurst is a far cry. But, as it was said of old, 'Many things may happen in a long time.' We have not to deal with direct transmission *per saltum*, but with gradual propagation through intervening media. This brief survey of 'the Eastern Question in Anthropology' will not have been made in vain if it helps to call attention to the mighty part played by the early Ægean culture as the mediator between primitive Europe and the older civilisations of Egypt and Babylonia. Adequate recognition of the Eastern background of the European origins is not the 'Oriental Mirage.' The independent European element is not affected by its power of assimilation. In the great days of Mycenæ we see it already as the equal, in many ways the superior, of its teachers, victoriously reacting on the older countries from which it had acquired so much. I may perhaps be pardoned if in these remarks, availing myself of personal investigations, I have laid some stress on the part which Crete has played in this first emancipation of the European genius. There far earlier than elsewhere we can trace the vestiges of primæval intercourse with the valley of the Nile. There more clearly than in any other area we can watch the continuous development of the germs which gave birth to the higher Ægean culture. There before the days of Phœnician contact a system of writing had already been worked out which the Semite only carried one step further. To Crete the earliest Greek tradition looks back as the home of divinely inspired legislation and the first centre of maritime dominion.

Inhabited since the days of the first Greek settlements by the same race, speaking the same language, and moved by the same independent impulses, Crete stands forth again to-day as the champion of the European spirit against the yoke of Asia.

The following Report and Papers were read:—

1. *Report on the Mental and Physical Condition of Children.*
See Reports, p. 592.

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2. *Stone Implements in Somaliland. By* H. W. SETON-KARR.

The author exhibited at Ipswich ('Proc. Brit. Assoc.,' 1895, pp. 824–5) specimens of Palæolithic implements collected in Somaliland (1893–4–5), mostly broad-trimmed flakes of 'le Moustier' type. He has since (1895–6) revisited the country with the special object of collecting such implements, and secured many hundreds of them, ranging up to nine inches in length, during a journey of nineteen days, in about 8° N. latitude, and 1,000–2,000 feet above Red Sea level. They are sometimes eroded even to a depth of $\frac{1}{10}$ inch; the eroded areas have a chalcedonic appearance, and the chipping is only preserved on the raised patches.

These are the first Palæoliths from this part of tropical Africa. 'They seem to be scattered all over the country, and to have been washed out of sandy or loamy deposits by the action of rain, or in some instances to have been laid bare by the wind. Their great interest consists in the identity of their forms with those found in the Pleistocene deposits of W. Europe and elsewhere. . . . Under any circumstances this discovery aids in bridging over the interval between Palæolithic man in Britain and in India, and adds another link to the chain of evidence by which the original cradle of the human race may eventually be identified, and tends to prove the unity of race between the inhabitants of Asia, Africa, and Europe in prehistoric times.' (Sir John Evans, 'Communication to the Royal Society,' April 27, 1896.)

On the way home the author stayed some days on the Upper Nile, and found implements, perhaps Palæolithic, on the undisturbed surface of the Egyptian desert plateau.

The author calls attention to the fact that in the later Palæolithic age the glacial cold may have driven Palæolithic man towards the equator; and that although hitherto more Palæolithic implements have been found in well-searched temperate than in unexplored tropical regions, yet that under more favourable conditions more Palæolithic implements were found in Somaliland than in Egypt, and in Egypt than in Europe. He infers that Africa may have been the primeval home of man, and notes the fact that Somaliland is about midway between the sources of the Nile and the Persian Gulf, two sites which have been suggested for the 'Garden of Eden.'

[Cf. Besides the references given above:—
SETON-KARR, *Jour. Anthr. Inst.*, No. 94, p. 271, ff. Pl. xix.-xxi.; No. 96. p. 65 ff.
FLINDERS PETRIE, *Illahun*, p. 51. *Tell-el-Amarna*, p. 37 ; *Koptos* (forthcoming).
Archæological Journal, xlix. p. 49 (Egyptian Flints of the Fourth Dynasty), and p. 53 (Early Sickles in Egypt).
L'Anthropologie, vol. vi. No. 4.]

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3. *The Older Flint Implements of Ireland.* By W. J. KNOWLES, *M.R.I.A.*

Locality.—Large rudely made implements have been observed by the author in a raised beach of sand and gravel on the N.E. coast of Ireland. Good sections occur at the Curran near Larne, along the harbour railway, &c. Cores and implements occur at all depths to 16 ft. to 20 ft. in the gravel, and even in the estuarine clay, below sea level, at 28 ft. (in a shaft cut for the Belfast Naturalists' Field Club).[1] Similar implements are found in débris from this gravel on the shores of Belfast, Lough, Larne, and Island Magee.[2]

Weathering.—The implements have a thick deeply stained crust, and have undergone protracted weathering and rolling. This weathering results from atmospheric exposure; for flints from peat bogs and boulder clay retain their broken surfaces fresh. Successive layers of weathering seem to indicate *repeated* arrest of the process, *i.e.* repeated burial. Neolithic implements very rarely have any such weathered surface crust, and those actually found on this raised beach show no signs of it.

At Ballyrudder, seven miles north of Larne, a glacial gravel with shells, overlain by 30 ft. of boulder clay, yield flints fresh, slightly and deeply weather-stained.

At Whitepark Bay, co. Antrim, neolithic settlers have carried away, to sites among the sandhills, the weathered cores and flakes from the raised beach, and worked them up into fresh implements, which still show the older flaked surfaces. Their new surfaces, however, are still fresh.[3]

Similar old cores and flakes in a reworked condition have been found by the author at Portstewart, co. Derry; Dundrum, co. Down; Glenluce, Scotland; and elsewhere.

Forms.—Three types of implement found, besides flakes:—

1. Chipped all over; usually triangular in section, with a blunt point at each end.

2. Split pebbles (*a*) chipped to a point, (*b*) dressed to a circular shape as knives or scrapers.

3. Partially and irregularly dressed to a pear shape, with extreme economy of labour; but certainly intended, in the author's opinion, as striking weapons.

Age.—The raised beach has yielded a mammoth tooth; and as, according to Professor Boyd Dawkins,[4] it is highly probable the mammoth is preglacial in Ireland, the associated implements may be so too. Some bear striæ which have been pronounced to be glacial.

[1] Annual Report, 1889–90, p. 205. The Clubs' Committee call the objects found in the estuarine clay 'flint-chips,' bearing a considerable resemblance to flakes.
[2] *Proceedings Royal Irish Academy*, 2nd series, vol. ii., No. 5. *Polite Lit. and Antiq.* p. 209. 'Belfast Nat. Field Club Report,' 2nd series, vol. ii. p. 541.
[3] *Journal Royal Historical and Archæological Association*, vol. vii. pp. 124–125.
[4] *Early Man in Britain*, p. 152.

4. *The Dolmens of Brittany. By* Professor W. A. HERDMAN, *F.R.S., and* Professor W. BOYD DAWKINS, *F.R.S.*

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5. *The Sculptured Stones of Scotland. By* Miss C. MACLAGAN.

The following classes of sculptured stones were described in outline:—

1. '*Cup and Ring*' markings: engraved probably with stone tools in the later Stone Age on ice-worn and other rock surfaces; common in the Cheviot Hills; occasionally found inside *Brochs*; not confined to Scotland. The authoress believes that they were used for purposes of divination.

2. *Symbolic* or *Hieroglyphic* sculpture: worked with metal tools; peculiar to Scotland.

3. *Ogham* inscriptions: the earliest indigenous alphabetic script.

4. *Runic* inscriptions: the characters of which are modified from the Roman alphabet.

5. *Christian* monumental art: represented by the schools of *St. Ninian*, of *Iona*, of *Arbroath*, of *St. Andrews*, and of *Fearn Abbey*. In the *East* its rise is gradual; the stones are large, upright, carved on both sides, one of which has always a cruciform scheme. Ships are not represented, but riding, hunting, and frequently fighting with crossbows and spears. There are no inscriptions, but symbolic devices occur. In the *West* the sword is more frequent than the cross, and the latter is always small. Ships and short inscriptions are frequent, but symbols are absent.[1]

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6. *The 'Brochs' of Scotland (with Model). By* Miss C. MACLAGAN.

The '*Brochs*' are buildings of rough masonry, with a circular enclosure open to the sky, and sometimes surrounded by a portico about 8 feet from the ground. The height varies from 30 feet to 45 feet, and the diameter in proportion. The encircling wall, which is often built hollow, is from 9 feet to 20 feet thick. The entrance is by a doorway in the outer wall, closed by a massive doorstone never more than 2½ feet wide, and therefore not intended to admit long-horned cattle, as has been supposed. The door is secured by a stone bolt, and could not be opened or closed from without; therefore the *brochs* cannot be sepulchres. Secondary chambers in the thickness of the wall, reached by a spiral staircase similarly constructed, and opening by windows into the inner court, seem to indicate that the *brochs* were fortified dwellings. There is sometimes a doorkeeper's chamber below, and often a look-out opening in the top of the wall. These structures are often surrounded by a fortified enclosure of large stones set vertically, which have been mistaken for 'Druidic' circles.

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7. *Ancient Measures in Prehistoric Monuments.*[2] *By* A. L. LEWIS, *F.C.A., Treasurer, Anthropological Institute.*

The author, having analysed the measurements of the ruins in Mashonaland given by Messrs. Bent and Swan, and the indications of sun and star worship or observance contained in them, finds many instances of peculiarities of position and

[1] 300 sheets of rubbings, by Miss Maclagan, are in the MS. Department of the British Museum.

[2] Lewis, *Proc. Soc. Antiq.*, April 28, 1892; *Journ. Anthr. Inst.*, Aug. 1895; *Proc. Shropshire Archæol. Soc.*, 1892; *Journ. Roy. Inst. Cornwall*, 1896; *Nature*, June 9, 1892; W. M. Flinders Petrie, *Inductive Metrology*, London, 1877; J. T. Bent, *The Ruined Cities of Mashonaland*, London, 1893; R. W. M. Swan, *The Orientation and Mensuration of the Zimbabwe Temples* (in the last-named work); 'Some Notes on Ruined Temples in Mashonaland,' *Journ. Anthr. Inst.*, August 1896; C. W. Dymond, 'The Megalithic Antiquities of Stanton Drew,' 1896 (privately printed, cf. *Journ. Brit. Archæol. Assoc.*, xxxiii., 1877, pp. 297–307).

measurement in connection with British stone circles which he believes to be the same in principle and often in detail. The measurements of the circles at Stanton Drew by Mr. Dymond, and of those on Bodmin Moor by the author, show that there was in all the same fundamental idea of expressing something by proportioned measurements, although the unit of measurement and the manner of using it were different in each case. It may therefore be contended that, though the circles were sometimes used for burials, they were not, as some have suggested, merely the outer railings of family cemeteries, but had other objects and meanings, which it is worth some pains to discover.

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8. *Palæolithic Spear- and Arrow-heads.* *By* H. Stopes.

From the terrace gravels of the lower Thames Valley a large number of worked stones have been obtained. Of these some closely resemble in size and shape spear heads and arrow tips, and they also present signs of wear or use that indicate similar employment. The number exhibited was:—

	No.
1. Very small tips not exceeding $1\frac{1}{2}$ in. in length . .	110
2. Larger and thicker points not exceeding 2 ins. in length	150
3. Still larger and thicker points not exceeding $3\frac{1}{2}$ ins. in length	64
4. Very large points exceeding $3\frac{1}{8}$ ins. by $1\frac{3}{4}$ in. wide to $5\frac{5}{8}$ ins. by $2\frac{3}{4}$ ins.	28
	352

These represent two per cent. of the total number found, so their occurrence is not rare.

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9. *Palæoliths Derived and Re-worked.* *By* H. Stopes.

Great numbers of worked stones are being continually found in the terrace gravels of the Lower Thames Valley. The worked surfaces of the majority of these implements are of the same date as the latest deposition of the gravel, but a considerable number give unmistakable evidence that they have been derived from older gravels, so that their more recent fashioners and users have utilised stones which already had attained great antiquity. Some, nevertheless, still show that they had been skilfully fashioned into form, and had been largely used by man once, or, in rarer cases, twice before. Eighty such stones were exhibited, which is less than two per cent. of the number obtained from the gravels of the Kentish shore, all at or above the level of 70 feet above O.D. Commonly about one worked stone in seven found in this position gives signs of reworking, but the proportion of such stones is largest in the higher terraces.

FRIDAY, SEPTEMBER 18.

1. The Centenary of the Birth of A. Retzius was commemorated.

The following Papers and Report were read:—

2. *Physical Anthropology of the Isle of Man.* *By* A. W. Moore, *M.A.*, *and* John Beddoe, *M.D.*, *F.R.S.*

This Paper consists mainly of an analysis by Mr. Moore of the 'Description Book of the Royal Manx Fencibles,' in which are contained particulars of 1,112 native Manxmen, enrolled between 1803 and 1810. Their average stature was

5 feet 7·52 inches (1,715 mm.), which is probably about equal to that of the general population of the Isle of Man. It seems to be highest in the north-western parishes, where also dark hair and dark eyes are least prevalent. Dark hair, usually coupled with grey eyes, is most abundant in the somewhat rough and infertile parishes of Maughold and Lonan; while dark eyes are comparatively frequent in the central parishes, which contain the two towns of Douglas and Peel, where the Scandio-Gaelic stock is probably less pure.

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3. *The Trinil Femur* (Pithecanthropus erectus) *contrasted with the Femora of various Savage and Civilised Races. By* DAVID HEPBURN, *M.D., F.R.S. Ed., Lecturer on Regional Anatomy in the University of Edinburgh.*

In this paper the *Trinil femur* was criticised from the standpoint claimed for it by Dr. Dubois, namely, that it presents a conjunction of three features not found on human femora:

1. 'The trochanteric line is less raised.'
2. 'The shaft is on the inner side far more round.'
3. 'The popliteal space is less developed, convex in its middle, so that at this height the shaft is almost round instead of flattened.'

According to Dr. Dubois this last feature has never been found by him 'in human femora, even separately.'

Dealing especially with the popliteal space, the author presented the results of a detailed examination of the varied collection of human femora in the Anatomical Museum of the University of Edinburgh, in which he followed the methods of enquiry adopted by Professor Manouvrier, of Paris.

The femora examined in this research were: 13 Maori, 14 Aboriginal Australian, 12 Andamanese, 5 Sandwich Islands, 4 Lapp, 4 Eskimo, 6 Hindu, 2 Bengalee, 2 Sikh, 2 Malay, 2 Chinese, 2 Bushman, 2 Kaffir, 9 Negro, 2 Creole, 1 Egyptian, 3 Guanche, and several dozens of British femora obtained from the dissecting-room and used for the ordinary purposes of anatomical teaching.

As the majority of these race femora formed natural pairs, attention was drawn to the absence of symmetry existing between the two femora of the same individual.

Reference was made to the signification of the antero-posterior diameters of the popliteal region which Professor Manouvrier has symbolised as 'mn' and 'mp,' and attention drawn to the fact that 'mp' > 'mn' implies either flattening or convexity of this surface, which in modern European femora tends to show concavity, and therefore 'mp' < 'mn.'

The author has found 'mp' > 'mn' in the following femora: Lapp 1, Eskimo 1, Maori 1, Hindu 2, Negro 3, Bushman 2, Andaman 5, Aboriginal Australian 4, Guanche 2, British 4.

Measurements and *indices* of these femora were given and their significance commented upon, in the course of which the factors concerned in producing a high *popliteal index* were criticised and their fallacies pointed out.

In an Australian femur from Swan Hill, N.S.W., the same popliteal measurements and *index* as given for the Trinil femur were obtained.

The differences in the popliteal indices of the two femora forming a natural pair were given and commented upon, in order to show that the appearances found in one bone form no certain guide to the state of its fellow.

The author therefore claims convexity of the popliteal surface of the femur as a human character, and, moreover, he has seen the condition of the anterior intertrochanteric line, and the convexity of the inner aspect of the femoral shaft conjoined on one bone, as in the Trinil femur, *e.g.* in Australian and Negro femora.

In endeavouring to explain the causes of convexity of the popliteal surface the author divided them into normal and pathological groups.

In the former he referred to mechanical needs for resisting strain, and to the special features resulting from muscular and aponeurotic attachments.

The pathological causation of convexity of the popliteal surface being admissible by reason of the *exostoses* shown by the Trinil femur, the author drew attention to the influence of rachitis in producing convexity of the popliteal surface.

Finally, special reference was made to the condyles of the Trinil femur, which are human and not simian in type.

The author arrives at the following conclusions:—

1. The distinguishing features of the Trinil femur are found both singly and in conjunction on human femora, with sufficient frequency to enable them to rank as human characters.

2. The features of the Trinil femur do not entitle it to the distinction of a separate genus, but it is a human femur which, from the geological horizon connected with its discovery, associates the genus *Homo* with a period immensely more remote than any former discovery of man's remains.

Reasoning from the above conclusions, with regard to the femur, either the skull-cap and the molar teeth discovered by Dr. Dubois were also parts of a human being, or it has yet to be proved that they really formed parts of the individual who provided the femur.

[DUBOIS. 'Trans. Roy. Soc. Dub.' i. 1896.

MANOUVRIER. *Deuxième Étude sur le 'P. erectus,' &c.*, 'Bull. Soc. Anthrop. de Paris,' tom. vi. 1896, fasc. v (4e série).

HEPBURN. The Comparative Anatomy of the Muscles and Nerves of the Superior and Inferior Extremities of the Anthropoid Apes, 'Journ. Anat. and Phys.' vol. xxvi. p. 333.]

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4. *Proportions of the Human Body.* *By* J. G. GARSON, *M.D.*

The author began by giving a short historical outline of the study of the canon of proportion of the human body from the time of the Ancient Egyptians to the present. The Egyptian canon showed that the models from whom it was made out were negroes. The Greeks appear to have adopted that of the Egyptians. The canon of modern artists is essentially an ideal one, apt to vary as opinions change. The first real attempt at a scientific canon was that of Quetelet; it was, however, based upon too small a number of observations. The canon which has been published by Professor Topinard of Paris is much more reliable. As a number of circumstances would appear to modify the proportions of the people of different countries, such as the race elements of which a nation is composed, the social condition of the models, climatic conditions, &c., the author considered that no better data could be obtained for establishing the true canon of the people of Great Britain than the measurements which were made in the anthropometric laboratory of the British Association on its members during seven successive meetings, the models being persons living under the most favourable conditions of life. The method of obtaining the mean dimensions of each measurement, so as to eliminate causes of error, was explained. The mean stature thus obtained is 5 ft. $7\frac{3}{4}$ in. This being taken as 100, the proportions of the various parts of the head and face, as well as the trunk and limbs, were shown expressed in percentages. The head is 12·6 per cent., the neck and truuk 40, the lower limbs 47·5, the arm 43·1, the span 102·3. The canon of the head and of the span indicated, differ considerably from that of artists.

The paper will be published in full in the Journal of the Anthropological Institute.

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5. *Some Pagan Survivals.* *By* F. T. ELWORTHY.

SATURDAY, SEPTEMBER 19.

The following Reports and Papers were read:—

1. *Report on the Ethnographical Survey of Great Britain and Ireland.*
See Reports, p. 607.

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2. *Kent in Relation to the Ethnographical Survey.*
By E. W. BRABROOK, F.S.A.

[Published in full in the 'Archæological Journal,' 1896, liii., pp. 215–234.]

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3. *An Imperial Bureau of Ethnology. By* C. H. READ, *Sec. S.A., Keeper of the Ethnographical Department of the British Museum.*

The author proposed the establishment of a bureau in London, in which should be gathered information relating to the manners and customs, religious beliefs, and laws of all the primitive races inhabiting the British Colonies, or upon the borders of the Empire. He strongly urged that it was not only the duty of the Government to place on record such facts connected with races that were in a condition either of decay or of constant change, but that it would be to the interest of the nation to have such information at hand. He contended that the possession of such facts would enable the settler or traveller to avoid many misunderstandings with natives that are now so prolific a cause of disaster. A valid reason for the prompt establishment of such a bureau is, in Mr. Read's opinion, that the machinery for the collection of the necessary data already exists; that such officers as those of the Intelligence branch of the War Office, the surgeons in the navy, and many others, are quite competent to furnish such returns as are required by the bureau; and if they obtained credit at home for intelligence in this direction, many men of these branches of the service would be very ready to spend their leisure in such pursuits. Thus only a small staff at home would be required for arranging and editing the material. Mr. Read spoke in the highest terms of the work done by the United States Bureau of Ethnology which the government of that country had thought it worth while to establish and endow for the preservation of memorials of a single race—that of the American Continent.

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4. *Anthropological Opportunities in British New Guinea.*
By SIDNEY H. RAY.

The purpose of the author was to reaffirm the danger of delay in commencing an investigation of the Anthropology of British New Guinea, and to call attention to the opportunities which exist at the present time for successfully carrying out a system of ethnographical and philological enquiry. If anything is to be done, it should be done soon. Already there are signs of change, customs and languages are dying out before the advance of civilisation. Stress is laid upon languages as folk-lore, religious beliefs, and practices, and legal customs can only be thoroughly studied through the medium of the languages. We want to know the native's reason for his thought and practice. An European observer will make his observations from his own standpoint, and, without a knowledge of inner motives, will often draw the most erroneous conclusions from native practices. The opportunity besides being in time is also fortunate in circumstances. The country is singularly quiet and safe for Europeans. Sir William MacGregor says: 'In gaining the confidence and respect of the natives the Government has been more successful than could ever have been expected. They begin to think in may places that whatever is ordered or required by the Government is right. They fear the

Government greatly.' Other advantages are the facilities which would doubtless be afforded by the New Guinea Government. It is fortunate for anthropological science that the affairs of the Possession are in the hands of so enlightened an administrator as Sir William MacGregor. Lastly, the cost would not be excessive.

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5. *Interim Report on the Immediate Investigation of Oceanic Islands.*
See Reports, p. 487.

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6. *On a Method of Determining the Value of Folk-lore as Ethnological Data, illustrated by Survivals of Fire-worship in the British Isles. By* G. LAURENCE GOMME.

Appendix to Ethnographical Survey Report.—See Reports, p. 626.

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7. *Report on the North-Western Tribes of Canada.*
See Reports, p. 569.

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8. *The Coast Indians of British Columbia. By* Professor E. ODLUM.

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9. *The Growth of Agriculture in Greece and Italy, and its Influence on Early Civilisation. By* Rev. G. HARTWELL JONES, *M.A.*

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10. *Report on the North Dravidian and Kolarian Races of India.*
See Reports, p. 659.

MONDAY, SEPTEMBER 21.

The following Papers and Report were read :—

1. *Cyprus and the Trade Routes of S.E. Europe. By* JOHN L. MYRES, *M.A., F.S.A.*

Several considerations indicate that Cyprus may have been the first centre of copper-working in the Mediterranean, and that the knowledge of copper in Europe was probably derived hence, *viâ* Asia Minor, Hissarlik and the Dardanelles, and the valley routes of the Hebros, Morawa and Danube.

1. Copper is found abundantly and accessibly in Cyprus; but is not here associated with tin. Cyprus had in early times abundant supplies of timber, in fact all the necessaries for an extensive and easy manufacture. There is, however, no native copper, which corresponds with the fact that the early implements in Cyprus appear to be usually cast.

2. The Copper Age in Cyprus seems to overlap the Stone Age of the Levant.

3. The persistence of early types in Cyprus would be inexplicable if Cyprus had been importing implements from the more progressive areas of the Ægean and the Danube basin. The late arrival in Cyprus of both tin and amber confirms this supposition. The view that copper implements are simply bronze weapons made during a scarcity of tin fails to account for the predominance of primitive types among the pure copper weapons.

4. Cypriote types determine those of the neighbouring mainland, and of the

earliest implements of Hissarlik and Central Europe; though local industries soon arise in Central Europe, and outstrip the parent industry.

5. The Bronze Age pottery of Cyprus is followed in fabric and ornament, and to some extent in forms, by the pottery of Hissarlik and Central Europe at the point where copper implements first appear. As this Cypriote pottery itself does not seem to have been exported northward, the knowledge of the fabric must have been introduced in connection with some other object of commerce, presumably with the copper.

6. The fully-developed Copper Age in Cyprus can be dated by objects of Egyptian twelfth-dynasty styles; and the beginnings of copper-working in Cyprus must consequently be earlier.

7. The early existence of a trade route between south-west Asia Minor and the Danube valley is indicated by the catalogue of the allies of Troy in Homer's Iliad II. The Trojan War may represent an attempt on the part of the Ægean thalassocracy to force a way into the Euxine, and obtain possession of the fortress which commanded the ferry on the older land route.[1]

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2. *The Transition from Pure Copper to Bronze made with Tin.* *By* Dr. J. H. Gladstone, *F.R.S.*

This communication was supplementary to a paper read at the Meeting at Nottingham three years ago, and to matters published in the Proceedings of the Society of Biblical Archæology for March 1890, February 1892, and February 1894. The new matter consisted mainly of the analysis of some metal tools obtained by the author last winter in Egypt, and of borings of implements of the supposed Libyan race found at Nagada, and of a dagger-knife from Cyprus, which had been given him by Mr. Arthur Evans.

The use of copper in Egypt can be traced from the fourth dynasty, when King Seneferu captured the copper and turquoise mines of the Sinaitic peninsula. Tools made of this metal have been found not only in Egypt, belonging to the fourth, sixth, and twelfth dynasties, but also in Assyria, at Lachish in Palestine, Hissarlik in Asia Minor, and Nagada. Attempts were made to render this copper harder and stronger, and that in three ways. First, the admixture of a large quantity of suboxide of copper, or of its formation in the process of smelting, as seen in adzes from Egypt and Palestine, and perhaps Nagada. Second, the presence of a little arsenic or antimony, as shown in many tools from Kahun dating from the twelfth dynasty, and from the Sinaitic mines, as shown in a communication to the French Academy by Berthelot a few weeks since. Third, the admixture of a little tin, as at Kahun, the Sinaitic mines, and Cyprus, perhaps not exceeding one per cent. When, however, the superiority of tin, as the hardening material, came to be acknowledged, it was added in larger quantities, and formed the alloy known as bronze. Such proportions as four and six per cent. occur in early specimens, as at Hissarlik; but subsequently about ten per cent. was usually employed. Tools of this composition are found not only in Egypt during the eighteenth dynasty, but in most countries, and for an immense variety of purposes.

This indicates a large traffic in the metals, and probably in the manufactured tools themselves. The similarity of pattern observed in the instruments is also suggestive of the latter hypothesis.

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3. *Hallstatt and the Starting-point of the Iron Age in Europe.* *By* Professor W. Ridgeway, *M.A.*

The origin of the Iron Age is one of the most important points in European archæology. Scandinavia cannot be its place of origin, for there the Iron Age

[1] Cf. Much, *Kupferzeit in Europa*, Wien (2nd ed.), 1893; Virchow, *Zeitschr. d. Anthr. Gesellsch.* xii. p. 73; Naue, 'Die Bronzezeit auf Cypern,' *Korresp.-Blatt*, 1888, p. 124; Myres, 'Early Man in the Eastern Mediterranean,' *Science Progress*, July 1896. Myres & Ohnefalsch Richter, *Cyprus Museum Catalogue*, Oxford, 1896.

began late. It is admitted that the Iron Age comes in *per saltum* in Swiss lake dwellings, in Italy, in Greece, in France, and in Britain. Iron is found going with the Kelts into these various regions.

Hallstatt, in Austria, is the only place in Europe where articles of iron are found gradually replacing those of the same kind made in bronze. It has not been hitherto pointed out that within a very short distance of the Hallstatt cemetery lies one of the most famous iron mines of antiquity. Strabo (v. i. 8) tells us of the ironworks of Noreia, the chief town of the Keltic Taurisci, which gave its name to Noricum, and to the *Noricus ensis* so dreaded by the Romans.

From this centre the use of iron spread into Italy, Switzerland, Gaul, Spain, Greece, and into Eastern Germany, where the mining of iron by the Keltic Cotini is mentioned by Tacitus (Germ. 43).

At many places in the Alps it is possible that there may have been outcrops of terrestrial iron. Men would thus find ready to hand sources of iron, and there is no need to suppose that meteorites first supplied him with that metal.

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4. *The Tyrrhenians in Greece and Italy.*[1] *By* Dr. Oscar Montelius.

The author brings a great variety of evidence in support of the following conclusions:—

1. That the Oriental civilisation long before 1500 B.C. was brought over to the Greek coasts and isles.
2. That during this so-called Mycenean period an influence can also be traced in Greece from the Phœnicians and from Egypt.
3. But that the main influence came from Asia Minor.
4. That it was due to the immigration of peoples from this part of Asia.
5. That these are the peoples generally called *Pelasgi* or *Tyrrhenians* by the Greek authors.
6. That the Oriental civilisation advanced farther to the West, and was introduced in the eleventh century B.C. into that part of Central Italy which the Romans called *Etruria* and the Greeks *Tyrrhenia.*
7. That it was due, there also, to the immigration of a people of Oriental origin, the Tyrrhenians, coming from over the sea, not over the Alps. This people was consequently a non-Italian one. The question is reserved whether it was of Aryan race or not.

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5. *Report on the Lake Village at Glastonbury.*—See Reports, p. 656.

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6. *Sergi's Theory of a Mediterranean Race.* *By* J. L. Myres, *M.A.*

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7. *Boat Graves in Sweden.* *By* Dr. H. Stolpe.

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8. *Notes on a Prehistoric Settlement in Co. Kerry.*[2] *By* R. A. S. Macalister, *M.A.*

The Barony of Corkaguiney, co. Kerry, is remarkable for the number and interest of its antiquities; and foremost among these must be placed a settlement of stone-built dwellings at its south-west corner, between Dunmore Head and Ventry Harbour. These consist of beehive-shaped houses—single, double, and triple, some alone, some congregated together, and surrounded by a strong enclosing

[1] The Paper will be published in full in *Journ. Anthr. Inst.*, Feb. 1897.
[2] To be published in full in a forthcoming work on the Barony of Corkaguiney.

wall. In the modern village of Conmeenoole, at the western end of the settlement, the ancient style of building is perpetuated in some of the cow-houses. The most remarkable building is Dunbeg Fort, a great wall 22 feet thick, cutting off a tongue of land which projects into the sea, and on which is built one of the finest of the domestic buildings. The whole settlement has suffered by recent restorations.

Though the settlement is not unlike the monastic remains of the west of Ireland in some respects, it is in others widely different from them, especially in size, in the absence of any distinctly ecclesiastical building contemporary with the rest, and in the prevalence of multiple clocháns or houses. The fact that a stone was found in Caher Glengaun, used as building material, which bears Christian symbols, proves nothing but that this particular building probably dates from the Pagan-Christian overlap. On the other hand, an Ogham inscription on Dunmore Head, which is entirely destitute of any trace of Christian influence, and which probably commemorates some notable resident in the settlement, seems to put the latter back to Pagan times. The person commemorated was a descendant of Duibne, the ancestress of the clan from whom the Barony of Corkaguiney is named.

The people were agricultural, and open to the attacks of enemies, especially from Ventry; this is evident from an examination of the remains. A great battle was at some time fought at Ventry; the historical facts are obscured by fictitious accretions, but the site is still in existence, showing some remarkable earthworks.

The conclusion to be drawn from these remains is, that Ptolemy and other ancient geographers were right in asserting the existence of *towns, i.e.* centres of a concentrated population, in ancient Ireland, and that archæologists have been wrong in denying their existence. Other places might be mentioned where the magnitude of the remains proves the former existence of such centres, but their habitations in these places not being of stone, have all perished.

TUESDAY, SEPTEMBER 22.

The three following Papers were read as contributions to a discussion on the Early Civilisation of the Mediterranean.

1. '*Who Produced the Objects called Mykenæan?*'[1] *By* Prof. W. RIDGEWAY.

The discovery of Mykenæan remains in various parts of the Greek world outside of Peloponnese, such as Attica, Thessaly, Crete, Cyprus, Rhodes, Egypt, Asia Minor, Italy and Sicily, makes it desirable to re-examine the question of the origin of these remains. In Peloponnese and Crete we are fairly limited to the same possibilities of race. For in Peloponnesos either the Greeks of classical times, or the Achæans of the Homeric Age, or the older race, who preceded the Achæans, and who, according to the consensus of Greek history, continued to occupy Arcadia in historical times, must be the producers of the objects termed Mykenæan.

Homer enumerates[2] the races which occupied Crete—viz., Eteocretes, Kydonians, Achæans, Dorians, and Pelasgians. As there is no evidence that the first two ever played any important part in Peloponnese, they may be jetisoned, and the claim for precedency must be fought out by the same three as in Peloponnese.

1. Busolt and others put forth a claim for the Dorians as the builders of Mykenæ and Tiryns, but as this not only gives the lie direct to all Greek history, but also makes the Dorians build the walls of Tiryns, and create beautiful works of art—though in historical times they were notoriously incapable in building and

[1] Printed in full in *Journal of Hellenic Studies*, xvi. (1896), pp. 77 *ff*.
[2] *Od.* xix. 175.

art—we may leave them aside. As, moreover, Attica, which was not conquered by the Dorians, shows Mykenæan remains, we may boldly reject the Dorian claim.

2. It then rests between Achæans and the older race, who were called Pelasgians by the Greeks. Homer gives us a picture of a culture which Schliemann and Helbig (till lately), followed by most scholars, have sought to identify with that of Mykenæ. This involves many difficulties: (1) The age of Mykenæ is that of *Bronze*; that of Homer's Achæans is distinctly of *Iron*. (2) *Engraved gems* are characteristic of Mykenæ, but such engraved gems, used either as signets or as ornaments, are unknown to Homer. (3) No *fibulæ* have been found in the Acropolis of Mykenæ, but Homer's Achæans use them to keep on their dress. (4) The Mykenæans were skilled in painting, but when Homer mentions it he speaks of it as 'Carian' art. (5) The Mykenæans had a peculiar oblong shield, like the figure 8; they had no breastplate, no greaves of metal, and wore their hair in three locks behind; whilst the Achæans had round shields, bronze breastplates and greaves, and wore their hair flowing.

To obviate such difficulties Reichel,[1] followed by Leaf, would make wholesale excision of passages which describe Achæan warriors as armed with round shields, breastplates, and greaves. But such passages cannot be 'late,' even though later than some other parts of the poems; for if interpolation had been practised in late times, we should have the use of coined money, signets, and alphabetic writing, colonies in Asia Minor and Italy, and Dorians in Peloponnese, alluded to as they are by the tragic poets when they treat of the Heroic Age.

3. The Greeks themselves thought that Mykenæ and Tiryns were built before the Achæans entered Peloponnese, and by the Pelasgians. The Greek historians declared that Attica was never inhabited by any other race than the Pelasgians, and as Mykenæan remains have been found in abundance in Attica, the conclusion is that it was the same race who made similar monuments in Peloponnese.

There is no need to cut Homer to pieces to fit the Mykenæan Age. The Achæans came into Peloponnese marrying the heiresses of the kings of the older race—*e.g.*, Menelaos married the daughter of Tyndaros.

The Mykenæan culture is that of the Bronze period, which was supplanted by the Iron Age, which was introduced by the Achæans into Greece.

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2. *Preclassical Chronology in Italy and Greece.*[2] *By* Dr. Oscar Montelius.

For chronological purposes, Italy and Greece must be taken together, because their early culture has a large common element, and because whereas Greek evidence supplies the more accurate date-marks, Italy affords a vastly larger mass of material hitherto, owing to the more scientific manner in which the content of each tomb has been registered in recent Italian excavations.

The author's examination of the extant evidence enables him to construct a *relative* chronology of short intervals, which divides the Bronze Age into *seven* periods, and the Iron Age in Central Italy, down to the end of the VIth century, B.C., into *six* more.

During the Bronze Age the evolution was the same in Northern and in Central Italy; but from the beginning of the Iron Age the development in Etruria, south of the Apennines, is quite distinct from that in Northern Italy.

The typological analysis shows evolution within each period; the periods themselves, therefore, must have been of considerable length, each period of the Iron Age in Central Italy being of the approximate length of a century

The *absolute* chronology is fixed by the occurrence of a series of exactly dateable objects imported from Greece in the eighth to fifth centuries B.C., and associated in Italian tombs with objects characteristic of successive periods in the lower part of the series. The result of the Author's analysis is to raise to the ninth century B.C. certain tombs (the Regulini-Galassi tomb at Cervetri, &c.) com-

[1] *Homerische Waffen.* Wien, 1895.

[2] The Paper will be published in full in *Journ. Anthr. Inst.*, Feb. 1897.

monly assigned to the time about 600 B.C., and to expand the whole series upwards in proportion. The fifth period of the Italian Bronze Age is proved by fibulæ, Greek pottery, and Egyptian scarabs to be contemporaneous with Amenhotep III., of the XVIIIth Egyptian Dynasty, who lived in the XVth century, B.C.

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3. *Pillar and Tree Worship in Mycenæan Greece.* *By* ARTHUR J. EVANS, M.A., F.S.A.

New evidence, supplied by finds in Crete and the Peloponnese, is brought forward to show the great part played in the Mycenæan religion by the worship of deities in aniconic shape as stone pillars or as trees. On a gold ring obtained by Mr. Evans from the site of Knôsos in Crete, and dating from the early Mycenæan period (about 1500 B.C.), a dual cult of a male and female divinity in their pillar shape is illustrated, and an armed Sun-god is being brought down on to his obelisk or 'Beth-el' by ritual incantation. Parallels to this dual cult of deities in a columnar form are cited from Cypriote cylinders of Mycenæan date, and the later cone of Aphrodite at Paphos is shown to be a survival of a cult once common to prehistoric Greece, and of 'Ægean' rather than Semitic importation into Cyprus. Various religious designs on signets recently discovered by Dr. Tsountas at Mycenae are described for the first time, which throw additional light on the cult of Mycenæan deities in the shape of pillars and trees enclosed in small shrines, and the column of the Lion's Gate at Mycenæ is identified with the aniconic idol of the Phrygian goddess Kybelê, whose anthropomorphic image later supplants the pillar form in the same position between the lion supporters. It is pointed out that a confusion seems at times to have taken place between the pillar form of the divinity and the tombstone of the god himself, or some allied hero who is really his double; and reasons are adduced for identifying the traditional 'Tomb of Zeus' in Crete with the remains of a prehistoric sanctuary visited by Mr. Evans on Mount Juktas. Attention is further called to a low-walled building in the great Mycenæan city of Goulâs, in the same island, as probably actually representing one of the small shrines which contained a sacred tree. An interesting fragment of a Mycenæan steatite vase also obtained by the author from the site of Knôsos is described, in which an altar appears in front of a stone enclosure containing a sacred fig tree, and the cult of this tree, illustrated by other Mycenæan relics, is compared with that of the *ficus ruminalis* in Ancient Rome, where (as in Cyprus) the traditional Arcadians represent a Mycenæan influence. The early sanctity of the dove is also seen associated throughout Mycenæan Greece with this primitive worship, and new evidence is adduced as to the part played by it in the religion of prehistoric Crete. Finally, the pillar and tree worship of Mycenæan Greece is seen largely to survive in the rustic cult of classical Greece at a time when in the more civilised centres the images of the gods had been mainly anthropomorphised. This is illustrated by the rural sanctuaries with their sacred trees and stones so well represented on the Pompeian frescoes.

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4. *The Ornament of N. E. Europe.* *By* G. COFFEY.

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5. *Manx Crosses as Illustrations of Celtic and Scandinavian Art.*[1] *By* P. M. C. KERMODE.

Nearly a hundred crosses and inscribed stones have been found in the Isle of Man, dating from the beginning of the sixth to the first quarter of the thirteenth century.

[1] Cumming, *Runic Remains*, 1854 (poor figures of about forty examples); other examples in *Trans. Cambrian Society* (passim); Kermode, *Catalogue of Manx Crosses* (the second edition gives eighty-five examples; a larger, fully illustrated work is in preparation).

The earlier *Celtic* examples are mostly undecorated; the Calf of Man crucifix is an unique, elaborately-carved specimen of the early ninth century. Celtic crosses are also found of the tenth and early eleventh centuries.

The *Scandinavian* crosses are dated by style and inscriptions to the eleventh and following centuries. The style gradually becomes bolder, though it lacks accuracy, and later fails through over-elaboration. Celtic geometrical patterns and 'tendril' and 'loop' forms of 'twist' are developed with much artistic skill, and the characteristic Scandinavian 'vertebral' motive is introduced. The absence of foliage, of panel arrangement, and of diagonal and spiral patterns, and the characteristic type of zoomorphism, are also derived from the Celtic prototypes.

An analysis of Manx decorative art—*Geometric, Zoomorphic,* and *Pictorial*—indicates, as peculiar features: (1) the 'tendril' variety of 'twist'; (2) the treatment of the head of the cross; (3) the representation of Pagan mythological scenes from the Norse Sagas, especially from the *Volsungsaga.*

WEDNESDAY, SEPTEMBER 23.

The following Papers were read:—

1. *An Ethnological Storehouse.* *By* Professor W. M. Flinders Petrie, *D.C.L.*

Memorandum on Proposed Repository for Preserving Anthropological or other Objects. *(Drawn up by* Professor Flinders Petrie, *for the use of a Committee of the Council.)*

Necessity.—The impossibility of preserving more than a small portion of the material for anthropology in the very limited area of London or town museums leaves only the alternatives of—(1) the destruction of materials which can never be replaced, illustrating modern races that are fast disappearing, and ancient races as revealed by excavation; or (2) the storing of such materials accessibly in a locality and a manner which shall yield the greatest possible storage space for a given expenditure.

Scope.—Such a repository might be solely anthropological, including an example of every variety of object of human work of all ages. Or it might be extended to zoology, mineralogy, geology, &c. Here we only consider the human side.

The *minimum* use of such a place would be only to store the surplus objects which cannot find place in existing museums.

The *maximum* development of it would be to form a systematic scientific collection of man's works, ancient and modern, reserving to existing museums such objects as illustrate the subject best to the general public, and such as need the protection due to their market value. All such exhibition objects could be properly replaced in the repository collection by photographs.

If fully developed such a repository would become a centre for study and higher education; a reference library would then be needed; but the value of land would be so enhanced that further expenditure would be covered by rents of adjacent ground.

Form.—The conditions of such a repository are so wholly different from those of existing museums that the proportions of expenditure are entirely changed. The essential and primary condition is that space shall be of minimum value; and therefore wages and the cost of moving objects and arranging them will be a far larger item in proportion. It is therefore needful that changes shall not be necessitated by any amount of expansion.

The type of structure must therefore be a long gallery, with lateral expansions to be built as any section increases. The galleries must be sufficiently apart to allow of any likely increase, irregularly distributed.

The type of gallery which would seem most economical would be about 54 feet wide, divided into a nave and two aisles across the breadth, and into bays of 16 feet along the length. A blocked doorway in each bay would allow of opening laterally, into added buildings, for expansion of any section. It should be well lighted, about one-fourth of the roof to be of glass. The walls should be low—say 10 feet—so that the area of lighting would be near the objects.

The essence of the scheme is that the site shall be ordinary agricultural or wooded land, so that a space far larger than is likely to be wanted can be utilised for irregular expansion as any section grows; while all that is not actually in use for galleries will continue to be productive, as before. Thus every possible need of the future can be accommodated without incurring more immediate expense than is now requisite, and without any loss of interest on capital not utilised.

For this purpose it would not be unreasonable to secure about 500 acres, in view also of the probable rise in the value of land for building as such an institution grew. On this land galleries of 54 feet wide, built in blocks of 100 bays or 1,600 feet length at once, should be placed at about a furlong apart. This would allow of each gallery expanding on either side for about 250 feet of outbuilding.

Each gallery should have in the middle of its length a policeman's cottage (fire-proof), with its windows looking along the inside of the gallery.

SITE.—The site should be within about half an hour's journey from London. Flat, for view along the galleries. Healthy for residence. Fairly dry, and sandy if possible. Wooded, so that belts of trees should occupy the spaces between the galleries, and thus reduce the effect of wind and rain. Near a railway; but, for cheapness, far from a station, as the institution would soon claim a station for its own use. A siding for goods should be provided.

FITTINGS.—No glass cases would be required, except for a few objects that needed to be kept dry by lime. There would be little dust in a wooded country, without any internal heating, and with air all filtered on passing in. Where glass was desirable, large loose sheets could be laid over boxes or shelves; cost about a tenth of the price of the cheapest cases. Thus specimens could be put out of reach by having strips screwed down to secure the glass.

REGISTRATION.—Perhaps a system of photographic registration would be cheapest, as it would be worked on large groups of objects, continuously in a fixed place and in routine. Such register photographs should be to one of two or three definite scales; and they should be sold, thereby helping the cost of the registration.

CONSTITUTION.—A body of Trustees would be supreme. One possible system would be for one Trustee to be nominated by each of the following persons:—The Principal Librarian of the British Museum, the Director of the Natural History Museum, the Director of the South Kensington Museum, the Presidents of the British Association, the Royal Society, the Society of Antiquaries, and the Anthropological Institute. Such nominees to hold office for seven years each, retiring in rotation, but capable of re-nomination. Active men with sufficient time to attend to the work might thus be obtained to represent the various interests involved.

The Keeper should be solely an administrator and organiser, and not a specialist in any line.

ACQUISITIONS.—Any object might be refused by the Keeper, subject to an appeal to the Trustees.

Objects might be deposited by any public body or private person, the legality of their removal to the Repository being provided in the constituting Act.

All objects deposited for over thirty years, without claim and re-deposit, should become the property of the Trust.

Unless depositors make conditions, any duplicates may be lent to any public museum by the Keeper, sanctioned by the Trustees.

No responsibility will attach to the Trustees for the safety or condition of any object deposited.

Presented objects may be kept together in any system required by the donor for thirty years.

Objects found together, or required to illustrate each other, shall be permanently inseparable.

COST.—The site would continue to be productive except where actually built over. For every 100 bays, or 1,600 feet of gallery, a clearance 75 feet wide would be needed, or an area of $2\frac{3}{4}$ acres. Capital value (say) 100*l.* The estimate for the gallery is 200*l.* per bay of 16 feet length, or for 1,600 feet 20,000*l.* For cottage and ends (say) 500*l.*

For comparison it may be stated that the whole exhibition floor-area of the British Museum for antiquities and ethnology is about equal to 3,200 feet length of such galleries, or two galleries such as above described, which would cost about 42,000*l.*

Thus the exhibiting space of the British Museum might be reduplicated at a prime cost equal to three or four months' maintenance of the existing Museum.

If the repository were started with one gallery, equal to half the British Museum exhibiting area, and if a full allowance of ground were secured for future expansion, the cost might be estimated as follows:—

	Prime Cost.	Cost per Annum.
500 acres at (say) £40	= £20,000 at $2\frac{1}{2}$ %	£500
[Any increase in the cost of the land above this amount might be balanced by the produce of the land, the loss remaining at £500.]		
Building 100 bays of gallery	£20,000 at $2\frac{1}{2}$ %	£500
Repairs and renewals (say)		250
Shelving and glass (say)		200
Keeper and house		500
Policeman, carpenter, and labourers		500
Total cost per annum		£2,450

for a building equal to half the British Museum exhibiting area, and the securing of space for future building up to 50 or 100 times the present exhibiting area. This amounts to $1\frac{1}{2}$ per cent. on the present annual grant of the British Museum at Bloomsbury.

The foregoing memorandum was submitted for criticism by the Committee of the Council to several distinguished men of science, and the remarks received in reply show what points of the scheme should be discussed more fully and modified and what points need further explanation. I therefore beg to suggest the following amendments and additions to the memorandum:—

The *scope* in one opinion should be restricted to anthropology. As the utility of such space for other subjects was only hinted at, and does not enter into the proposals, this limitation may be accepted without altering any point.

In *form* the use of such long low galleries is said to be 'simply impossible, on account of its extreme ugliness.' As part of the original proposal is to entirely screen the buildings with trees outside, and divide them by stands and cases inside, the æsthetic consideration need hardly compel extra expense, for the building would not be seen.

Another proposal is to add a second story or provide for such. As the extra building work would be more than double the proposed, and the added floor equal in cost to a roof, there would only be saved the value of land and a concrete floor. Against this the lighting would be so bad in a low wide gallery with only side windows that the space gained would be worth far less than if all were top-lighted. As the essence of the scheme is cheap space, there does not seem to be much gained by a second story.

In the question of fire, insurance is stated by one authority to be essential. If, however, there be nothing inflammable in the construction (for the building itself may be absolutely incombustible), and if there is only the risk of detached stands and cases being set on fire, the risk is so very minute that even if insured the cost would be only nominal. A system of dividing the groups of cases into bays by brick and slate shelvings at intervals would still further reduce any possibility of combustion.

Regarding *fittings*, one opinion is that glass cases to protect smaller specimens would be necessary. It was already proposed to cover such things by large sheets of glass screwed down; and such covering would be effective, and cost little more than the glass at 3*d*. a square foot. Where a permanent fitted case was required such can be thoroughly well made and finished at 1*s*. 4*d*. a cubic foot. The amount already provided in the estimate for shelving and glass would allow of adding 3,000 cubic feet of glass cases yearly if such were required.

Another opinion is that dust would be so serious that a great part of the things 'must be placed in good cases.' It is already proposed to filter all the air passing into the building, which would be quite practicable in a place where no crowds would assemble and but little change of air was wanted. And the use of sheets of glass laid over boxes and shelves may be made quite as dust-tight as the best made cases if a line of cotton wool be laid to bed the glass upon. It must be considered that the conditions of exhibiting would be very different from those in a crowded city museum.

Regarding *registration*, the difficulty and time involved in photographic registration seems to be overestimated by those only accustomed to the tedious work of arranging objects on a screen in an ordinary room. By having two fixed scales of reduction (say $\frac{1}{2}$ and $\frac{1}{10}$) the need of focussing and time required for that would be abolished, for with the rapid plates now used a very small stop is enough, and differences due to thickness of objects would entirely disappear. The proposal is to have a glass table (say), 80 × 100 inches, with white ground below, on which to lay out objects for $\frac{1}{10}$ scale, avoiding all the delay of fixing on screens and all the shadows; a second glass shelf (say), 16 × 20 inches, at a high level for small things on $\frac{1}{2}$ scale, the camera fixed looking down vertically on the tables, and two slides for plates according to which table was in use. This would give suitable scales on whole plate size. The lighting should be quickly adjustable by strips of blind round three sides of the room. With such a routine arrangement a man at labourer's wages would be quite capable of working it for all ordinary instances.

In the matter of *constitution* two opinions are that such a repository should belong to one definite existing museum only. This would be very well for that one museum; but there are many museums which require such an addition; and it would tie down what is essentially required to be a very elastic and experimental institution to the existing routine of one body whose ideas are all based on a very different order of things. To expect any one body with the traditions and system which are requisite for a very different institution to adopt and work flexibly in an entirely changed set of conditions is hardly promising. The reason for hinting at a combined representation of many bodies on the management is that no one set of traditions would prevail, and an energetic Keeper might have a chance of a free policy. In any case the constitution is by no means an essential matter, and I merely express the difficulty that I see in keeping new wine in old skins.

On the subject of allowing a donor the privilege of making conditions about his donations for (say) thirty years, one opinion is that no such conditions should be allowed. That is purely a matter of experience, and of no essential importance. If people will give things as freely when they are not allowed any voice as to their disposal times have changed. The past history has been that too many collections have been bound by a name, not for thirty years only, but far longer.

On the very important question of site two opinions are against the requisite cheap land being within half an hour of London. It is very probable that it might be requisite to go further out, an hour from London. The speed varies much on different lines, any line east of Aldershot being much slower than others. The half-hour from London by good trains reaches to Harold Wood, Hatfield, Watford, Slough, and Aldershot. The hour circle touches Witham, Hitchin, Leighton, Reading, and nearly Basingstoke; that is, half Essex, most of Hertfordshire, half

Buckinghamshire, part of Berks, and Hants. If land were to be purchased within this distance it seems that some reasonably cheap part might be found. But as we can afford to wait for opportunities, if the scheme be otherwise well formulated, it seems not chimerical to hope for the chance of an appropriation of open land for such a public purpose out of some of the numerous downs, commons, and heaths within the hour's distance.

There remain some other questions that have been raised outside of the memorandum:—

1. That the plan is impracticable for want of funds. The amount suggested is 2,500*l.* a year. Supposing even that this was doubled, that would be 5,000*l.* a year. Now the British Museum alone has increased its budget by 100,000*l.* per annum within fifty or sixty years. Is, then, an increase of 5,000*l.* more not to be thought of for twenty or thirty years to come? Or, looking at capital expense, the cost of the small increase of room in the White Wing and Mausoleum Room has been much more than the capital cost of a space equal to half the museum. It may be safely said that long before we can hope to see this economical system in working order the British Museum budget will have increased by many times the amount required for this.

2. The cost of packing and carriage of things from existing institutions would of course be met by those places which had the benefit of the relief of valuable space. For other cases of private donation 10 per cent. extra on the estimate would probably quite provide. In any case this cannot make the scheme unworkable.

3. The proposal to avoid acquiring things that are not worth the most expensive accommodation in the city museums is fatal to scientific study. And equally fatal would be the idea of leaving all preservation to local museums, for the main purpose of this is not local English, but mankind in general—the colonies and other lands—as no student could be expected to visit Dakota, Brazil, Uganda, and Mongolia to collect the information he might need, even if there was a uniform appreciation in every country of the desirability of preserving history.

The broad view remains untouched by all these minor details. We cannot at present preserve large quantities of irreplaceable antiquities and ethnographic specimens, owing to the existing costliness of museum accommodation, and which come from countries where no local museums are possible. By the time every country came up to the level of England in local museums there would be nothing left to preserve. And yet, making every allowance for the unexpected, and even tripling all the presumed costs, a space equal to the whole British Museum can be provided for less than the average increase in Government grants for museums during four or five years. So that if this repository should not be realised in less than twenty years hence—as I quite expect—the cost of it will have been spent many times over in increased grants, which will only provide an invisible fraction of the space that might thus be had.

It is not proposed as an additional expense, but as a vastly more economical mode of spending the normal increase which is always being made on the existing lines. The real question is not whether money can be found—money is certain to be found during the next twenty years for fresh museum space. The real question is whether we shall have a small increase in our present London museums which cripple our study, or a great increase in another form which shall give a new life altogether to our study of man.

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2. *The Duk Duk and other Customs as Forms of Expression of the Intellectual Life of the Melanesians. By* Graf von Pfeil.

The European who has a sufficiently prolonged experience of the natives of the Bismarck Archipelago is particularly struck by their very apparent desire towards physical and psychical seclusion. Left to themselves, the natives confine their intercourse to members of their own village and at most to those of immediately neighbouring villages. The fact is that twenty years' intercourse with White Men has failed to win the natives to any of the ways of civilisation; they care more for the tobacco brought by the White Man than for anything else he brings them.

The natives hate the foreigners, and distrust even their fellow-countrymen. This seclusive disposition is taken as a key with which to open, to some extent at least, the mysteries with which the Melanesian loves to surround his actions.

A lengthly description of the Duk Duk is not given, as it is fairly well known. It is here viewed psychologically. The ceremony apparently serves two purposes: (*a*) The first is to propitiate evil-disposed spirits—and there is no doubt that this part still represents some of the original traits of worship of the departed. It is, however, next to impossible to gain sufficient insight into the ceremony to establish a plausible theory. (*b*) The other purpose is a very materialistic one, as it is nothing but a clever system of levying black-mail from the women who may not be, and from the men who are not, members of the Duk Duk.

The *Eineth* ceremony is celebrated at irregular intervals. Within a dense hedge square huts are built, on the white clay plaster of which curious figures of birds, crocodiles, &c., are painted. On surrounding trees other figures, such as snakes, the sting-ray, &c., are drawn, and two shapeless figures, which are stated to be the spirits of deceased people. Only members of the Duk Duk can enter the enclosure. Amongst other ceremonies observed is that of placing a 'tambu' on certain articles of food as well as on certain actions and words. During this period of tambu the participators meet at intervals and perform simple dances.

The *Marawot* is celebrated only at very long intervals. A platform, 15 feet square and 50 to 60 feet high, is erected, and entirely covered with leaves; on this a sort of war dance is held. The meaning of this was not discovered.

It is important—nay more, it is necessary—to clear up all the affected mysticism connected with the Duk Duk and the customs related to it before it is too late. The people themselves are forgetting their customs, because the Europeans, to whose trading interests they form an impediment, sneer them into derision, and the Duk Duk begins to retire into remoter parts. It is only through the study of the habits of people who, like the Kanakas, still live in a primeval state, that the development and history of our own race can ever be thoroughly understood.

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3. *An Ancient British Interment. By* F. T. Elworthy.

The author exhibited photographs of an ancient British interment discovered on August 29, 1896, by men in quarrying on the top of Culbone Hill, Somersetshire, close to the road from Porlock to Lynton. The kist is still *in situ*, but will have to be removed as the quarry advances. It is at about 5 feet from the surface of the soil; there is no appearance of there ever having been a cairn or barrow above it. The direction of the grave is due north and south, it measures 3 feet 6 inches long by 1 foot 10 inches by 1 foot 6 inches high. It is constructed with four upright slabs of light-blue Devonian slate, of which plenty is to be found eight or nine miles off, but it is totally different from the Old Red Sandstone immediately beneath the interment.

In the kist were found a very perfect skull, together with several bones of the skeleton, of which photographs in three positions were shown. Alongside the skull at the north end of the kist was found an urn of very early pottery, measuring $6\frac{3}{4}$ in. high × 5 in. diam. There were no weapons or other objects found.

The find was on the property of Earl Lovelace, and it is hoped that on his return from abroad he will grant the request of the County Society, that the entire interment may be placed in their Museum at Taunton.

Some sketches in oil by Mr. Whyte Holdich showing the general surroundings were also exhibited.

The interment was pronounced by Dr. Montelius, Mr. Coffey, Dr. Munro, Sir John Evans and the President, to be certainly of the early Bronze Age, not later than the second millenium, B.C.

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4. *On the Aboriginal Stick and Bone Writing of Australia.* *By* Dr. George Harley, *F.R.S.*

The Australian aborigines use a script of straight incised lines or notches, which resemble Ogam characters, except that they are written without a stem line. They are arranged in groups, across a perpendicular column, sometimes on one side, sometimes on the other, and occasionally across the centre. Sometimes the perpendicular columns are two or more in number. Different sizes of characters are used in the same communication; and an emphatic form occurs with longer lines, more widely spaced. Inscriptions on bone are found in Australia, as in Ireland, in the Ogam script; and the Australians, like the old Scandinavians, tie hair, human or other, to their letters.

Similar straight line scripts are found among the Gilas in Central America, and among the Samoyeds, and are all written in the same way. The question remains open whether these are independent inventions, or derived from a common source.

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5. *The Straw Goblin.* *By* C. G. Leland.

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6. *Marks on Ancient Monuments.* *By* C. G. Leland.

SECTION I.—PHYSIOLOGY (including EXPERIMENTAL PATHOLOGY and EXPERIMENTAL PSYCHOLOGY).

PRESIDENT OF THE SECTION.—W. H. GASKELL, M.D., LL.D., M.A., F.R.S.

The PRESIDENT delivered the following Address on Monday, September 21.

WHEN I received the honour of an invitation to preside at the Physiological Section of the British Association, my thoughts naturally turned to the subject of the Presidential Address, and it seemed to me that the traditions of the British Association, as well as the fact that a Physiological Section was a comparatively new thing, both pointed to the choice of a subject of general biological interest rather than a special physiological topic; and I was the more encouraged to choose such a subject because I look upon the growing separation of physiology from morphology as a serious evil, and detrimental to both scientific subjects. I was further encouraged to do so by the thought that, after all, a large amount of the work done in physiological laboratories is anatomical—either minute anatomy or topographical anatomy, such as the tracing out of the course of nerve-fibre tracts in the central and peripheral nervous system by physiological methods. Such methods require to be supplemented by the morphological method of inquiry. If we can trace up step by step the increasing complexity of the vertebrate central nervous system; if we can unravel its complex nature, and determine the original simpler paths of its conducting fibres, and the original constitution of the special nerve centres, then it is clear that the method of comparative anatomy would be of immense assistance to the study of the physiology of the central nervous system of the higher vertebrates. So also with numbers of other physiological problems, such as, for instance, the question whether all muscular substances are supplied with inhibitory as well as motor nerves; to which is closely allied the question of the nature of the mechanism by which antagonistic muscles work harmoniously together. Such questions receive their explanation in the researches of Biedermann on the nerves of the opening and closing muscles of the claw of the crayfish, as soon as it has been shown that a genetic relationship exists between the nervous system and muscles of the crayfish and those of the vertebrate.

Take another question of great interest in the present day, viz. the function of such ductless glands as the thyroid and the pituitary glands. The explanation of such function must depend upon the original function of these glands, and cannot, therefore, be satisfactory until it has been shown by the study of comparative anatomy how these glands have arisen. The nature of the leucocytes of the blood and lymph spaces, the chemical problems involved in the assigning of cartilage into its proper group of mucin compounds, and a number of other questions of physiological chemistry, will all advance a step nearer solution as soon as we definitely know from what group of invertebrates the vertebrate has arisen.

I have therefore determined to choose as the subject of my address 'The

Origin of Vertebrates,' feeling sure that the evidence which has appealed to me as a physiologist will be of interest to the Physiological Section; while at the same time, as I have invited also the Sections of Zoology and Anthropology to be present, I request that this address may be considered as opening a discussion on the subject of the origin of vertebrates. I do not desire to speak *ex cathedrâ*, and to suppress discussion, but, on the contrary, I desire to have the matter threshed out to its uttermost limit, so that if I am labouring under a delusion the nature of that delusion may be clearly pointed out to me.

The central pivot on which the whole of my theory turns is the central nervous system, especially the brain region. There is the *ego* of each animal; there is the master-organ, to which all the other parts of the body are subservient. It is to my mind inconceivable to imagine any upward evolution to be associated with a degradation of the brain portion of the nervous system. The striking factor of the ascent within the vertebrate phylum from the lowest fish to man is the steady increase of the size of the central nervous system, especially of the brain region. However much other parts may suffer change or degradation, the brain remains intact, steadily increasing in power and complexity. If we turn to the invertebrate kingdom, we find the same necessary law: when the metamorphosis of an insect takes place, when the larval organs are broken up by a process of histolysis, and new ones formed, the central nervous system remains essentially intact, and the brain of the imago differs from that of the larva only in its increased growth and complexity.

A striking instance of the same necessary law is seen in the case of the transformation of the larval lamprey, or Ammocœtes, into the adult lamprey, or Petromyzon; here also, by a process of histolysis, most of the organs of the head region of the animal undergo dissolution and re-formation, while the brain remains intact, increasing in size by the addition of new elements, without any sign of preliminary dissolution. On the other hand, when, as is the case in the Tunicates, the transformation process is accompanied with a degradation of the central nervous system, we find the adult animal so hopelessly degraded that it is impossible to imagine any upward evolution from such a type.

It is to my mind perfectly clear that, in searching among the Invertebrata for the immediate ancestor of the Vertebrata, the most important condition which such ancestor must fulfil is to possess a central nervous system, the anterior part of which is closely comparable with the brain region of the lowest vertebrate. It is also clear on every principle of evolution that such hypothetical ancestor must resemble the lowest vertebrate much more closely than any of the higher vertebrates, and therefore a complete study of the lowest true vertebrate must give the best chance of discovering the homologous parts of the vertebrate and the invertebrate. For this purpose I have chosen for study the Ammocœtes, or larval form of the lamprey, rather than Amphioxus or the Tunicates, for several reasons.

In the first place, all the different organs and parts of the higher vertebrates can be traced directly into the corresponding parts of Petromyzon, and therefore of Ammocœtes. Thus, every part of the brain and organs of special sense—all the cranial nerves, the cranial skeleton, the muscular system, &c., of the higher vertebrates can all be traced directly into the corresponding parts of the lamprey. So direct a comparison cannot be made in the case of Amphioxus or the Tunicates.

Secondly, Petromyzon, together with its larval form, Ammocœtes, constitutes an ideal animal for the tracing of the vertebrate ancestry, in that in Ammocœtes we have the most favourable condition for such investigations, viz. a prolonged larval stage, followed by a metamorphosis, and the consequent production of the imago or Petromyzon—a transformation which does not, as in the case of the Tunicates, lead to a degenerate condition, but, on the contrary, leads to an animal of a distinctly higher vertebrate type than the Ammocœtes form. As we shall see, the Ammocœtes is so full of invertebrate characteristics that we can compare organ for organ, structure for structure, with the corresponding parts of Limulus and its allies. Then comes that marvellous transformation scene during which, by a process of histolysis, almost all the invertebrate characteristics are destroyed or changed, and there emerges a higher animal, the Petromyzon, which can now be compared organ for organ, structure for structure, with the larval form of the Amphibian; and so through the medium of these larval forms we can trace upwards without a break the evolution of the vertebrate from the ancient king-crab form. On the other hand, Amphioxus and the Tunicates are distinctly degenerate; it is easier to look upon either of them as a degenerate Ammocœte than as giving a clue to the ancestor of the Ammocœte. It is to my mind surprising how difficult it appears to be to get rid of preconceived opinions, for one still hears, in the assertion that Petromyzon as well as Amphioxus is degenerate, the echoes of the ancient myth that the Elasmobranchs are the lowest fishes, and the Cyclostomata their degenerated descendants.

The characteristic of the vertebrate central nervous system is its tubular character; and it is this very fact of its formation as a tube which has led to the disguising of its segmental character, and to the whole difficulty of connecting vertebrates with other groups of animals. The explanation of the tubular character of the central nervous system is the keystone to the whole of my theory of the origin of vertebrates. The explanation which I have given differs from all others, in that I consider the nervous system to be composed of two parts—an internal epithelial tube, surrounded to a greater or less extent by a segmented nervous system; and I explain the existence of these two parts by the hypothesis that the internal epithelial tube was originally the alimentary canal of an arthropod animal, such as Limulus or Eurypterus, which has become surrounded to a greater or less extent by the nervous system.

Any hypothesis which deals with the origin of one group of animals from another must satisfy three conditions:—

1. It must be in accordance with the phylogenetic history of each group. It must therefore give a consistent explanation of all the organs and tissues of the higher group which can be clearly shown not to have originated within the group itself. At the same time, the variations which have occurred on the hypothesis must be in harmony with the direction of variation in the lower group, if not actually foreshadowed in that group.

This condition may be called the Phylogenetic test.

2. The anatomical relation of parts must be the same in the two groups, not only with respect to coincidence of topographical arrangement, but also with respect to similarity of structure, and, to a large extent, also of function.

This condition may be called the Anatomical test.

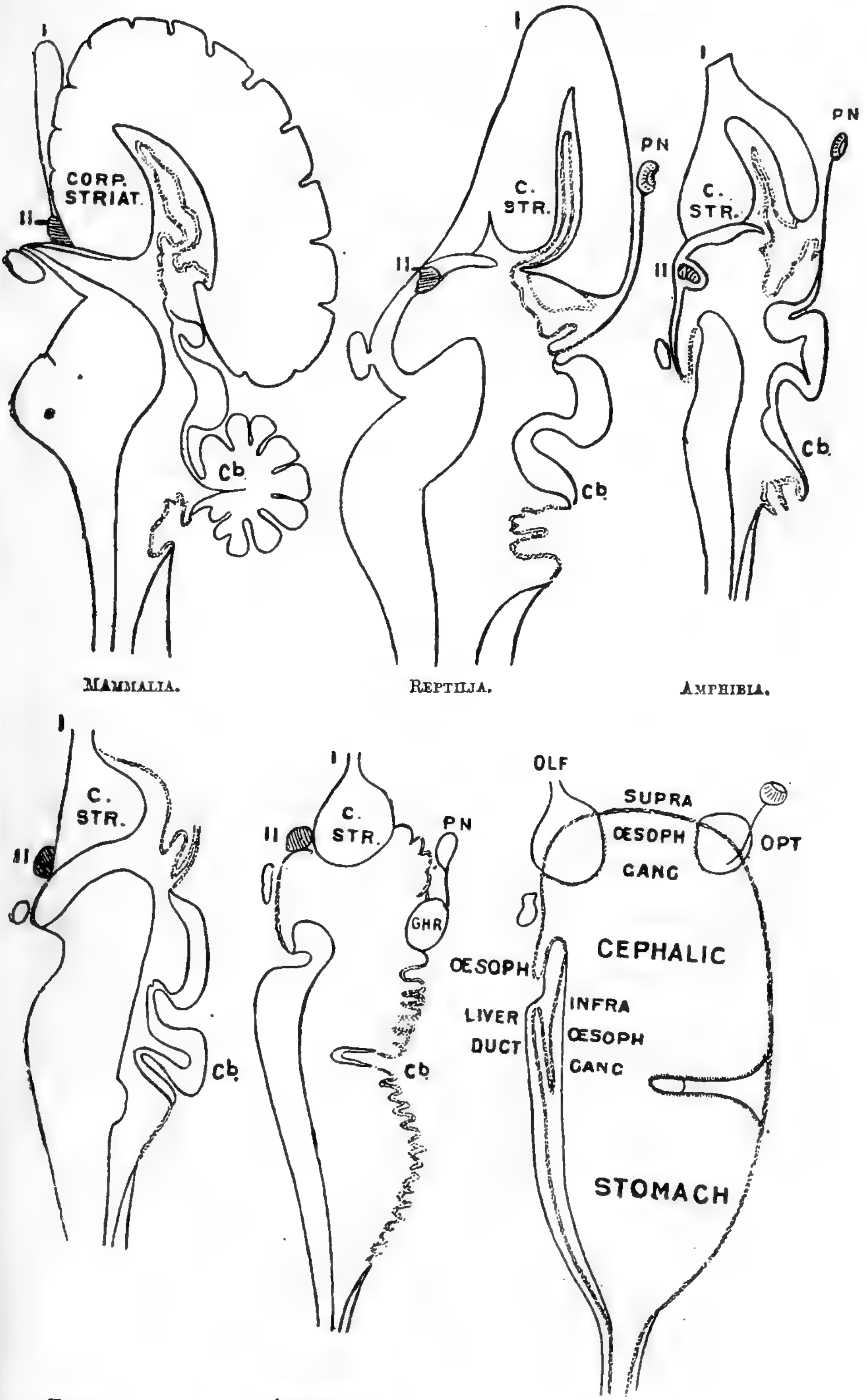
3. The peculiarities of the ontogeny or embryological development of the higher group must receive an adequate explanation by means of the hypothesis, while at the same time they must help to illustrate the truth of the hypothesis.

This condition may be called the Ontogenetic test.

I hope to convince you that all these three conditions are satisfied by my hypothesis as far as the head region of the vertebrate is concerned. I speak only of the head region at present, because that is the part which I have especially studied up to the present time, and also because it is natural and convenient to consider the cranial and spinal nerves separately; and I hope to demonstrate to you that not only the nervous system and alimentary canal of such a group of animals as the Gigantostraca—*i.e.* Limulus and its allied forms—is to be found in the head region of Ammocœtes, but also, as must logically follow, that every part of the head region of Ammocœtes has its homologous part in the prosomatic and mesosomatic regions of Limulus and its allies. I hope to convince you that our brain is hollow because it has grown round the old cephalic stomach; that our skeleton arose from the modifications of chitinous ingrowths; that the nerves of the medulla oblongata—*i.e.* the facial, glosso-pharyngeal, and vagus nerves—arose from the mesosomatic nerves to the branchial and opercular appendages of Limulus, while the nerves of the hind brain are derived from the nerves of the prosomatic region of Limulus; that our cerebral hemispheres are but modifications of the supra-œsophageal ganglia of a scorpion, while our eyes and nose are the direct descendants of its eyes and olfactory organs.

In the first place, I will give you shortly the reasons why the central nervous

FIG. 1.—Comparison of Vertebrate Brain from Mammalia to Ammocœtes. (Epithelial parts represented by dotted lines.)



system of the vertebrate must be considered as derived from the conjoined central nervous system and alimentary canal of an arthropod.

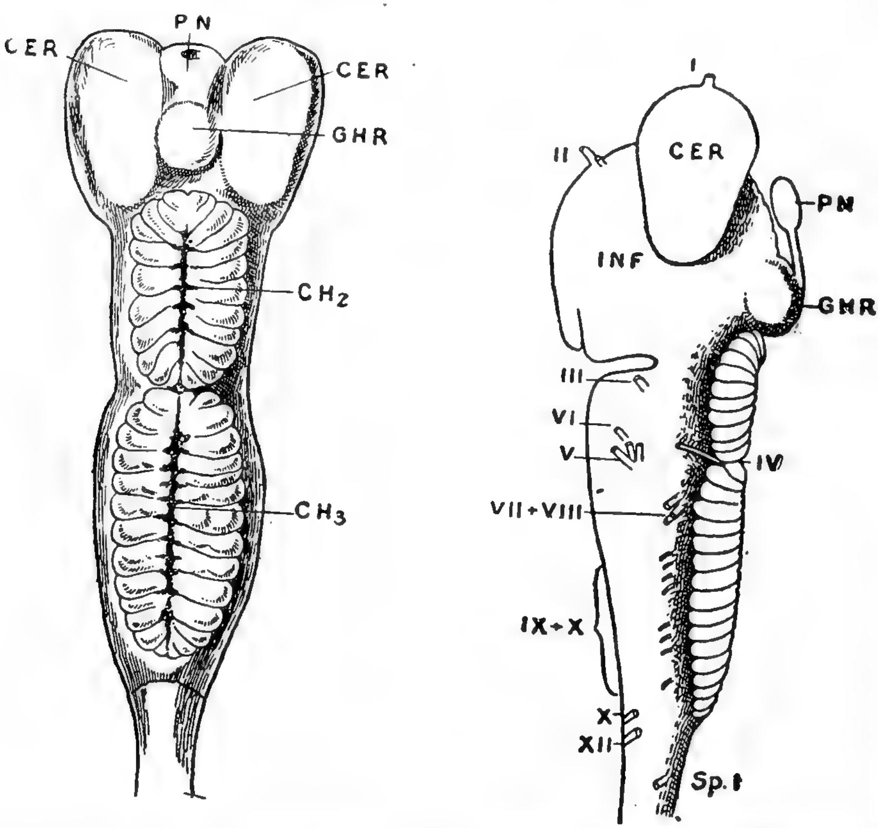
Comparison of the Central Nervous System of Ammocœtes with the Conjoined Central Nervous System and Alimentary Canal of an Arthropod Animal such as Limulus.

1. *The phylogenetic test* proves that the tube of the central nervous system was originally an epithelial tube, surrounded to a certain extent by nervous material.

The anatomical test then proves that this epithelial tube corresponds in its topographical relations to the nervous material exactly with the alimentary canal of an arthropod in its relations to the central nervous system; and, further, that the topographical relations, structure, and function of the corresponding parts of this nervous material are identical in the Ammocœtes and in the arthropod.

We see from these diagrams, taken from Edinger, how the greater simplicity of the brain region as we descend the vertebrate phylum is attained by the reduction

FIG. 2.—Dorsal and Lateral view of the Brain of Ammocœtes.



of the nervous material more and more to the ventral side of the central tube, with the result that the dorsal side becomes more and more epithelial, until at last, as is seen in Ammocœtes, the roof of the epichordal portion of the brain consists entirely of fold upon fold of a simple epithelial membrane, interrupted only in one place by the crossing of the IVth nerve and commencement of the cerebellum. In the prechordal part of the brain this simple epithelial portion of the tube is continued on in the middle line as the first choroid plexus of Ahlborn, and the lamina terminalis round to the ventral side; where, again, in the infundibular region, the epithelial saccus vasculosus, which has been becoming more and more conspicuous in the lower vertebrates, together with the median tube of the infundibulum, testifies to the withdrawal of the nervous material from this part of the brain, as well as from the dorsal region. Further, as already mentioned in my previous papers, the invasion of this epithelial tube by nervous material during the upward development of the vertebrate is beautifully shown by the commencing development of the cerebellar hemispheres in the dogfish; by the dorsal growth of nervous material to form the optic lobes in the Petromyzon; by the occlusion of the ventral part of the tube in the epichordal region to form the raphé, as seen in its commencement in Ammocœtes. Finally, evidence of another kind in favour of the tubular formation being due to an original non-nervous epithelial tube is given by the frequent occurrence of cystic tumours, and also by the formation of the sinus rhomboidalis in birds.

The phylogenetic history of the brain of vertebrates, in fact, is in complete harmony with the theory that the tubular nervous system of the vertebrate originally consisted of two parts—viz. an epithelial tube and a nervous system outside that tube, which has grown over it more and more, and gives not only no support whatever, but is in direct opposition, to the view that the whole tube was originally nervous, and that the epithelial portions, such as the choroid plexuses and roof of the fourth ventricle, are thinned-down portions of that nerve tube. Passing now to

2. *The anatomical test,* we see immediately why this epithelial tube comes out so much more prominently in the lowest vertebrates, for, as can be seen from the diagrams, and is more fully pointed out in my previous papers,[1] every part of the central tube of the vertebrate nervous system corresponds absolutely, both in position and structure, with the corresponding part of the alimentary canal of the arthropod, and the nervous material which is arranged round this epithelial tube is identically the same in topographical position, in structure, and in function as the corresponding parts of the central nervous system of an arthropod.

Especially noteworthy is it to find that the pineal eye (PN), with its large optic ganglion, the ganglion habenulæ (GHR), falls into its right and appropriate place as the right median eye of such an animal as Limulus or Eurypterus. In the following table I will shortly group together the evidence of the anatomical test.

A. *Coincidence of Topographical Position.*

Limulus and its Allies.	Ammocœtes and Vertebrates.
Alimentary Canal:—	
1. Cephalic stomach.	Ventricles of the brain.
2. Straight intestine, ending in anus.	Spinal canal, ending by means of the neurenteric canal in the anus.
3. Œsophageal tube.	Median infundibular tube and saccus vasculosus.
Nervous System:—	
1. Supra-œsophageal ganglia.	Brain proper, or cerebral hemispheres.
2. Olfactory ganglia.	Olfactory lobe.
3. Optic ganglia of the lateral eyes.	Optic ganglia of the lateral eyes.
4. Optic ganglia of the median eyes.	Ganglia habenulæ.
5. Median eyes.	Pineal eyes.
6. Œsophageal commissures.	Crura cerebri.
7. Infra-œsophageal or prosomatic ganglia, giving origin to the prosomatic nerves.	Hind brain, giving origin to the IIIrd, IVth, and Vth cranial nerves.
8. Mesosomatic ganglia, giving origin to the mesosomatic nerves.	Medulla oblongata, giving origin to the VIIth, IXth, and Xth cranial nerves.
9. Metasomatic ganglia.	Spinal cord.

[1] Gaskell, *Journ. of Anat. and Physiol.* vol. xxiii. 1888; *Journ. of Physiol.* vol. x. 1889; *Brain,* vol. xii. 1889; *Q. J. of Micr. Sci.* 1890.

B. *Coincidence of Structure and Physiological Function.*

1. The simple non-glandular epithelium of the nerve tube coincides with the simple non-glandular epithelium of the alimentary canal, ciliated as it is in Daphnia.[1]

2. The structure and function of the cerebral hemispheres, olfactory lobes, and optic ganglia closely resemble the corresponding parts of the supra-œsophageal ganglia.

3. The structure of the right pineal eye, with its nerve end-cells and rhabdites, is of the same nature as that of a median arthropod eye.

4. The structure of the right ganglion habenulæ is the same as that of the optic ganglion of the median eye.

5. The region of the hind brain, like the region of the infra-œsophageal ganglia, is concerned with the co-ordination of movements.

6. The region of the medulla oblongata, like the mesosomatic region of Limulus and its allies, is concerned especially with the movements of respiration.

7. The centres for the segmental cranial nerves resemble closely in their groups of motor cells and plexus substance the centres for the prosomatic and mesosomatic nerves, with their groups of motor cells and reticulated substance (Punkt-Substanz).

3. *The third test is the ontogenetic test.* The theory must be in harmony with, and be illustrated by, the embryonic development of the central nervous system. Such is the case, for we see that the nerve tube arises as a simple straight tube opening by the neurenteric canal into the anus, the anterior part of the tube, *i.e.* the cephalic stomach region, being remarkably dilated; the anterior opening of this tube, or anterior neuropore, is considered by most authors to have been situated in the infundibular region.

Next comes the formation of the cerebral vesicles, indicating embryologically the constricting growth of nervous material outside the cephalic stomach. First, the formation of two cerebral vesicles by the growth of nervous material in the position of the ganglia habenulæ, posterior commissure, and Meynert's bundle, *i.e.* the constricting influence of commissures between the optic part of the supra-œsophageal ganglia and the infra-œsophageal ganglia; then the formation of the third cerebral vesicle by the constricting influence of the IVth nerve and commencing cerebellum. Subsequently the first cerebral vesicle is divided into two parts by another nerve commissure—the anterior commissure, *i.e.* by nerve material joining the supra-œsophageal ganglia. Further, the embryological evidence shows that in the spinal cord region the nerve masses are at first most conspicuous ventrally and laterally to the original tube, such ventral masses being early connected together with the strands of the anterior commissure; ultimately, by the growth of nervous material dorsalwards, the dorsal portion of the tube is compressed to form the posterior fissure and the substantia Rolandi, the original large lumen of the old intestine being thus reduced to the small central canal of the adult nervous system. Finally, this nerve tube is formed at a remarkably early stage, just as ought to be the case if it represented an ancient alimentary canal.

The ontogenetic test appears to fail in two points:—

1. That the nerve tube of vertebrates is an epiblastic tube, whereas if it represented the old invertebrate gut it ought to be largely hypoblastic.

2. The nerve tube of vertebrates is formed from the dorsal surface of the embryo, while the central nervous system of arthropods is formed from the ventral surface.

With respect to the first objection, it might be argued, with a good deal of plausibility, that the term hypoblast is used to denote that surface which is known by its later development to form the alimentary canal; that in fact, as Heymons[2] has pointed out, the theory of the germinal layers is not sufficiently well established to give it any phylogenetic value. It is, however, unnecessary to discuss

[1] Hardy and McDougall, *Proc. Camb. Philos. Soc.* vol. viii. 1893.

[2] Heymons, *Die Embryonalentwickl. v. Dermapteren u. Orthopteren*, Jena, 1895.

this question, seeing that Heymons has shown that the whole alimentary tract in such arthropods as the earwig, cockroach, and mole cricket, is, like the nerve tube of vertebrates, formed from epiblast.

The second objection appears to me more apparent than real. The nerve layer, in the vertebrate, as soon as it can be distinguished, is always found to lie ventrally to the layer of epiblast which forms the central canal. In the middle line of the body, owing to the absence of the mesoblast layer, the cells which form the notochord and those which form the central nervous system form a mass of cells which cannot be separated in the earlier stages. The nerve layer in the arthropod lies between the ventral epiblast and the gut; the nerve layer in the vertebrate lies between the so-called hypoblast (*i.e.* the ventral epiblast of the arthropod) and the neural canal (*i.e.* the old gut of the arthropod). The new ventral surface of the vertebrate in the head region is not formed until the head fold is completed. Before this time, when we watch the vertebrate embryo lying on the yolk, with its nervous system, central canal, and lateral plates of mesoblast, we are watching the embryonic representation of the original Limulus-like animal; then, when the lateral plates of mesoblast have grown round, and met in the middle line to assist in forming the new ventral surface, and the head fold is completed, we are watching the embryonic representation of the transformation of the Limulus-like animal into the scorpion-like ancestor of the vertebrates.

In the Arthropoda, the simple epithelial tube which forms the stomach and intestine is not a glandular organ, and we find that the digestive part of the alimentary tract is found in the large organ, the so-called liver. This organ, together with the generative glands, forms an enormous mass of glandular substance, which, in Limulus, is tightly packed round the whole of the central nervous system and alimentary canal, along the whole length of the animal (represented in fig. 4 by the dark dotted substance). The remains of this glandular mass are seen in Ammocœtes in the peculiar so-called packing tissue around the brain and spinal cord (represented in fig. 6 by the dark dotted substance). It satisfies the three tests to the following extent:—

1. *The phylogenetic test.*—As we descend the vertebrate phylum, we find that the brain fills up the brain-case to a less and less extent, until finally in Ammocœtes a considerable space is left between brain and brain-case, filled up with a peculiar glandular-looking material, interspersed with pigment, which is not fat tissue, and is most marked in the lowest vertebrates. The natural interpretation of this phylogenetic history is that the cranial cavity is too large for the brain in the lowest vertebrates, and is filled up with a peculiar glandular substance because that glandular substance pre-existed as a functional organ or organs, and not because it was necessary to surround the brain with packing material in order to keep it steady, owing to the unfortunate mistake having been made of forming a brain much too small for its case.

2. *The anatomical test* shows that this glandular and pigmented material is in the same position with respect to the central nervous system of Ammocœtes as the generative and liver material with respect to the central nervous system and alimentary canal of Limulus.

3. *The ontogenetic test* remains to be worked out. I do not know the orgin of this tissue in Ammocœtes; the evidence has not yet been given by Kuppfer.[1] He has, however, shown that the neural ridge gives origin to a mass of mesoblastic cells, the further fate of which is not worked out. The whole story is very suggestive from the point of view of my theory, but incomprehensible on the view that the neural ridge is altogether nervous.

Finally, we ought to find in the invertebrate group in question indications of the commencement of the enclosure of the alimentary canal by the central nervous system; such is, in fact, the case. In the scorpion group a marked process of cephalisation has gone on, so that the separate ganglia, both of the prosomatic and mesosomatic region, have fused together, and fused

[1] Kuppfer, *Studien z. vergleich. Entwicklungsgesch. d. Kopfes der Kranioten* 2. Heft, München u. Leipzig, 1894.

also with the large supra-œsophageal mass. In the middle of this large brain mass a small canal is seen closely surrounded and compressed with nervous matter, as is shown in this specimen of Thelyphonus; this canal is the alimentary canal. Again, Hardy, in his work on the nervous system of Crustacea, has sections through the brain of Branchipus which demonstrate so close an attachment between the nervous matter of the optic ganglion and the anterior diverticulum of the gut that no line of demarcation is visible between the cells of the gut wall and the cells of the optic ganglion.

For all these reasons I consider that the tubular nature of the vertebrate central nervous system is explained by my hypothesis much more satisfactorily and fully than by any other as yet put forward; it further follows that if this hypothesis enables us to homologise all the other parts of the head region of the vertebrate with similar parts in the arthropod, then it ceases to be an hypothesis, but rises to the dignity of the most probable theory of the origin of vertebrates.

Origin of Segmental Cranial Nerves.

1. *The phylogenetic test.*—It follows from the close resemblance of the brain region of the central nervous systems in the two groups of animals that the cranial nerves of the vertebrate must be homologous with the foremost nerves of such an animal as Limulus, and must therefore supply homologous organs. Leaving out of consideration for the present the nerves of special sense, it follows that the segmental cranial nerves must be divisible into two groups corresponding to two sets of segmental muscles, viz. a group supplying structures homologous to the appendages of Limulus and its allies, and a group supplying the somatic or body muscles; in other words, we must find precisely what is the most marked characteristic of the vertebrate cranial nerves, viz. that they are divisible into two sets corresponding to a double segmentation in the head region. The one set, consisting of the Vth, VIIth, IXth, and Xth nerves, supply the muscles of the branchial or visceral segments; the other set, consisting of the IIIrd, IVth, VIth, and XIIth nerves, the muscles of the somatic segments. Further, we see that the nerves supplying the branchial segments, like the nerves supplying the appendages in Limulus, are mixed motor and sensory, while the nerves supplying the somatic segments are all purely motor, the corresponding sensory nerves running separately as the ascending root of the fifth nerve; so also in Limulus, the nerves supplying the powerful body muscles arise separately from those supplying the appendages, and also are quite separate from the purely sensory or epimeral (Milne Edwards) [1] nerves which supply the surfaces of the carapace in the prosomatic and mesosomatic regions. Finally, the researches of Hardy [2] have shown that the motor portion of these appendage nerves, just like the nerves of the branchial segmentation in vertebrates, *i.e.* the motor part of the trigeminal, of the facial, of the glosso-pharyngeal, and of the vagus, arise from nerve centres or nuclei quite separate from those which give origin to the motor nerves of the somatic muscles. The phylogenetic history, then, of the cranial nerves points directly to the conclusion that the Vth, VIIth, IXth, and Xth nerves originally innervated structures of the nature of arthropod appendages.

We can, however, go further than this, for we find, as we trace downwards throughout the vertebrate kingdom the structures supplied by these nerves, that they are divisible into two well-marked groups, especially well seen in Ammocœtes, viz.:—

1. A posterior group, viz. the VIIth, IXth, and Xth nerves, which arise from the medulla oblongata and supply all the structures within a branchial chamber.
2. An anterior group, viz. the Vth nerves, which arise from the hind brain and supply all the structures within an oral chamber.

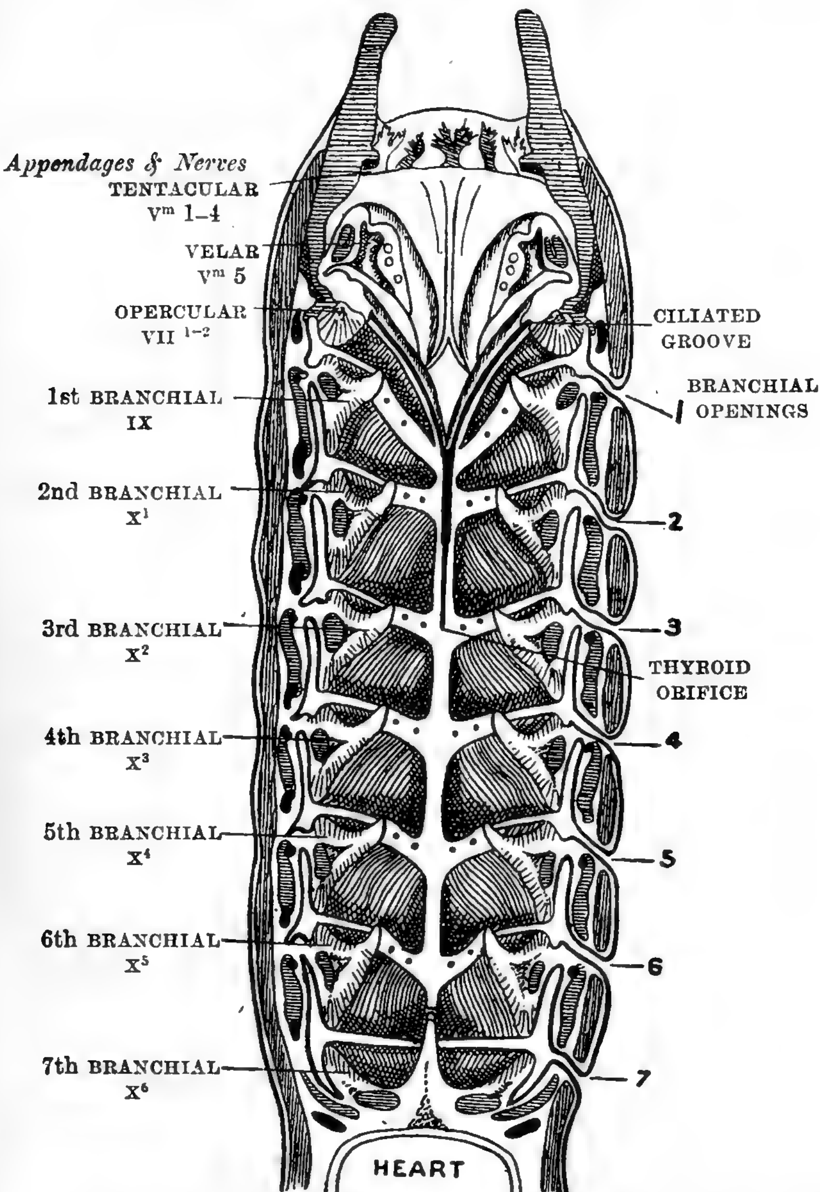
[1] Milne Edwards, 'Recherches sur l'Anatomie des Limulus,' *Ann. des Sc. Nat.*, 5th ser.

[2] Hardy, *Phil. Trans. Roy. Soc.* 1894.

The reason for this grouping is seen when we turn to Limulus and its allies, for we find that the body is always divided into a prosoma and mesosoma, and that the appendage nerves are divisible into two corresponding well-marked groups, viz.:—

1. A posterior or mesosomatic group, which arise from the mesosomatic ganglia and supply the operculum and branchial appendages.

FIG. 3.—Head Region of Ammocœtes, split longitudinally into a ventral and dorsal half. (Ventral Half.)

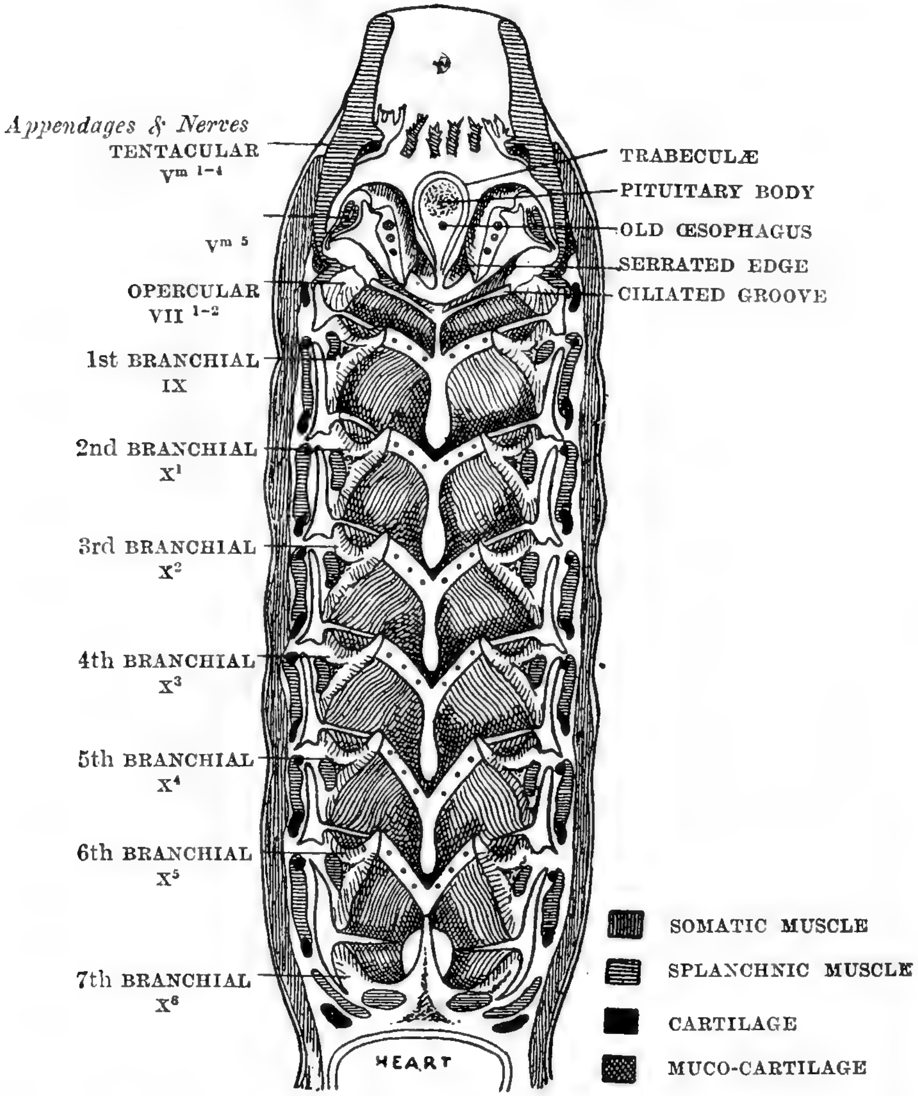


2. An anterior or prosomatic group, which arise from the prosomatic ganglia and supply the oral or locomotor appendages.

Comparison of the Branchial Appendages of Limulus, Eurypterus, &c., with the Branchial Appendages of Ammocœtes. Meaning of the IXth and Xth Nerves.

We will first consider the posterior group—the VIIth, IXth, and Xth nerves—and of these I will take the IXth and Xth nerves together, and discuss the VIIth separately. These nerves are always described as supplying in the fishes the

FIG. 3.—Head Region of Ammocœtes, split longitudinally into a ventral and dorsal half. (Dorsal Half.)



muscles and other tissues in the walls of a series of gill-pouches, so that the respiratory chamber is considered to consist of a series of pouches, which open on the one hand into the alimentary canal, and on the other to the exterior. Such a description is possible even as low down as Petromyzon, but when we pass to the Ammocœtes we find the arrangement of the branchial chamber has become so different that it is no longer possible to describe it in terms of gill-pouches. The

FIG. 4.—Limulus. Nerves of Appendages and Cartilages.

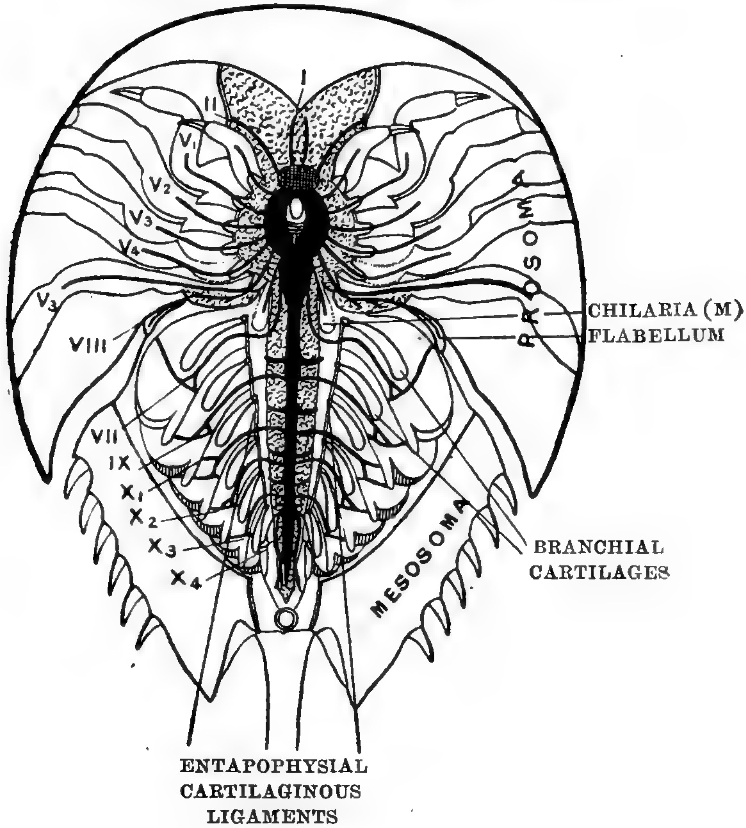


FIG. 5.—Eurypterus.

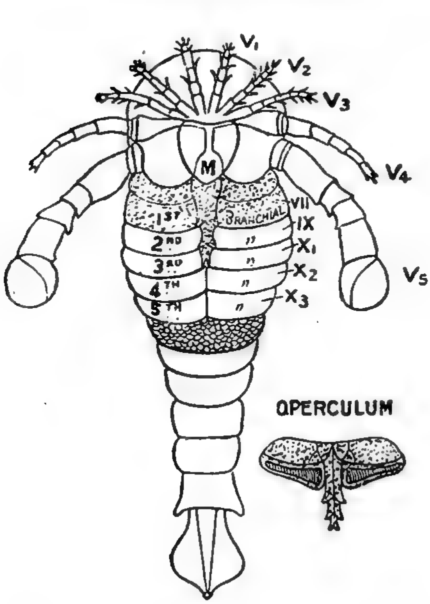
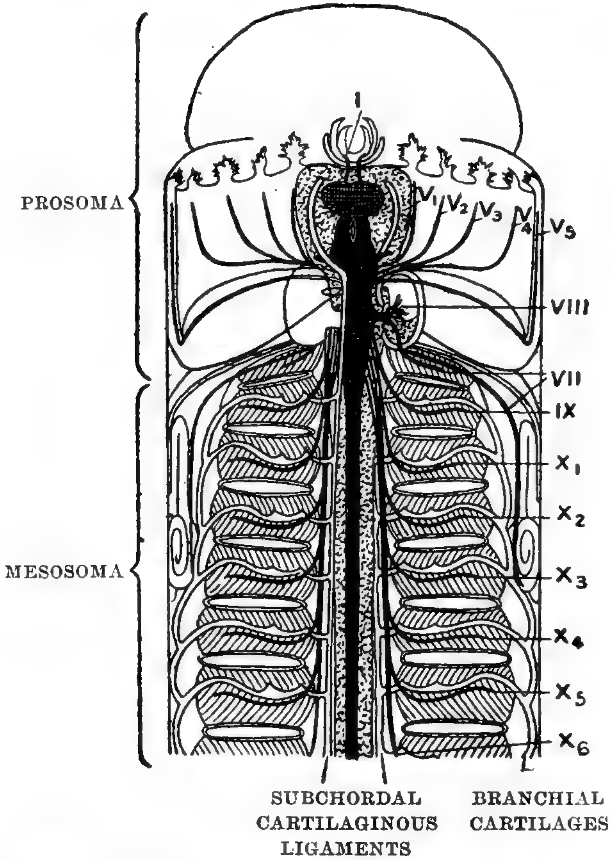


FIG. 6.—Ammocœtes. Nerves of Visceral Segments and Cartilages.



In all three Figures $v_1 - v_6$ = Prosomatic appendages and nerves; vii = 1st mesosomatic appendage or opercular appendage and nerves; ix, x_1 . . . = remaining mesosomatic appendages and nerves; M = Chilaria in Limulus, metastoma in Eurypterus.

nature of the branchial chamber is seen in fig. 3, which demonstrates clearly that the IXth and Xth nerves supply a series of separate gill-bearing structures or appendages, which hang freely into a common respiratory chamber; each one of these appendages is moved by its own separate group of branchial muscles, and possesses an external branchial bar of cartilage, which, by its union with its fellows, contributes to form the extra-branchial basket-work so characteristic of this primitive respiratory chamber. The segmental branchial unit is clearly in this case, as Rathke originally pointed out, each one of these suspended gills, or rather gill-bearing appendages; it is absolutely unnatural, as Nestler[1] attempts to do, to take a portion of the space between two consecutive gills and call that a gill-pouch. It is, to my mind, one of the most extraordinary and confusing conceptions of the current morphology to describe an animal in terms of the spaces between organs, rather than in terms of the organs by which those spaces are formed. We might as well speak of a net as a number of holes tied together with string. Another most striking advantage is obtained by considering the segmental unit to be represented by each of these separate branchial appendages—viz. that we can continue the series in the most natural manner (as seen in fig. 3) in front of the limits of the IXth and Xth nerves, and so find a series of appendages in the oral chamber serially homologous with the branchial appendages. The uppermost of the respiratory appendages is the hyo-branchial, supplied

[1] Nestler, *Archiv f. Naturgeschich.* 56, vol. i.

by the VIIth nerve, then, passing into the oral chamber, we find a series of non-branchial appendages, viz. the velar and tentacular appendages, supplied by branches of the Vth nerve. In fact, by simply considering the tissue between the so-called gill-pouches as the segmental unit, we no longer get lost in a maze of hypothetical gill-pouches in front of the branchial region, but find that the resemblances between the oral and branchial regions, which have led to the endless search for gill-slits and gill-pouches, really mean that the oral chamber contains appendages just as the branchial chamber, but that the former were not gill-bearing.

The study of Ammocœtes, then, leads directly to the conclusion that the ancestor of the vertebrate possessed an oral or prosomatic chamber, which contained a series of non-branchial, tactile and masticatory appendages, which were innervated from the fused prosomatic ganglia or hind brain, and a branchial or mesosomatic chamber, which contained a series of branchial appendages which were innervated from the fused mesosomatic ganglia or medulla oblongata. These two chambers did not originally communicate with each other, for the embryological evidence shows that they are separated at first by the septum of the stomatodæum, and also that the oral chamber is formed by the forward growth of the lower lip.

The phylogenetic test on the side of Limulus and its congeners agrees in a remarkable manner with the conclusions derived from the study of Ammocœtes, for we see that the variation which has occurred in the formation of Eurypterus from Limulus is exactly of the kind necessary to form the oral and branchial chambers of the Ammocœtes. Thus, we find with respect to the mesosomatic appendages that the free, many-jointed appendages of the crustacean become converted into the plate-like appendages of Limulus, in which the separate joints are still visible, but insignificant in comparison with the large branchiæ-bearing lamella; then comes the in-sinking of these appendages, as described by Macleod,[1] to form the branchial lamellæ, or so-called lung-books of Thelyphonus, and the branchiæ of Eurypterus, in which all semblance of jointed and free appendages disappears and the branchiæ project into a series of chambers or gill-pouches, each pair of which in Thelyphonus open freely into communication. In this way we see already the commencement of the formation of a branchial chamber similar to that of Ammocœtes.

So also with the innervation of these mesosomatic appendages, originally a series of separate mesosomatic ganglia, each of which innervates a separate appendage; then a process of cephalisation takes place, in consequence of which, in the first place, a single ganglion, the opercular ganglion, fuses with the already fused prosomatic ganglia, as is seen in the stage of Limulus; then, as pointed out by Lankester, in the different groups of scorpions more and more of the mesosomatic ganglia fuse together, and so we find the upward variation in this group is distinctly in the direction of the formation of the medulla oblongata coincidently with the formation of a branchial chamber.

In a precisely similar way, we find the variation which has occurred in the prosomatic appendages leads directly to the formation of the oral chamber and oral appendages of Ammocœtes; for the original chelate and locomotor appendages of Limulus become converted into the tactile non-chelate appendages of Eurypterus (*cf.* figs. 4 and 5), and the small chilaria (M) of Limulus, according to Lankester, fuse in the middle line and grow forward to form the metastoma of Eurypterus, thus forming an oral chamber, into which the short tactile appendages could be withdrawn, closely similar in its formation to the oral chamber of Ammocœtes. The prosomatic ganglia supplying these oral appendages have already, in Limulus (see fig. 4), been fused together to form the infra-œsophageal ganglia or hind brain.

The phylogenetic test, then, both on the side of the vertebrate and of the invertebrate, points direct to the conclusion that the peculiarities of the trigeminal and vagus groups of nerves are due to their origin from nerves supplying prosomatic and mesosomatic appendages respectively.

2. *The anatomical test* confirms and emphasises this conclusion in a most striking manner, for we find not only coincidence of topographical arrangement, as

[1] Macleod, *Archiv. de Biologie*, vol. v. 1884.

already mentioned, but also similarity of structure; thus we see that the blood in the gill lamellæ and velar appendages of Ammocœtes does not circulate in distinct capillaries, but, as in the arthropod appendages, in lacunar spaces, which by the subdivision of the surface of the appendage to form gill lamellæ become narrow channels; that also certain of the branchial muscles and of the muscles of the velar appendages are of the invertebrate type of so-called tubular muscles. These invertebrate muscles are not found in higher vertebrates, but only in Ammocœtes, and moreover disappear entirely at transformation.

Origin of the Vertebrate Cartilaginous Skeleton.

Perhaps, however, the most startling evidence in favour of the homology between the branchial segments of Ammocœtes and the branchial appendages of Limulus is found in the fact that a cartilaginous bar external to the branchiæ exists in each one of the branchial appendages of Limulus, to which some of the branchial muscles are attached in precisely the same way as in Ammocœtes. The branchial cartilages of Limulus (see fig. 4) spring from the entapophyses and form strong cartilaginous bars which are extra-branchial in position, just as in Ammocœtes, in addition to each branchial bar, a cartilaginous ligament passes from one entapophysis to another, so as to form a longitudinal or entapophysial ligament, more or less cartilaginous, which extends on each side along the length of the mesosoma. In precisely the same way the branchial bars of Ammocœtes are joined together along each side of the notochord by a ligamentous band of more or less continuous cartilaginous tissue, forming a subchordal or parachordal cartilaginous ligament.

Further, we see that this cartilage of Limulus is of a very striking structure, quite different from that of vertebrate cartilage, and that it is formed in a fibro-massive tissue which, like the matrix of the cartilage, gives a deep purple stain with thionin, thus showing the presence of some form of chondro-mucoid. This fibro-massive tissue is closely connected with the chitinogenous cells of the entapophyses.

Startling is it to find that the branchial cartilages of Ammocœtes possess identically the same structure as the cartilages of Limulus; that the branchial cartilages are formed in a fibro-massive tissue which, like the matrix of the cartilage, gives a deep purple stain with thionin, and that this fibro-massive tissue, to which Schneider [1] gives the name of muco-cartilage, or Vorknorpel, entirely disappears at transformation.

Further, according to Shipley,[2] the cartilaginous skeleton of the Ammocœtes when first formed consists simply of a series of straight branchial bars, springing from a series of cartilaginous pieces arranged bilaterally along the notochord.

The formation of the trabeculæ, of the auditory capsules, of the crossbars to form the branchial basket-work, all occur subsequently, so that exactly those parts which alone exist in Limulus are those parts which alone exist at an early stage in Ammocœtes. Another distinction is manifest between these branchial cartilages and those of the trabeculæ and auditory capsules, in that the latter do not stain in the same manner; whereas the matrix of the branchial cartilages stains red with picro-carmine, that of the trabeculæ and auditory capsules stains deep yellow, so that the junction between the trabeculæ and the first branchial bar is well marked by the transition from the one to the other kind of staining. The difference corresponds to Parker's [3] soft and hard cartilage.

The new cartilages which are formed at transformation, either in places where muco-cartilage exists before or by the invasion of the fibrous tissue of the brain-case by chondroblasts, are all of the hard cartilage variety.

The phylogenetic, anatomical, and ontogenetic history of the formation of the

[1] Schneider, *Beiträge z. Anat. u. Entwicklungsgesch. der Wirbelthiere.* Berlin, 1879.
[2] Shipley, *Quart. Journ. of Micr. Sci.* 1887.
[3] Parker, *Phil. Trans. Roy. Soc.* 1883.

vertebrate skeleton all show how the bony skeleton is formed from the cartilaginous, and how the cartilaginous skeleton can be traced back to that found in Petromyzon, and so to the still simpler form found in Ammocœtes; from this, again, we can pass directly to the cartilaginous skeleton of Limulus, and so finally trace back the cranial skeleton of the vertebrate to its commencement in the modified chitinous ingrowths connected with the entapophyses of Limulus. A similar explanation of the origin of cartilage from modifications of the chitinous ingrowths of Limulus was suggested by Gegenbauer[1] so long ago as 1858, in consideration of the near chemical resemblances between the chitin and mucin groups of substances.

Comparison of the Thyroid and Hyo-branchial Appendage of Ammocœtes with the Opercular Appendage of Eurypterus, Thelyphonus, &c. Meaning of the VIIth Nerve.

Seeing, then, how easily the IXth and Xth nerves in Ammocœtes correspond to the mesosomatic nerves to the branchial appendages in Limulus, and therefore to the corresponding nerves in such an animal as Eurypterus, we may with confidence proceed to the consideration of the VIIth nerve, and anticipate that it will be found to innervate a mesosomatic appendage in front of the branchial appendages, and yet belonging to the branchial group; in other words, if the VIIth nerve is to fit into the scheme, it ought to innervate a structure or structures corresponding to the operculum of Limulus or of Thelyphonus, &c. Now we see in figs. 5 and 8 the nature of the operculum in Eurypterus and in Thelyphonus, Phrynus, &c. It is in reality composed of two parts, a median and anterior portion which bears on its under surface the external genital organs, and a posterior part which bears branchiæ; so that the operculum of these animals may be considered as a genital operculum fused to a branchial appendage, and therefore double. It is absolutely startling to find that the branchial segment immediately in front of the glosso-pharyngeal segment in Ammocœtes (fig. 3) consists of two parts, of which the posterior, the hyo-branchial, is gill-bearing, while the anterior carries on its under surface the pseudo-branchial groove of Dohrn, which continues as a ciliated groove up to the opening of the thyroid gland.

Again, the comparison of the ventral surfaces of Eurypterus and Ammocœtes (*cf.* fig. 8) brings to light a complete coincidence of position between the median tongue of the operculum in the one animal and the median plate of muco-cartilage in the other animal, which separates in so remarkable a manner the cartilaginous basket-work of each side, and bears on its under surface the thyroid gland. Finally, Miss Alcock has shown that not only the hyo-branchial, but also the thyroid part of this segment, is innervated by the VIIth nerve; so that every argument which has forced us to the conclusion that the glosso-pharyngeal and vagus nerves are the nerves which originally supplied branchial appendages equally points to the conclusion that the facial nerve originally supplied the opercular appendage—an appendage which closed the branchial chamber in front, which consisted of two parts, a branchial and a genital, probably indicating the fusion of two segments; and that the thyroid gland belonged to the genital operculum, just as the branchiæ belonged to the branchial operculum. This interpretation of the parts supplied by the facial nerve immediately explains why Dohrn is so anxious to make a thyroid segment in front of the branchial segments, and why a controversy is still going on as to whether the facial supplies two segments or one.

What, then, is the thyroid gland? Of all the organs found in the vertebrate, with perhaps the single exception of the pineal eye, there is no one which so clearly is a relic of the invertebrate ancestor as the thyroid gland. This gland, important as it is known to be in the higher vertebrates, remains of much the same type of structure down to the fishes, and even to Petromyzon; suddenly, when we pass to the Ammocœtes, to that larval condition so pregnant with invertebrate surprises, we find that the thyroid has become a large and important organ,

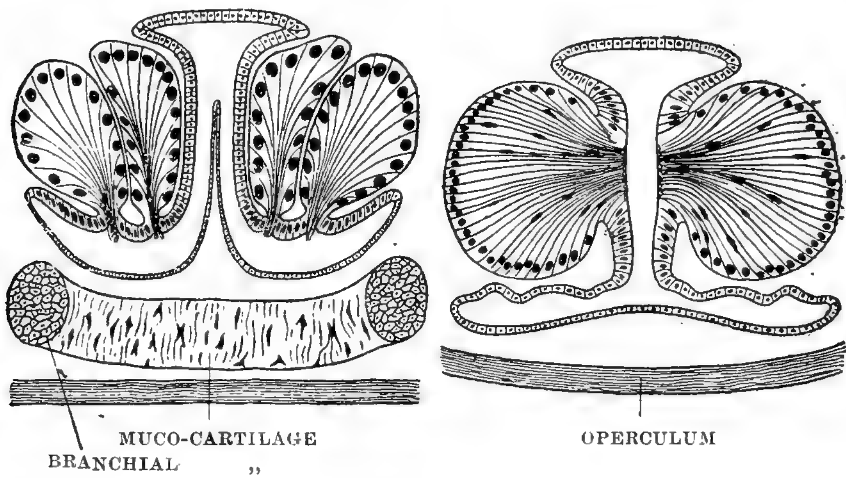
[1] Gegenbauer, 'Anat. Untersuch. eines Limulus,' *Abhandl. der Naturf. Gesellsch. in Halle*, 1858.

totally different in structure from the thyroid of all other vertebrates, though resembling the endostyl of the Tunicates.

The thyroid of Ammocœtes may be described as a long tube, curled up at its posterior end, which contains in its wall, along the whole of its length, a peculiar glandular structure, confined to a small portion of its wall.

A section through this tube is given in fig. 7, and shows how this glandular structure possesses no alveoli, no ducts, but consists of a column of elongated cells arranged in a wedge-shaped manner, the apex of the wedge being in the lumen of the tube; each cell contains a spherical nucleus, situated at the very extreme

FIG. 7.



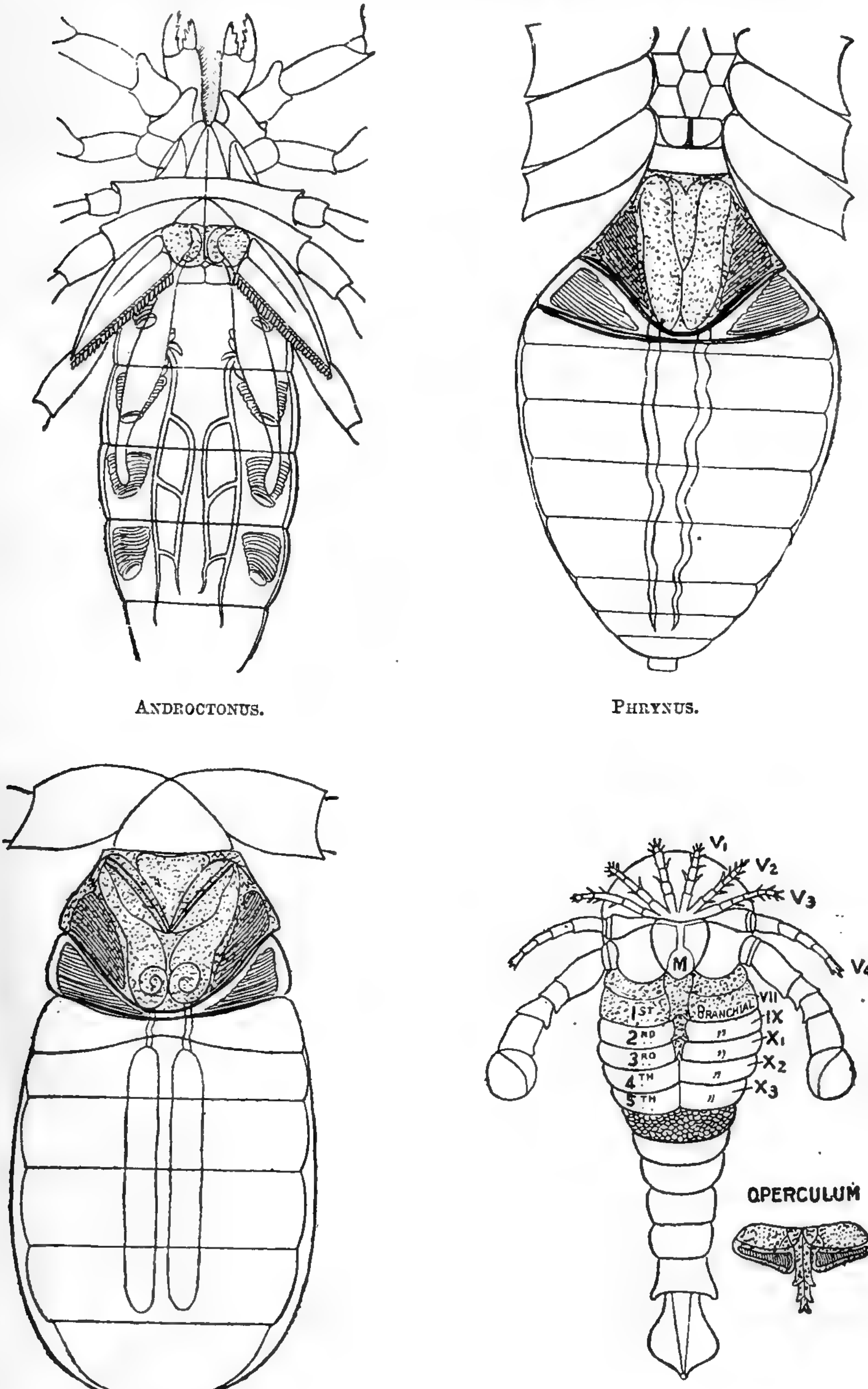
Thyroid (Ammocœtes). Thyroid (Scorpion).

end of the cell, farthest away from the lumen of the tube. Such a structure is different form that of any other vertebrate gland. Its secretion is not in any way evident. It certainly does not secrete mucus or take part in digestion, and for a long time I was unable to find any structure which resembled it in the least degree, apart, of course, from the endostyl of the Tunicates.

Guided, however, by the considerations already put forward, and feeling therefore convinced that in Eurypterus there must have been a structure resembling the thyroid gland underneath the median projection of the operculum, I proceeded to investigate the nature of the terminal genital apparatus underlying the operculum in the different members of the scorpion family, and reproduce here (fig. 8) the figures given by Blanchard [1] of the appearance of the terminal male genital organs in Phrynus and Thelyphonus. Emboldened by the striking appearance of these figures, I proceeded to cut sections through the operculum of the European scorpion, and found that that part of the genital duct which underlies the operculum, and that part only, contains within its walls a glandular structure which resembles the thyroid gland of Ammocœtes in a remarkable degree. A section is represented in fig. 7, and we see that under the operculum in the middle line is situated a tube, the walls of which in one part on each side are thickened by the formation of a gland with long cells of the same kind as those of the thyroid; the nucleus is spherical, and situated at the farther end of the cell, and the cells are arranged in wedges, so that the extremities of each group of cells come to a point on the surface of the inner lining of the tube. This point is marked by a small round opening in the internal chitinous lining of the tube. These cells form a column along the whole length of the tube, just as in the thyroid gland, so that the chitinous lining along that column is perforated by numbers of small round

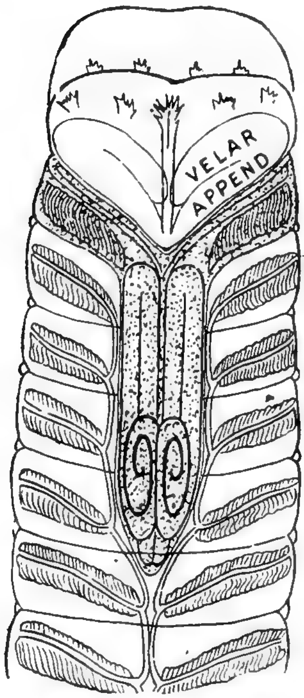
[1] Blanchard, *L'Organisation du Règne Animal.*

Fig. 8.—Comparison of the Ventral Surface of the Branchial Region.



ANDROCTONUS. PHRYNUS.

THELYPHONUS. EURYPTERUS.



AMMOCŒTES.

In all figures the opercular appendage is marked out by its dotted appearance.

holes. This glandular structure is not confined to the male scorpion, but is found also in the female, though not so well developed.

So characteristic is the structure, so different from anything else, that I have no hesitation in saying that the thyroid of Ammocœtes is the same structurally as the thyroid of the scorpion, and that, therefore, in all probability the median projection of the operculum in the old forms of scorpions, such as Eurypterus, Pterygotus, Slimonia, &c., covered a glandular tube of the same nature as the thyroid of Ammocœtes.

We see, then, that the structures innervated by the VIIth, IXth, and Xth nerves are absolutely concordant with the view that the primitive vertebrate respiratory chamber was formed from the mesosomatic appendages of such a form as Limulus by a slight modification of the method by which the respiratory apparatus of Thelyphonus and other Arachnids has been formed, according to Macleod. The anterior limit of this chamber was formed by the operculum, the basal part of which formed a septum which originally separated the branchial from the oral chamber.

Comparison of the Oral Chamber of Ammocœtes with that of Eurypterus. Meaning of the Vth Nerve.

Passing now to the oral chamber—*i.e.* to the visceral structures innervated by the Vth nerve—we find, as already suggested, distinct evidence in Ammocœtes of the presence of the modified prosomatic appendages of the original Eurypterus-like form. The large velar appendage is the least modified, possessing as it does the arthropod tubular muscles, a blood system of lacunar blood-spaces, and a surface covered with a regular scale-like pattern, formed by cuticular nodosities, similar to that found on the surface of Eurypterus and other scorpions. The velar appendages show, further, that they are serially homologous with the respiratory appendages, in that they have been utilised to assist in respiration, their movements being synchronous with the respiratory movements.

The separate part of the Vth nerve which supplies the velar appendage passes within it from the dorsal to the ventral part of the animal, and then, as Miss Alcock has shown, turns abruptly forward to supply the large median tentacle. This extraordinary course leads directly to the conclusion that this median tentacle, which is in reality double, constitutes, with the velum of each side, the true velar appendages.

Again, on each side of the middle line there are in Ammocœtes four large tentacles, each of which possesses a system of muscles, muco-cartilage, and blood-spaces, precisely similar to the median ventral tentacle already mentioned. Each of these is supplied, as Miss Alcock has shown, by a separate branch of the motor part of the Vth nerve (see fig. 6), and each branch is comparable with the branch supplying the large velar appendage.

That such tentacles are not mere sensory papillæ surrounding the mouth, but have a distinct and important morphological meaning, is shown by the fact that they are transformed in the adult Petromyzon into the remarkable tongue and suctorial apparatus: a modification of oral appendages into a suctorial apparatus which is abundantly common among Arthropods.

Finally, the Vth nerve innervates the visceral muscles of the lower and upper lips of Ammocœtes. In order, then, for the story to be complete, the homologues of the lower and upper lips must also be found in the system of prosomatic appendages of forms like Limulus and Eurypterus. The lower lip, like the opercular or thyroid appendage, possesses a plate of muco-cartilage, and, as already mentioned, falls into its natural place as the metastoma of the old Eurypterus-like form, by the enlargement and forward growth of which the oral chamber of Ammocœtes was formed. The meaning of the upper lip will be considered with the consideration of the old mouth tube. The comparison of the metastoma of Eurypterus with the lower lip of Ammocœtes demonstrates the close resemblance between the oral chambers of Eurypterus and Ammocœtes. In order to obtain the condition of affairs in Ammocœtes from that in Eurypterus, it is only necessary that the metastoma should increase in size, and that the last oral appendage, the large oar-appendage, should follow the example of the other oral appendages, and be withdrawn into the oral cavity, and so form the velar appendage.

Thus we see that, just as the mesosomatic appendages of Limulus can be traced into the branchial and thyroid appendages of Ammocœtes through the intermediate stage of forms similar to Eurypterus, so also the prosomatic appendages and chilaria of Limulus can be traced into the velar and tentacular appendages and lower lip of Ammocœtes through the intermediate stage of forms similar to Eurypterus.

3. *Lastly comes the ontogenetic test.* The concordant interpretation of the origin of the motor part of the Vth, of the VIIth, IXth, and Xth nerves given by the anatomical and phylogenetic tests must explain and be illustrated by the facts of the development of Ammocœtes.

We see:—

1. The oral chamber of Ammocœtes is known in its early stage by the name of the stomatodæum, and we find, as might be anticipated, that it is completely separated at first from the branchial chamber by the septum of the stomatodæum.

2. This septum is the embryological representative of the basal part of the operculum, and demonstrates that originally the operculum separated the oral and branchial chambers.

3. Subsequently these two chambers are put into communication by the breaking through of this septum, illustrating the communication between the two chambers by the separation of the median basal parts of the operculum.

4. The velar appendages, the tentacular appendages, the lower lip, all form as out-buddings, just as the homologous locomotor appendages are formed in arthropods.

5. The branchial bars are not formed by a series of inpouchings in a tube of uniform thickness, but, as Shipley[1] has pointed out, by a series of ingrowths at

[1] *Loc. cit.*

regular intervals; in other words, the embryological history represents a series of buddings—*i.e.* appendages within the branchial chamber similar to the buddings within the oral chamber—and does not indicate the formation of gill-pouches by the thinning of an original thick tube at definite intervals.

6. The communication of the branchial chamber with the exterior by the formation of the gill-slits represents a stage in the ancestral history which is conceivable, but cannot at present be explained with the same certainty as most of the embryological facts of vertebrate development. I can only say that Strübel[1] has pointed out, and I can confirm him, that after the young Thelyphonus has left the egg, and is on its mother's back, before the moult which gives it the same form as the adult, the gills and gill-pouches are fully formed, but do not as yet communicate with the exterior.

7. The branchial cartilages in the Ammocœtes are formed distinctly before the auditory capsules and trabeculæ, illustrative of the fact that they alone are formed in Limulus.

Comparison of the Auditory Apparatus of Ammocœtes with the Flabellum of Limulus. Meaning of the VIIIth Nerve.

The correctness of a theory is tested in two ways:—(1) It must explain all known facts; and (2) it ought to bring to light what is as yet unknown, and the more it leads to the discovery of new facts, the more certain is it that the theory is true. So far, we see that the prosomatic and mesosomatic regions of the body in Limulus and the scorpions are comparable with the corresponding regions of Ammocœtes as far as their locomotor and branchial appendages are concerned, and that, therefore, a satisfactory explanation is given of the peculiarities of the Vth, VIIth, IXth, and Xth nerves. In all vertebrates, however, there is invariably found a special nerve, the VIIIth nerve, entirely confined to the innervation of the special sense-organs of the auditory apparatus. It follows, therefore, that if my theory is true the VIIIth nerve must be found in such forms as Limulus and its allies, and that, therefore, a special sense-organ, probably auditory in nature, must exist between the prosomatic and mesosomatic appendages, at the very base of the last prosomatic appendage. At present we know nothing about the nature or locality of the hearing apparatus of Limulus. It is, therefore, all the more interesting to find that in the very position demanded by the theory, at the base of the last prosomatic appendage, is found a large hemispherical organ, to which a movable spatula-like process is attached, known by the name of the *flabellum*. This organ is confined to the base of this limb; it is undoubtedly a special sense-organ, being composed mainly of nerves, in connection with an elaborate arrangement of cells and innumerable fine hairs, which are thickly imbedded in the chitin of the upper surface of the spatula. The arrangement of these cells and hairs is somewhat similar to that of various sense-organs described by Gaubert,[2] and supposed to be auditory. When the animal is at rest this sensory surface projects upwards and backwards into the crack between the prosomatic and mesosomatic carapaces, so that while the eyes only permit a look-out forwards and sidewards, and the whole animal is lying half buried in the sand, any vibrations in the water around can still pass through this open crevice, and so reach the sensory surface of this organ.

Finally, the most striking and complete evidence that this sense-organ of Limulus is homologous with the auditory capsule of Ammocœtes is found in the fact that in each case the nerve is accompanied into the capsule by a diverticulum of the liver and generative organs. (See dotted substance in figs. 4 and 6.) In Limulus the liver and generative organs, which surround the central nervous system from one end of the body to the other, do not penetrate into any of the appendages, with the single exception of the *flabellum*.

In Ammocœtes the peculiar glandular and pigmented tissue which surrounds

[1] Strübel, *Zool. Anzeiger*, vol. xv. 1892.

[2] Gaubert, *Ann. d. Sci. Nat., Zool.*, 7th ser., tome 13, 1892.

the brain and spinal cord, and has already been recognised as the remains of the liver and generative organs, does not penetrate into the velar or other appendages, but is found only in the auditory capsule, where it enters with and partly surrounds the auditory nerve.

The coincidence is so startling and unexpected as to bring conviction to my mind that in the *flabellum* of Limulus we are observing the origin of the vertebrate auditory apparatus; and it is, to say the least of it, suggestive that in Galeodes the last locomotor appendage should carry the extraordinary racquet-shaped organs which Gaubert has shown to be sense-organs of a special character, and that in the scorpion a large special sense-organ of a corresponding character, viz. the pecten, should be found which, from its innervation, as given by Patten,[1] appears to belong to the segment immediately anterior to the operculum, rather than to that immediately posterior to it.

Comparison of the Olfactory Organ of Ammocœtes with the Camerostome of Thelyphonus. Meaning of the 1st Nerve. Also comparison of the Hypophysis with the Mouth-tube of Thelyphonus.

In precisely the same way as the theory has led to the discovery of a special sense-organ in Limulus and its allies which may well be auditory, so also it must lead to the discovery of the olfactory apparatus of the same group, for here also, just as in the case of the auditory apparatus, we are at present entirely in the dark.

The olfactory organ in such an animal as Thelyphonus ought to be innervated from the supra-œsophageal ganglia, and ought to be situated in the middle line, in front of the mouth. The mouth is at the anterior end in these animals, the lower lip or hypostoma (see fig. 9) being formed by the median projecting flanges of the basal joints of the two pedipalpi; above, in the middle line, is a peculiar median appendage called the camerostome. Still more dorsal we find in the median line the rostrum, with the median eyes near its extremity, and laterally on each side of the camerostome, and dorsal to it, are situated the powerful cheliceræ, which are considered by some authorities to represent antennæ. Of these parts the camerostome is certainly innervated from the supra-œsophageal ganglia, and upon cutting sagittal and transverse sections in a very young Thelyphonus we find that the surface is remarkably covered with very fine sense-hairs, arranged with great regularity and connected with a conspicuous mass of large cells. Upon making transverse sections through this region we see that the camerostome projects into the orifice of the mouth, and that its sense-epithelium forms, together with a similar epithelium on the lower lip, a closed cavity surrounded by a thick hedge of fine hairs. Here, then, in the camerostome of Thelyphonus is a special sense-organ which, from its position and its innervation, may well be olfactory in function, or at all events subserve the function of taste.

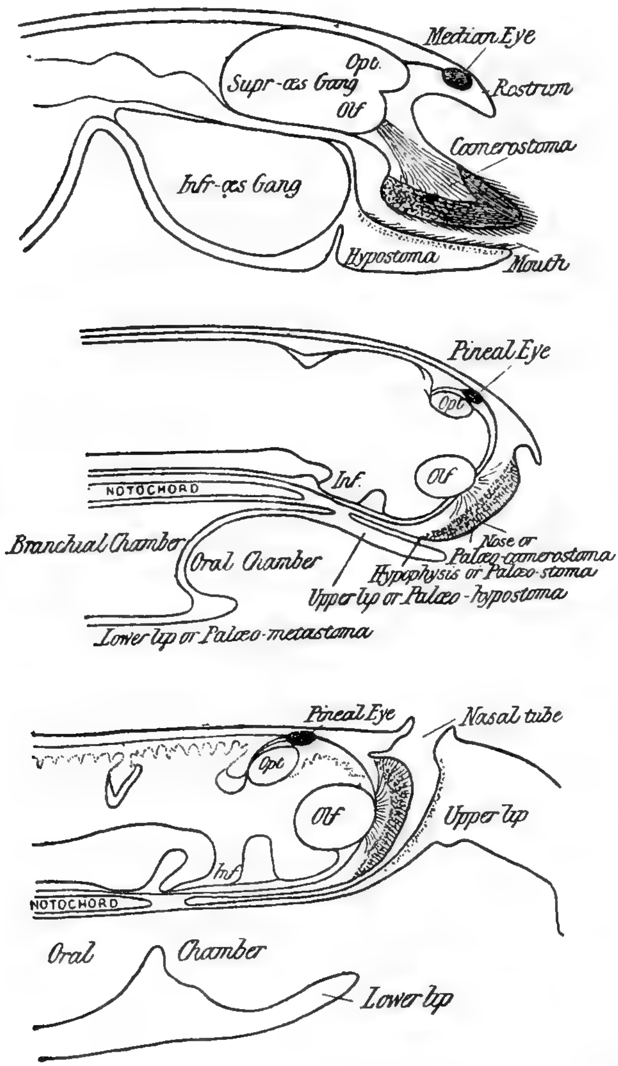
Upon comparing this organ with the olfactory organ of Ammocœtes we see a most striking resemblance in general arrangement and structure.

Just as the mouth tube of Thelyphonus is formed of two parts, the pedipalp and camerostome, so, according to Kuppfer, the nasal tube of Ammocœtes is composed of two parts, the upper lip and the olfactory protuberance. Of these two parts we see that the upper lip, or hood, like the pedipalp, is innervated by the Vth nerve, or nerve of the prosomatic appendages, while the olfactory protuberance, like the camerostome, is innervated by the 1st nerve. Kuppfer's investigations show us further (fig. 9) how the olfactory protuberance is at first free, is directed ventralwards, and lies at the opening of the hypophysial tube; how afterwards, by the forward and upward growth of the upper lip to form the hood, the nasal tube is formed, with the result that the nasal opening lies on the dorsal surface just in front of the pineal eye. Kuppfer, like Dohrn and Beard, looks upon this hypophysial tube as indicating the palæostoma, or original mouth of the vertebrate, a view which harmonises absolutely with my theory, and receives the simplest of explanations from it, for, as you see on the screen, sections through the mouth tube

[1] Patten, *Quart. Journ. of Micr. Sci.* vol. xxxi. 1890.

of Thelyphonus correspond absolutely with sections through the nasal tube of Ammocœtes; here in the one section is the projecting camerostome, there is the corresponding projection of the olfactory protuberance, here is the sense-epithelium of the lower lip or hypostoma, there is the sense-epithelium of the upper lip or hood. Here, as fig. 9 shows, the mouth tube passes in the ventral middle line to where it turns dorsalwards into the middle of the conjoined nervous mass

FIG. 9.



A.—Median sagittal section through head of young Thelyphonus.
B.— " " " " " " Ammocœte (after Kuppfer).
C.— " " " " " full-grown Ammocœte (after Kuppfer.)

of the supra- and infra-œsophageal ganglia. There the nasal tube ends blindly at the spot where the infundibular tube lies on the surface of the brain.

Further, the topography of corresponding parts is absolutely the same in the two animals: in the dorsal middle line the rostrum, with the two median eyes near its extremity; in the corresponding position the two pineal eyes; below this, in the middle line, the camerostome; corresponding to it in the Ammocœtes the olfactory protuberance; then the modification of the median projections of the foremost ventral appendages—the pedipalpi—to form the hypostoma, in the corresponding position the upper lip or hood of Ammocœtes, which forms the hypostoma as far as the hypophysial tube or palæostoma is concerned, but an upper lip as far as the new mouth is concerned. The muscles of this upper lip belong all to the splanchnic and not to the somatic group, and are innervated by the appropriate nerve of the prosomatic appendages, viz. the motor part of the Vth. Ventral to the pedipalpi in Thelyphonus there is nothing, ventral to the corresponding lip in the Ammocœtes is the lower lip, and we have seen that, although such a structure is absent in the land scorpions of the present day, it was present in the sea scorpions of old time, was known as the metastoma, and is supposed to be a forward growth which started at the junction of the prosoma with the mesosoma. Precisely corresponding to this we see from Kuppfer that the lower lip of Ammocœtes is a forward growth from the junction of the stomatodæum with the respiratory chamber.

We see then, so far, that the comparison of the vertebrate nervous system with the conjoined central nervous system and alimentary canal of the arthropod has led to a perfectly consistent explanation of almost all the peculiarities of the head region of Ammocœtes. We have solved the segmentation of the skull and the mysteries of the cranial nerves, for we have found that the cranial segmentation of the vertebrate can be reduced to the segmentation of the prosomatic and mesosomatic regions of the Limulus, that the cranial skeleton arose from the modified internal chitinous skeleton of the Limulus, that the new mouth was formed by the forward growth of the metastoma, leading to the formation of an oral chamber, while the old mouth remained as the hypophysial tube, guarded by its olfactory and taste organs.

Search as we may in the prosomatic and mesosomatic regions of scorpion-like animals, there are but few points left for elucidation; among these the most important are, 1, the fate of the cœlomic cavities and coxal gland; 2, the fate of the heart; 3, the fate of the external chitinous covering.

Comparison of the Head Cavities of the Vertebrate with the Prosomatic and Mesosomatic Cœlomic Spaces of Limulus.

A recent paper by Kishinouye [1] on the development of Limulus enables us to compare the cœlomic cavities in the head region of a vertebrate with those of the prosomatic and mesosomatic segments of Limulus, and we see that the comparison is wonderfully close; for whereas each mesosomatic segment possesses a cœlomic cavity, just as each of the segments of the branchial chamber supplied by the vagus, glossopharyngeal, and facial nerves possesses a cœlomic cavity, this is not the case with the prosomatic segments. In these latter the first cœlomic cavity is a large præoral one, common to the segment of the first appendage and all the segments in front of it; the segments belonging to the second, third, and fourth appendages have no cœlomic cavities formed in them, the second cœlomic cavity belongs to the segment of the fifth appendage. Similarly in the vertebrate in the region corresponding to the prosoma there are only two head cavities recognised, viz. the 1st præoral head cavity of Balfour and V. Wijhe; and 2nd or mandibular head cavity, associated especially with the Vth nerve. According to my view the motor part of the Vth nerve represents the locomotor prosomatic appendages of Limulus, and we see that already in Limulus the three foremost of these appendages do not form cœlomic cavities.

In fact, the agreement in the formation and position of the cœlomic cavities in the head region of the vertebrate and in the prosomatic and mesosomatic regions of Limulus could not well be more exact; further, these cavities agree in this, that in neither case are they permanent; both in the vertebrate and in the arthropod they are supplanted by vascular spaces.

[1] Kishinouye, *Journ. of Coll. of Sci. Tokio*, vol. v. 1891.

Comparison of the Pituitary Gland with the Coxal Gland of Limulus.

In connection with the second cœlomic cavity in Limulus is found an ancient gland, partially degenerated according to some views, which was probably excretory in function and has been considered as homologous to the crustacean green glands. In a precisely corresponding position, and presenting a structure fairly similar to that of the coxal gland of Limulus, we find in Ammocœtes and in other vertebrates the pituitary gland. How far this gland tissue is developed in connection with the mandibular head cavity I do not know, but I venture to suggest that the complete evidence of its homology with the coxal gland will be found in its developmental connection with the walls of the 2nd or mandibular head cavity.

Comparison of the Vertebrate Heart and Ventral Aorta with the Ventral Longitudinal Branchial Sinuses of Limulus and its Allies.

The heart of the vertebrate presents two striking peculiarities, which make it different from all invertebrate hearts: first, its developmental history is different; and, secondly, it is at first essentially a branchial rather than a systemic heart. The researches of Paul Mayer [1] have shown that the subintestinal vein, from which in the fishes the heart and ventral aorta arise, is in its origin double, so that in all vertebrates the heart and ventral aorta arise from two long veins which are originally situated on each side of the middle line. By the formation of the head fold these come together ventrally, coalesce into a single tube to form the subintestinal vein and heart, still remaining double as the two ventral aortæ with their branchial branches into each gill, as is well shown in the case of Ammocœtes.

It is a striking coincidence that in Limulus and the Scorpions two large venous collecting sinuses are found situated in the same ventral position, for the same purpose of sending blood to the branchiæ, as already described for the vertebrate; still more striking is it to find, according to the researches of Milne Edwards and Blanchard, that these longitudinal sinuses have already begun to function as branchial hearts, for they are connected with the pericardium by a system of transparent muscles, described by Milne Edwards and named by Lankester veno-pericardiac muscles. These muscles are hollow, both near the vein and near the pericardium, so that the blood in each case fills the cavity, and, as they contract with the heart, that part of them in connection with the venous collecting sinus already functions, as pointed out by Milne Edwards and Blanchard, as a branchial heart.

By this theory, then, even the formation of the vertebrate heart is prevised in Limulus, and I venture to think that in Ammocœtes we see the remnant of the old dorsal single heart of the arthropod in the form of that peculiar elongated organ composed of fattily degenerated tissue which lies between the spinal cord and the dorsal median skin.

Comparison of the Cuticular and Laminated Layers of the Skin of Ammocœtes with Chitinous Layers.

The external epithelial cells of Ammocœtes possess a remarkably thick cuticular layer. The striated appearance of this layer is due to a number of pores through which the glandular contents of the cells are poured when the surface is made to secrete. That this striated appearance is due to true porous canals, just as in chitin, and not to a series of rods, is easily seen by the inspection of sections, and also by watching the secretion through them of rose-coloured granules when the living cell is stained with methylene blue. The surface layer of this cuticular layer, according to Wolff,[2] resists reagents in the same manner as chitin.

[1] Mayer, *Mitth. a. d. Zool. St. zu Neapel*, vol. vii.
[2] Wolff, *Jen. Zeitschr.* vol. xxiii.

Internal to the epithelial cells of the skin of Ammocœtes is a remarkable layer of tissue, generally called connective tissue. It resembles, however, histologically, in the Ammocœtes, a section through chitin most closely; the layers are perfectly regular and parallel; cells are found in it with great sparseness, and it is not until after transformation, when it is altered and invaded by new cell elements, that it can be looked upon as at all resembling connective tissue. It resembles chitin in its reaction to hypochlorite of soda. In order to completely dissect off this laminated layer from an Ammocœtes, all that is necessary is to place the animal in a weak solution of hypochlorite of soda, and in a short time it entirely disappears, bringing to view the muscles, branchial cartilages, pigment, front dorsal part of the central nervous system, &c., in a most striking manner. At present I am puzzled that so manifest a chitinous covering should lie internal to the epithelial cells of the surface; such a position is not, however, unknown among invertebrates, and may be accounted for in various ways.

For the sake of clearness I will sum up before you in the form of a table the corresponding parts in Ammocœtes and in Limulus and its allies, as far as I have discussed them up to the present, from which you will see that there is not a single organ which is present in the prosomatic and mesosomatic regions of Limulus and its allies which is not found in the corresponding situation and of corresponding structure in Ammocœtes.

Table of Coincidences between Limulus and its Allies, and between Ammocœtes and Vertebrates.

LIMULUS AND ITS ALLIES.	AMMOCŒTES AND VERTEBRATES.
Central Nervous System.	
Supra-œsophageal ganglia	Cerebral hemispheres.
Optic part	Optic thalami, ganglia habenulæ, &c.
Olfactory part	Olfactory lobes.
Œsophageal commissures	Crura cerebri.
Infra-œsophageal ganglia	Epichordal brain.
Prosomatic ganglia	Hind brain, cerebellum, post-corp. quadrig.
Mesosomatic ganglia	Medulla oblongata.
Ventral chain.	
Metasomatic ganglia	Spinal cord.
Alimentary Canal.	
Cephalic stomach	Ventricular cavities of brain.
Straight intestine	Central canal of spinal cord.
Terminal part	Neurenteric canal.
Œsophagus	Infundibular tube and saccus vasculosus.
Mouth tube	Hypophysial tube, later nasal canal.
Liver	Part of subarachnoideal glandular tissue.
Appendages and Appendage Nerves.	
Prosomatic or locomotor appendages	Appendages of oral chamber or stomatodæum.
Foremost appendages	Upper lip and tentacles.
Last appendages	Velar appendage and median ventral tentacle.
Metastoma	Lower lip.
Nerves of prosomatic appendages	Various branches of Vth nerve.
Mesosomatic or branchial appendages	Appendages of branchial chamber.
Opercular appendages	Appendage innervated by VIIth nerve.
Genital part	Thyroid gland and pseudo-branchial groove.
Branch. part	Hyobranchial.
Basal part	Septum of stomatodæum.
Branchial appendages	Branchial appendages innervated by IXth and Xth nerves.
Special Sense Organs and Nerves.	
Lateral eyes and optic nerves	Lateral eyes and optic nerves.
Median eyes and nerves	Pineal eyes and nerves.

Camerostoma and olfactory nerves	Olfactory organ and Ist nerve.
Flabellum and nerve . . .	Auditory organ and VIIIth nerve.
Epimeral nerves to surface of prosoma and mesosoma . .	Sensory part of Vth nerve.
Internal and External Skeleton.	
Internal skeleton.	
Branchial cartilages . .	Branchial cartilages.
Entapophysial cartilaginous ligaments . . .	Subchordal cartilaginous ligaments.
Fibro-massive tissue (forerunner of cartilage or 'Vorknorpel'). . .	Muco-cartilage or 'Vorknorpel.'
External skeleton.	
Chitinous layer . . .	Cuticular layer on surface of body and subepithelial laminated layer.
Excretory Organs and Cœlomic Cavities.	
Coxal gland	Pituitary gland.
1st head cavity, præoral . .	1st head cavity, præoral.
2nd head cavity. Cavity of prosomatic segments . . .	2nd head cavity, mandibular.
Cavities to each mesosomatic segment	Cavities of hyoid and branchial segments.
Heart and Vascular System.	
Dorsal heart	Column of fatty tissue dorsal to spinal cord.
Longitudinal venous sinuses .	Heart and ventral aortæ.
Lacunar blood spaces of appendages	Lacunar blood spaces in velar and branchial appendages.

The Possible Meaning of the Notochord.

Although we can say that every structure and organ in the prosomatic and mesosomatic regions of Limulus, &c., is to be found in the head region of Ammocœtes, we cannot assert the reverse proposition, that every organ in the head region of Ammocœtes is to be found in Limulus, &c., for we find a notable exception in the case of the notochord, a structure which is *par excellence* a vertebrate structure, and has in consequence given the current name to the group. Such a structure is clearly not to be found in Limulus and its allies; it has evidently arisen in connection with the formation of the vertebrate alimentary canal from the oral and branchial chambers, and it evidently at one time possessed a functional significance, for the lower we descend in the vertebrate scale the more conspicuous it becomes.

Unfortunately we know nothing of the condition of the notochord in the early extinct fishes, so that we are reduced to the embryological method of enquiry in our endeavours to find out the meaning of this organ. This method appears to point to the origin of the notochord from a tube connected with the alimentary canal, originally therefore an accessory digestive tube; the reasons why such a view has been put forward are, first, the origin of the notochord from hypoblast; secondly, the evidence that it is to a certain extent tubular; and thirdly, that it is an unsegmented tube extending from the oral to the anal regions of the body. Another argument, to my mind stronger than any other, is based on the principle that nature repeats herself, and if, therefore, we find the same proliferation of cells in the same place forming a series of solid notochordal rods, we may fairly argue that we are observing a series of repetitions of the same process for the same object. Now the formation of the head region of Petromyzon shows that at first a median proliferation of hypoblastic cells occurs to form the notochord, which then separates off from the hypoblast; later on a similar proliferation takes place to form the subnotochordal rod, which similarly separates off from the hypoblast; later still, at the time of transformation, a third median proliferation of the cells of the hypoblast takes place, to form a solid rod of cells. This solid rod then commences to hollow out at the end nearest the intestine, and the hollowing out process extends gradually to the oral end, until a hollow tube is formed connecting the mouth with the intestine. In this way the new gut of the adult Petromyzon is formed from a solid median rod of cells closely resembling in its formation the original notochord.

I put it forward therefore as a suggestion, that in the ancient times when the Merostomata were lords of creation and the competition was keen among these ancient arthropod forms, in which the nervous system was so arranged that increase of brain substance tended more and more to compress the food channel, and therefore to compel to the suction of liquid food instead of the mastication of solid, accessory digestive apparatuses were formed, partly in connection with the formation of the oral and respiratory chambers, and partly by means of the formation of the notochord. Of these accessory methods of digestion the former became permanent, while the latter becoming filled up with the peculiar notochordal tissue became a supporting structure, still showing by its unsegmented character its original function. That a tube formed from the external surface either as notochord or as the respiratory portion of the alimentary canal in Ammocœtes should be capable of acting as a digestive tube is clear from the researches of Miss Alcock,[1] for she has shown that the secretion of the skin of Ammocœtes easily digests fibrin in the presence of acid. Such a secretion, like the similar secretion of the carapace of Daphnia and other crustaceans, was originally for the purpose of keeping the skin clean.

The evidence which I have put before you is in agreement with the conclusion that the fore gut of the vertebrate arose gradually from a chamber formed by the lamellar branchial appendages, which functioned also as a digestive chamber. By the growth of the lower lip, or metastoma, and the modification of the basal portion of the last locomotor appendage, which basal part was inside the lower lip, into a valvular arrangement like the velum, the animal was able to close the opening into the respiratory chamber and feed as blood-sucker in the way of the rest of its kind, or, when living food was scarce, keep itself alive by the organic material taken into its respiratory chamber with the muddy water in which it lived.

The Possible Formation of the Vertebrate Spinal Region.

It remains to briefly indicate the evidence as to the formation of the rest of the alimentary canal and the spinal region of the body.

The problems connected with the formation of this region are of a different nature from those already considered in connection with the cranial region.

In the cranial region the variation that has taken place within the vertebrate group and in the course of the formation of the vertebrate is, on the whole, of the nature called by Bateson substantive, *i.e.* increase or suppression of parts, while throughout the parts remain constant in their relations to each other. It matters not whether it is frog, fish, bird, or mammal we are considering; we always find the same cranial nerves supplying the same segments. When we consider the spinal cord and its immediate junction with the cranial region, this is no longer so; here we find a repetition of similar segments, with great variation in the amount of that repetition; here we find the characteristic feature is meristic variation rather than substantive, and so indetermined is the vertebrate in this respect that even now the same species of animal varies in the number of its segments and in the arrangement of its nerves. In this part of the vertebrate body this repetition is seen not only in the central nervous system and its nerves, but also in the excretory organs, so that embryology teaches us that the vertebrate body has grown in length by a series of repetitions of similar segments formed between the head end and the tail end; such lengthening by repetition of segments has been accompanied by the elongation of the unsegmented gut, of the unsegmented notochord, and of the unsegmented neural canal.

To put it shortly, all the evidence points to and confirms the view so strongly urged by Gegenbauer, that the head region is the oldest part and the spinal

[1] Alcock, *Proc. Camb. Phil. Soc.* vol. vii. 1891.

region an afterthought, that the attempt so often made to find vertebræ and spinal nerves in the cranial region is an attempt to put the cart in front of the horse—to obtain youth from old age. We may, it seems to me, fairly argue from the sequence of events in the embryology of vertebrates that the primitive vertebrate form was chiefly composed of the head region, and that between the head and the tail was a short body region. In other words, the respiratory chamber and the cloacal region were originally close together, just as would be the case in Limulus if the branchial appendages formed a closed chamber. According, then, to my view, there would be no difficulty in the respiratory chamber opening originally into the cloacal region, *i.e.* the same cloacal region into which the neurenteric canal already opened. The short junction tube thus formed would naturally elongate with the elongation of the body, and, as it originally was part of the respiratory chamber, it equally naturally is innervated by the vagus nerve. This, then, is the explanation of that most extraordinary fact, viz. that a nerve essentially branchial should innervate the whole of the intestine except the cloacal region. Whether this is the true explanation of the formation of the mid-gut of the vertebrate cannot be tested directly, but certain corollaries ought to follow: we ought to find, on the ground that the sequence of the phylogenetic history is repeated in the embryo, that, 1, the growth in length of the embryo takes place between the cranial and sacral regions by the addition of new segments from the cranial end; 2, the formation of the fore-gut and hind-gut ought to be completed while the mid-gut is still an undifferentiated mass of yolk cells; 3. the cloacal region ought to be innervated from the sacral nerves, while the stomach, mid-gut and its appendages, liver and pancreas, ought to be innervated from the vagus.

The first proposition is a well-known embryological fact. The second proposition is also well known for all vertebrates, and is especially well exemplified in the embryological development of Ammocœtes, according to Shipley. The third proposition is also well known, and has received valuable enlargement in the recent researches of Langley and Anderson.[1] Further, we see that in this part of the body the ancestor of the vertebrate must have had a cœlomic cavity the walls of which were innervated, not from the mesosomatic nerves or respiratory nerves, but from the metasomatic group of nerves; and in connection with this body cavity there must have existed a kidney apparatus, also innervated by the metasomatic nerves; with the repetition of segments by which the elongation of the animal was brought about the body cavity was elongated, and the kidney increased by the repetition of similar excretory organs. All, then, that is required in the original ancestor in order to obtain the permanent body cavity and urinary organs characteristic of the vertebrate is to postulate the presence of a permanent body cavity in connection with a single pair of urinary tubes in the metasomatic region of the body. As yet I have not worked out this part of my theory, and am therefore strongly disinclined to make any assertions on the subject. I should like, however, to point out that, according to Kishinouye,[2] a permanent body cavity does exist in this part of the body in spiders, known by the name of the stercoral pocket; into this cœlomic cavity the excretory Malphigian tubes open.

The Palæontological Evidence.

It is clear, from what has already been said, that the palæontological evidence ought to show, first, that the vertebrates appeared when the waters of the ocean were peopled with the forefathers of the Crustacea and Arachnida, and, secondly, the earliest fish-like forms ought to be characterised by the presence of a large cephalic part to which is attached an insignificant body and tail.

Such was manifestly the case, for the earliest fish-like forms appear in the midst of and succeed to the great era of strange proto-crustacean animals, when the sea swarmed with Trilobites, Eurypterus, Slimonia, Limulus, Pterygotus, Ceratiocaris, and a number of other semi-crustacean, semi-arachnid

[1] Langley and Anderson, *Journ. of Physiology*, vols. xviii., xix.
[2] Kishinouye, *Journ. of Coll. of Sci. Tokio*, vol. iv. 1890, vol. vi. 1894.

creatures. When we examine these ancient fishes we find such forms as Pteraspis, Pterichthys, Astrolepis, Bothriolepis, Cephalaspis, all characterised by the enormous disproportion between the extent of the head region and that of the body. Such forms would have but small power of locomotion, and further evolution consisted in gaining greater rapidity and freedom of movements by the elongation of the abdominal and tail regions, with the result that the head region became less and less prominent, until finally the ordinary fish-like form was evolved, in which the head and gills represent the original head and branchial chamber, and the flexible body, with its lateral line nerve and intestine innervated by the vagus nerve, represents the original small tail-like body of such a form as Pterichthys.

Nay, more, the very form of Pterichthys and the nature of its two large oar-like appendages, which, according to Traquair, are hollow, like the legs of insects, suggest a form like Eurypterus, in which the remaining locomotor appendages had shrunk to tentacles, as in Ammocœtes, while the large oar-like appendages still remained, coming out between the upper and lower lips and assisting locomotion. The Ammocœtes-like forms which in all probability existed between the time of Eurypterus and the time of Pterichthys have not yet been found, owing possibly to the absence of chitin and of bone in these transition forms, unless we may count among them the recent find by Traquair of Palæospondylus Gunni.

The evidence of palæontology, as far as it goes, confirms absolutely the evidence of anatomy, physiology, phylogeny, and embryology, and assists in forming a perfectly consistent and harmonious account of the origin of vertebrates, the whole evidence showing how Nature made a great mistake, how excellently she rectified it, and thereby formed the new and mighty kingdom of the Vertebrata.

Consideration of Rival Theories.

In conclusion I would ask, What are the alternative theories of the origin of vertebrates? It is a strange and striking fact how often, when a comparative anatomist studies a particular invertebrate group, he is sure to find the vertebrate at the end of it: it matters not whether it is the Nemertines, the Capitellidæ, Balanoglossus, the Helminths, Annelids, or Echinoderms; the ancestor of the vertebrate is bound to be in that particular group. Verily I believe the Mollusca alone have not yet found a champion. On the whole I imagine that two views are most prominent at the present day—(1) to derive vertebrates from a group of animals in which the alimentary canal has always been ventral to the nervous system; and (2) to derive vertebrates from the appendiculate group of animals, especially annelids, by the supposition that the dorsal gut of the latter has become the ventral gut of the former by reversion of surfaces. Upon this latter theory, whether it is Dohrn or van Beneden or Patten who attempts to homologise similar parts, it is highly amusing to see the hopeless confusion into which they one and all get, and the extraordinary hypotheses put forward to explain the fact that the gut no longer pierces the brain. One favourite method is to cut off the most important part of the animal, viz. his supra-œsophageal ganglia, then let the mouth open at the anterior end of the body, turn the animal over, so that the gut is now ventral, and let a new brain, with new eyes, new olfactory organs, grow forward from the infra-œsophageal ganglia. Another ingenious method is to separate the two supra-œsophageal ganglia, let the mouth tube sling round through the separated ganglia from ventral to dorsal side, then join up the ganglia and reverse the animal. The old attempts of Owen and Dohrn to pierce the dorsal part of the brain with the gut tube either in the region of the pineal eye or of the fourth ventricle have been given up as hopeless. Still the annelid theory, with its reversal of surfaces, lingers on, even though the fact of the median pineal eye is sufficient alone to show its absolute worthlessness.

Then, as to the other view, what a demand does that make upon our credulity! We are to suppose that a whole series of animals has existed on the earth, the development of which has run parallel with that of the great group of appendiculate animals, but throughout the group the nervous system has always been dorsal to the alimentary canal. Of this great group no trace remains, either alive at the present day or in the record of the rocks, except one or two aberrant, doubtful forms, and the group of Tunicates and Amphioxus, both of which are to be looked upon as degenerate vertebrates, and indeed are more nearly allied to the Ammocœtes than to any other animal. This hypothetical group does not attempt to explain any of the peculiarities of the central nervous system of vertebrates; its advocates, in the words of Lankester, regard the tubular condition of the central nervous system as in its origin a purely developmental feature, possessing no phylogenetic importance. Strange power of mimicry in nature, that a tube so formed should mimic, in its terminations, in its swellings, in the whole of its topographical relations to the nervous masses surrounding it, the alimentary canal of the other great group of segmented animals so closely as to enable me to put before you so large a number of coincidences.

Just imagine to yourselves what we are required to believe! We are to suppose that two groups of animals have diverged from a common stock somewhere in the region of the Cœlenterata, that each group has become segmented and elongated, but that throughout their evolution the one group has possessed a ventral mouth, with a ventral nervous system and a dorsal gut, while in the other—the hypothetical group—the mouth and gut have throughout been ventral and the nervous system dorsal. Then we are further to suppose that, without being able to trace the steps of the process, the central nervous system in the final members of this hypothetical group has taken on a tubular form of so striking a character that every part of this dorsal nerve-tube can be compared to the dorsal alimentary tube of the other great group of segmented animals. The plain, straightforward interpretation of the facts is what I have put before you, and those who oppose this interpretation and hold to the inviolability of the alimentary canal are, it seems to me, bound to give a satisfactory explanation of the vertebrate nervous system and pineal eye. The time is coming, and indeed has come, when the fetish-worship of the hypoblast will give way to the acknowledgment that the soul of every individual is to be found in the brain, and not in the stomach, and that the true principle of evolution, without which no upward progress is possible, consists in the steady upward development of the central nervous system.

In conclusion, I would like to quote a portion of the last letter which I ever received from Professor Huxley; his words, in reference to this very subject, were as follows: 'Go on and prosper, there is nothing in the world of science half so good as an earthquake hypothesis, if it only serve to show the firmness of the foundations on which we build.' I have given you the earthquake hypothesis; it is for those of you who oppose my conclusions to prove the firmness of your foundations.

THURSDAY, SEPTEMBER 17.

The following Papers and Report were read:—

1. *The Genesis of Vowels.* *By* R. J. LLOYD, *D.Lit., M.A.*

After a general description of the vocal organs, the author classified vocal sounds according to origin as follows:—

1. Glottal (originating from the glottis).
2. Stomatic (originating from the stoma, or voice-passage).
3. Glotto-stomatic (originating from both simultaneously).

Class 2 may also be called *toneless*; but the others always either possess tone or are whispered. Class 2 cannot, strictly speaking, be either intoned or whispered.

The movable units of speech (corresponding roughly to the letters of the alphabet) are called *phones.* Phones are either vowels or consonants. The received division is somewhat arbitrary. Any phone which is the most sonorous phone in a syllable is the vowel of that syllable. There is hardly any phone which does not function in some locution of some language as a vowel. In the English words *able, bitten, paddled, hadn't, l* and *n* are vowels, but we are afraid to call them so, because the *Latin* grammar forbids it. It is clear from their function that the best phones for vowels must always be the strongest phones. The strongest phones all belong to Class 1, because here only does the larynx vibrate with perfect freedom. But there are wide differences within this class. The sounds of *m*, *n*, and *ng*, issuing only through the nostrils, are obstructed by insufficiency of exit, and the same applies to the sounds of *l*, untrilled *r*, consonantal *y*, and *w*. Thus good vowels are limited to glottal phones possessing a sufficient exit.

There is still a further limitation. The number of possible vocalic articulations is infinite. The number of articulations which produce vowels possessing a definite individuality of timbre is very few. These are the useful vowels, the cardinal vowels of human speech [Diagrams of the articulations of English long vowels were here exhibited]. Vowels produced in other positions are much more feebly differentiated to the ear. In a paper read at the Cardiff meeting in 1891, the author laid down as the first law of vowel-production *Like articulations produce like vowels* in all organisms, great or small. He now discussed the converse proposition, and showed its limitations: (1) in different individuals, (2) in the same individual on different occasions. He then discussed the differences between sung and spoken vowels, and concluded by pointing out the occasional effects of the uvula, the nose, and the trachea on vowels.

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2. *The Interpretation of the Phonograms of Vowels.* *By* R. J. Lloyd, *D.Lit.*, *M.A.*

Following up his papers 'On the Analysis of Vowel-Sounds,' read at Cardiff in 1891, and 'On the Genesis of Vowels,' read at the present Meeting, the author proceeded to discuss the phonographic evidence which has become accessible in the last five years, and the right principles of its interpretation. Their general result is to confirm the theory then advanced by the author, that a given vowel is essentially distinguished by the interval or ratio between its resonances and not by their actual pitch. Detailed results were exhibited in a table. The figures of actual pitch therein given are true only of full-sized male organisms, articulating widely, as in singing. In actual speech the air-spaces are more or less compressed and the resonances are higher. This is especially true of the middle members, marked *c* in the series. This letter *c* (= circa) indicates also in the same vowels a resonance which spreads some distance both ways from the value given. The identification of the β-resonances with those of the mouth is fairly certain; that of the a-resonances with those of the pharynx is more tentative, and subject to certain qualifications, especially in the latter half of the table. The γ-resonance seems special to the *a* vowels, and is perhaps due to the trachea.

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3. *Report on Physiological Applications of the Phonograph.*

See Reports, p. 669.

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4. *On a New Method of Distinguishing between Organic and Inorganic Compounds of Iron in the Tissues.* *By* Professor A. B. Macallum, *M.B.*, *Ph.D.*, *Toronto.*

The reagents hitherto at the service of the physiologist for distinguishing between organic and inorganic iron compounds have not enabled the investigator to determine whether iron compounds in the fœtal liver, the placenta and spleen, which react almost immediately with ammonium sulphide, are of inorganic or organic nature. An additional reagent is to be found in an absolutely pure aqueous solution of hæmatoxylin, which gives a yellow colour to all preparations of tissues, but when inorganic iron compounds are present these change the colour to blue or bluish-black. Organic iron compounds have no effect on the reagent.

5. *On the Different Forms of the Respiration in Man.* *By* W. Marcet, *M.D.*, *F.R.S.*

The different forms may be thus stated:—

1. Normal, automatic (unconscious) breathing.
2. Forced breathing
3. Breathing in exercise.
4. Breathing under the influence of a strong effort of volition.

Forced breathing.—If a succession of deep inspirations be taken, the tracing rises much more steeply than normal, a pause (apnœa) follows, and then breathing returns increased beyond normal, after which the line returns parallel to normal. Forced breathing includes sneezing, and sighing, and yawning.

Exercise breathing.—In exercise such as stepping, the line rises more steeply than normal, there is no pause or cessation of exercise, but the line continues steeper than normal for some time and gradually returns parallel to normal.

Volition breathing.—If the volition be exercised strongly towards muscular work of some kind, though with the muscles at rest, the volume of the air inspired is increased beyond the normal. On dropping the effort of volition a respiratory pause follows, and then increased breathing and gradual return to normal, the tracing taking much the same direction as in forced breathing. If, however, the volition be directed towards the respiration there is no pause, but the line returns parallel to normal almost directly. Volition for any kind of muscular exercise produces the pause, but when the attention is directed towards the respiration there is no apnœa.

Even when exercise such as stepping or gyrating the arms is taken, when the volition is exerted as strongly as possible towards the exercise, on dropping the effort of volition, even though the exercise be continued, the pause is still strongly marked.

The only possible explanation of the occurrence of the pause is that when the attention is directed towards the respiration only one brain centre is concerned, and hence when the effort of volition is dropped no time is lost before the centre of respiration asserts itself; whereas when the volition is exerted towards some form of exercise, two brain centres are concerned, and on dropping the effort of volition, some time (a few seconds) is lost before the centre of respiration has shaken off the influence of the centre of locomotion; and it is to this that the pause must be due, and not any excess of oxygen in the blood, as the automatic respiration of 50 per cent. oxygen produces no pause.

FRIDAY, SEPTEMBER 18.

The following Papers were read:—

1. *The Occurrence of Fever in Mice.* *By* Professor J. Lorrain Smith, *M.A.*, *M.D.*, *Queen's College, Belfast*, *and* F. F. Wesbrook, *M.D.*, *Minneapolis, U.S.A.*

Krehl's investigation on the production of fever in various species of animals has proved that a great difference exists in the extent to which some of the smaller mammals react to fever-producing substances. It is comparatively easy, he found, to produce fever in rabbits. Guinea-pigs and dogs were more resistent, and in the case of the hedgehog it was impossible, so far as his research was carried, to produce the condition at all. Similar results were obtained with pigeons and chickens. The present research attempts to discover whether in the case of mice the same difficulty in the production of fever exists; and, if so, whether there is at the same time an absence of the changes in metabolism which in other animals accompany fever.

A variety of microbes were used, including *B. pyocyaneus*, *B. anthracis*, *B. murisepticus*, and hay infusion. These were used in various degrees of virulence, but whether the rapidly fatal form or that which was more attenuated was inoculated, in no case did the effects include a rise in temperature. In three of the mice the respiratory exchange, and in five others the respiratory and nitrogenous exchanges, were observed. The temperature of the mouse varies from 35° C. to 39·2° C., and the average of seventy observations on normal mice, living in ordinary conditions, was 37·6° C. The highest temperature we obtained in inoculated mice was 40° C., and this we observed only once.

The variations in respiratory exchange were never so great as to be compared with those which can be obtained by giving food, or especially those due to varying the temperature of the surrounding air. As regards nitrogen it is possible in the case of mice to approximate very closely to balance in the normal condition. In the case of infected mice there was never obtained any increase in the excretion of nitrogen sufficient to warrant us in inferring that the metabolism had been disturbed.

The food supplied to the mice was dog biscuit, and with this the amount of nitrogen consumed per kilo was somewhere about twenty times as great as that taken by man per kilo (19·58 per kilo being the average).

This result is important, inasmuch as the gaseous exchange in the two cases shows an almost similar ratio. Since the demands for heat production in the economy of the mouse must be enormously greater than those in man this result throws some doubt on any attempt to regard the oxidation of carbon, &c., as exclusively concerned in heat production.

The conclusion involves the severance between fever and the infectious process in some of the most susceptible animals, and indicates anew the necessity of studying the occurrence of this condition in the separate species.

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2. *The Physiological Effects of 'Peptone' when Injected into the Circulation. By* Professor W. H. Thompson, *M.D., Queen's College, Belfast.*

This communication dealt with two of the effects of Witte's 'peptone' when introduced into the system of the dog by intravenous injection, viz. (1) Its influence on the rapidity of blood coagulation, and (2) the manner in which this substance brings about its well known vascular dilatation.

The animals were anæsthetised in the first place by a hypodermic injection of morphine and atropine, and subsequently, when necessary, by chloroform or a mixture of chloroform and ether. Curare was administered in certain cases.

A solution of Witte's 'peptone' in 0·7 per cent. sodium chloride was then rapidly injected into the femoral vein, blood-pressure being recorded from the carotid artery.

The results obtained were:—

1. That Witte's peptone in doses below two centigrammes per kilo *hastens* blood-coagulation, while in larger doses retardation of this process is caused, as other observers have found.

2. That this substance produces a fall of blood-pressure in doses as low as fifteen or even ten milligrammes per kilo. Differences between these results and those of others, in regard to the magnitude of the dose, probably depend on differences in the rate of injection employed. When slowly injected considerable quantities may be introduced without affecting blood-pressure.

3. That the fall of blood-pressure produced by this substance is due to a *peripheral* dilating influence on the blood-vessels. No 'central' influence has so far been proved.

4. That the vascular dilatation is not confined to the splanchnic area, but extends to other blood-vessels as well.

5. That the peripheral dilating influence is brought about by depressing the irritability of the neuro-muscular apparatus of the blood-vessels, rendering it irresponsive to vaso-constricting impulses.

6. It is probable that the depression of irritability is chiefly limited to the nervous segment of the neuro-muscular couple.

In arriving at the above results the following series of experiments were performed:—

Series *a*, in which the effects of small doses on blood-coagulation and blood-pressure were observed.

Series *b*, in which the effects of 'peptone' on blood-pressure *after section of the spinal cord* were observed.

Series *c*, in which its effects on blood-pressure *during excitation of the spinal cord* (after section) were studied.

Series *d*, in which its influence on blood-pressure *during excitation of the great splanchnics* (after section) was noted.

Series *e*, in which its effects on blood-pressure were recorded, *the great splanchnics being severed and the spinal cord excited* (after section) *during and subsequent to the injection.*

The research was carried out in Monsieur Dastre's laboratory at the Sorbonne, Paris.

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3. *On the Nerves of the Intestine and the Effects of Small Doses of Nicotine upon them. By* J. L. Bunch, *M.D., B.Sc.* (*From the Physiological Laboratory, University College, London.*)

1. Description of method adopted in the research for recording movements of the intestine.

2. When means are taken to eliminate its action on the heart, stimulation of the peripheral cut end of the vagus is found not to influence the intestinal movements (Dog, Cat).

3. The splanchnics probably contain fibres causing both contraction and dilatation of the intestine. Stimulation of the peripheral cut end usually causes contraction; rarely dilatation, never simple inhibition of movements.

4. The nerve roots which cause the maximum effect on the intestine when electrically stimulated are the 8th to 13th post-cervical.

5. Intravenous injection of small doses of nicotine puts the nerve roots out of action before the splanchnics; there is probably, therefore, a cell station for these fibres in the ganglia of the chain.

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4. *On the Effect of Peritonitis on Peristalsis. By* A. S. Grünbaum, *M.A., M.B. (Cantab.), M.R.C.P.*

Peritonitis was excited in rabbits by the injection of turpentine and other substances into the peritoneal cavity. The peristalsis was examined in the first instance through the shaved abdominal wall, and subsequently, by opening the abdomen with the animal immersed in normal saline solution at 38° to 39° C.

In the first twenty-four hours the peristalsis of both large and small intestine was increased; it then gradually diminished until complete paralysis resulted in about four days. The large intestine became paralysed before the small intestine.

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5. *The Glucoside Constitution of Proteid Matter. By* F. W. Pavy, *M.D., LL.D., F.R.S.*

Glucosides have long been known to chemists as a class of bodies which by the agency of ferments, or by the action of acids and alkalies, and even to a slight extent of water at elevated temperatures, undergo a cleavage or disruption with a carbohydrate as one of the products.

Until recently it is only in connection with the vegetable kingdom that these bodies have been recognised as existing, but it can now be said that it will probably be found that they play an important part as constituents of the animal economy.

They are met with as bodies presenting all grades of complexity of composition. In some, of which salicin may be adduced as an example, only the three elements, carbon, hydrogen, and oxygen are present. In others, of which amygdalin is an example, the four elements, carbon, hydrogen, oxygen, and nitrogen, exist. In myronic acid, a glucoside obtainable from the seed of the black mustard, we have the four elements that have been named, with the addition of sulphur. These are bodies of comparatively simple composition, and from them advance can be made to the complex bodies forming the basis of living matter. Mucin, found not only in mucus, but forming also a constituent of connective tissue, was a short time ago shown by Landwehr to fall in the category of glucosides. In my 'Physiology of the Carbohydrates,' published in 1894, p. 27 *et seq.*, I supplied evidence showing that proteid matter generally, alike of the animal and vegetable kingdoms of nature, is in constitution a glucoside.

As mentioned in the work referred to, I was led to this discovery in the course of my quantitative examination of the various structures of the body for glycogen. The process I had for many years adopted consisted of dissolving by boiling with potash, pouring into alcohol, collecting the precipitate, converting into glucose with sulphuric acid, and titrating with the copper test. I had been regarding the product derived from the structures as consisting of glycogen, but I subsequently learnt that it was influenced in quantity by duration of the exposure in contact with potash, and by the strength of the potash solution employed.

If glycogen only had constituted the source of the product obtained, the circumstances ought to have been otherwise. The treatment with potash should have produced no effect beyond dissolving the associated nitrogenous matter and placing it in a position to be separable by the agency of the alcohol, and no difference in the amount of product obtained should have resulted from varying the strength of the alkali or the length of time of contact. The conclusion became inevitable that there must be something besides glycogen to give rise to the result, and the only feasible conclusion was that an amylose carbohydrate was derived from a cleavage of the proteid molecule.

Having found that from a variety of proteids drawn from both animal and vegetable sources I could obtain carbohydrate, evidently derivable from a breaking-up of the proteid, and it is to be said in no insignificant amount, I took purified egg albumen as a material for the further study of the subject.

Summarily, it may be stated, as the result of this study, that by the agency of potash an amylose carbohydrate, corresponding with Landwehr's animal gum, is procurable, which is convertible by sulphuric acid into a body giving the various characteristic reactions of sugar.

By the direct action of sulphuric acid sugar at once is yielded, and the same occurs as a result of pepsin digestion.

Details are given in full upon these points in my work, to which I have already referred; and in my 'Epicriticism' (Churchill, 1895) analytical evidence is supplied from the laboratory of Mr. Ling, affording conclusive proof that the osazone obtainable from the product is a sugar osazone.

Since the publication of my results I have found that they are to the fullest extent corroborated by analytical experiments performed by the distinguished chemist Schützenberger upwards of twenty years ago. Schützenberger studied the products arising from the breaking-up of egg albumen by strong chemical agents, and his paper on the subject is contained in the 'Bull. de la Soc. Chim. de Paris,' vol. xxiii. (1875), p. 161.

Speaking of the products derived from the treatment with sulphuric acid, he mentions a non-azotised body which energetically reduced Fehling's solution, was precipitable by the ammoniated acetate of lead solution, and which, in his own words, 'paraît être de la glucose ou un corps analogue.'

Again, after exposing egg albumen with baryta to 100° C. for 120 hours, he obtained a non-azotised body, insoluble in alcohol, precipitable by the ammoniated acetate of lead, not reducing Fehling's solution, but transformable by boiling with sulphuric acid into a body which does so. Its elementary composition was found to be very close to that of dextrose, with which, remarks Schützenberger, it presents the greatest analogy. Evidently, he continues, there is a connection between the body obtained in the experiments with baryta and the cupric oxide reducing substance obtained in the experiments with sulphuric acid.

My own experiments were started upon grounds totally different from those which suggested the purely chemical investigation of Schützenberger. Sulphuric acid was used in common by us, but baryta took the place of the potash used by me. It is interesting to note the strict conformity traceable in the results, but persons have failed to see the importance of Schützenberger's work, for till now all the attention it has received is a passing allusion here and there to the bare facts observed.

That proteid matter, however, should thus constitute a glucoside is, I consider, a point of the deepest physiological interest, and that such should be its nature simply stands in harmony with what is to be learnt with respect to its formation.

For instance, taking Pasteur's experiments on the growth of yeast, irrefutable evidence is afforded that carbohydrate matter is appropriated in the construction of proteid. Pasteur showed that yeast cells freely multiply in a medium consisting of sugar, ammonium tartrate, the ash of yeast, and water. The growth that takes place implies a growth of cell protoplasm, and with it a corresponding formation of proteid matter. The ammonium nitrate, which contains no carbon, may be substituted for the ammonium tartrate, and then absolutely the only source for the carbon of the proteid is the sugar that is present.

Incorporated during its construction, the carbohydrate çan be withdrawn, as I have shown, from proteid matter by the cleaving power of chemical and ferment action. The position we are thus placed in is this. The carbohydrate of our food is in part applied to the construction of proteid matter, and in this locked-up state may be conveyed to the tissues for their growth and renovation without running off as waste material through the kidney, as could not do otherwise than occur if it were conveyed as sugar in a free form. From the proteid of the tissues it may be cleaved off by ferment agency, and probably this is the source of the carbohydrate found to be present to a certain extent in a free state in connection with the various components of the body. There is no doubt that in the grave form of diabetes the sugar eliminated is derived, not only from the food, but also from the tissues, and the glucoside constitution of proteid matter fits in with and affords a ready explanation of the state of things, all that is wanted being the existence of the requisite ferment agency.

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6. *The Discharge of a Single Nerve Cell.* *By* Professor F. GOTCH, *F.R.S.*

The electrical organ of *Malapterurus electricus* is innervated on each side by the axis-cylinder branches of a simple nerve cell. The response of the organ to stimulation presents characteristics which can only be explained on the assumption that it is the change in the nerve endings of these axis-cylinder branches. In consequence of these two facts, the time relations of the organ response to reflex stimulation afford grounds for deductions as to those of the single nerve cell discharge by which the response is evoked. These time relations may be divided into two classes: (1) The propagation time through the cell and its connections, *i.e.* central delay; (2) the periodicity of the excitatory changes issuing from the cell, *i.e.* reflex rhythm.

1. Experiments show with regard to the central delay, that it has a minimum of ·01 second. This delay is, in the opinion of the author, due to the character of the structural path, which in the central mechanism consists of (*a*) fine axis-cylinder branches of both afferent nerves and cell processes; (*b*) an unknown field of conjunction; (*c*) the body of the nerve cell.

In the efferent nerve branches a delay of ·003 second exists both in muscles and in electrical organs, which is termed the nerve ending excitatory delay. If such delay, due to retarded propagation, is present in the central fine nerve endings, then ·006 second of the total time would be accounted for; the remaining time would then be distributed over the other structures.

2. The rhythm of the electrical reflex responses is a slow one in Malapterurus with a maximal rate of 12 per second. Superimposed on this rhythm is a rapid peripheral organ rhythm due to self-excitation, and in no way due to central nervous discharge.

The rate of 12 per second is not often met with, and a series of this type has very few members, at most two or three. The most frequent rate is one of 4 per second.

The number of members of even this slower type is limited to from two to six.

The experiments thus show that the single nerve cell discharge can occur at 12 per second, but that it generally occurs at slower intervals, and in all cases rapidly fails.

The contrast offered by these results to those of Torpedo, in which the central rhythm varies from 100 to 30 per second, suggests that the latter owes its rapid periodicity to the large number of nerve cells which innervate the Torpedo organ, and which are thrown into successive activity.

SATURDAY, SEPTEMBER 19.

The following Papers were read:—

1. *On the Principles of Microtome Construction.* *By* Charles S. Minot, *Professor at the Harvard Medical School, Boston, Massachusetts.*

With the advance of biology, particularly in the domains of embryology and cytology, we have passed during the last twenty-five years through a complete revolution of methods, with the result that the microtome has become as indispensable as the microscope, and hence the construction of microtomes may fittingly occupy the attention of the Physiological Section of this Association.

The first object of a microtome is to make sections of even and known thickness; the second object is to make sections in large numbers of uniform thickness; the third object is to make sections rapidly. Finally, in recent years, there has been a growing and justified demand for microtomes to make good sections of great thinness, if possible not over one five-hundredth of a millimeter or two microns (0·002 mm.). Now, sections which vary more than one-tenth from their supposed thickness, can in the case of stained animal tissues be readily recognised by the naked eye as uneven, hence, it is obvious that the thinner the section the less must be the amount of absolute error in the cutting. For example, an error of 0·002 mm. is the maximum admissible for sections of 0·002 mm. (500 to a millimeter), though a much greater error would not be noticeable in sections of 0·01 mm. Applied to the microtome this means that a roughly made instrument is sufficient for thick sections, but the most perfect construction is necessary to secure a microtome for fine cutting.

In the automatic microtome, worked by a revolving wheel, which I have devised, and which is now made in England, Germany and France, as well as in America, the attempt is made to secure mechanical perfection, and so far successfully that sections of 1/300 mm. may be made with it. The microtome is, however, adapted only to cutting objects imbedded in paraffin. The model shown is the latest American pattern, and has certain minor improvements which have increased the accuracy and precision of the instrument.

A second microtome was also shown, which is novel in construction, and is suited for both paraffin and celloidine cutting. In designing this microtome precision was made the first object. The usual sources of error are—(1) in the bending of the knife; (2) the yielding of the object to be cut, chiefly because it is borne on an arm, which acts as a lever; (3) the 'jumping' of the sliding gear. All these defects are at their maximum in the Rivet type of microtome, of which the best known form is the Heidelberg or Thoma-Jung microtome. To obviate these errors we have:—

1. Arranged to clamp the knife at both ends, either placed transversely (paraffin cutting), or obliquely (celloidine cutting); also the knife is made very heavy and of the chisel type, not of the razor type. It is known that the razor is a worthless type for fine microtome knives, because the elasticity of the thin blade introduces a gross error, except of course with very small and soft objects.

2. We have provided a support for the object to be cut immediately under the object itself, and this support is very wide, thus reducing the possible tilting to an extreme minimum.

3. To prevent jumping, the knife is kept immovable, the object alone moves, and is clamped in the securest manner in the object-holder, while movable gibs fasten the carriage to the ways.

The apparatus includes two forms of movement, one of which is entirely automatic, for raising the object. There are also simple devices for removing the alcohol, when that is used for cutting, without any of the liquid falling on the working gear. Other details need not be described, as they are mainly for convenience in use. In working out the construction of the microtome, I have had the constant co-operation of Mr. Edward Bausch. His suggestions proved essential to the success achieved.

The microtome has been placed upon the market by Messrs. Bausch & Lomb, of Rochester, New York. The price will probably be seventy to eighty dollars.

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2. *Fragments from the Autobiography of a Nerve.* *By* A. W. WALLER, *M.D., F.R.S.*

Principle of method.—The isolated living nerve is stimulated at regular intervals and the series of electrical responses graphically recorded; various chemical reagents alter the character of the response. The nerve is practically submitted to question and answer at regular short intervals, the question being constant and the answer varying with the state of the nerve.

The method lends itself to a large range of inquiries, such as the action of anæsthetics, narcotics, sedatives, stimulants, &c. Nerve-records were presented exhibiting that—

1. Chloroform is more toxic than ether.
2. Carbon dioxide is typically an anæsthetic.
3. Nitrous oxide is inert.
4. The basic is more effective than the acid moiety of a neutral salt. (Illustrated by records of potassium bromide, sodium bromide, potassium chloride.)
5. Illustrations of the action of alkaloids—morphine, atropine, aconitine, aconine, veratrine, curarine, digitaline.

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3. *Structure of Nerve Cells as Shown by Wax Models.* *By* GUSTAV MANN, *M.D. Edin.*

General Method of Making Wax Models.—(1) Fix in picro-corrosive fluid (sp. gr. 1·020), take through alcohol and paraffin. (2) Make a complete series of sections of known thickness. (3) Multiply the thickness by the magnifying power used to ascertain the thickness of each wax plate to be used, *e.g.*, thickness of sections = 5 micromillimeters, the magnification = 1,000, therefore each section to be represented by a wax plate 5,000 micromillimeters or 5 millimeters. (4) The wax plates 1–2½ mm. thick, and for fine processes paper or cardboard soaked in wax. (5) With camera lucida make accurate outlines of all portions of cell and and all processes whether of same cell to be represented or others. (6) The transferring paper for tracing outlines on the wax plates. (7) With sharp pointed knife cut out cell and its processes, if the latter are detached from the body of the cell leave them joined by strips of wax, which must be removed after fitting the various sections together. (8) Adjust wax plates in pairs, fix to one another by piercing with hot tools and continue this till cell built up. (9) Smooth outlines with hot brass instruments and give final touches with a knife, controlling each touch by carefully focussing in the microscope the level of the proximal and distal ends of each process.

Some New Observations Obtained by this Method.—(1) The unipolar cells of spinal ganglia and multipolar cells of sympathetic ganglia are spherical or oval in the central parts of the ganglion and flattened parallel to the surface at the periphery of the ganglion. (2) The distal process of the bipolar cells from the spinal ganglion of the guinea-pig is thinner than the proximal process. (3) The cells from Clarks Column are frequently essentially bipolar, *i.e.*, one axis cylinder passes upwards and another downwards, while the dendritic processes are comparatively very few and insignificant. (4) The motor cells in the spinal cord have winglike processes. (5) In *Malapterurus* the cell body appears much broken up, because of the great development of the dendritic processes. Fritsch's idea of a 'Bodenplatte' from which the axis cylinder is supposed to spring is erroneous. This method of studying series of sections through the same cell has definitely shown that sensory, motor, and sympathetic nerve cells all possess an essential fibrillar structure, with chromatic granules lying between the fibrils.

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4. *Cell Granulations under Normal and Abnormal Conditions, with special reference to the Leucocytes.* *By* R. A. M. BUCHANAN, *M.D., Liverpool.*

Classification of granules:—

1. Normal cells with granules.
2. Granules of ingestion.
3. Granulation associated with the life-history of the cell.
    (*a*) Pigment granules.
    (*b*) Secretion granules.
    (*c*) Abnormal granules of degeneration.
    (*d*) Specific granules of doubtful significance.

Kanthack and Hardy's classification of leucocytes was used as a foundation.

There is considerable evidence to show that the granules of leucocytes are of definite formation, and analogous to secretion granules.

They are not structural internodal points.

In certain diseased conditions the granulation of one type of cell may so alter as to simulate another.

Abnormal granulations may occur in the way of increase or decrease in amount or size, and histo-chemical reaction.

Leucocytes may be classified according to the histo-chemical reactions of their granules into two main groups—(1) Oxyphile, and (2) Basophile.

In the oxyphile group are included—

(*a*) Finely granular oxyphile leucocytes.
(*b*) Coarsely granular oxyphile leucocytes.
(*c*) Myelocytes questionably.

In the basophile group are included—

(*a*) Lymphocytes } probably basophile.
(*b*) Hyaline leucocytes } probably basophile.
(*c*) Finely granular basophile cells.
(*d*) Coarsely granular basophile cells.

Though definite distinctions exist in many ways between the members of each main group there is evidence to show that they are closely interdependent, and probably derivations from one definite ancestral group; the differences arising from environment, &c.

In certain abnormal conditions either group may be affected separately or together.

Under abnormal conditions leucocytes are found exhibiting both oxyphile and basophile granulation at one time.

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5. *Some Points of Interest in Dental Histology.* *By* F. Paul, *F.R.C.S., Liverpool.*

The author sketched the development of teeth, and referred more in detail to various unsolved points. In regard to the enamel organ he explained the cavities or spaces frequently met with near the dentine as due to uncalcified processes of dentine matrix. All spaces or tubes in enamel were between and never within the prisms, and were due to imperfect calcification or absence of intercellular substance. In regard to calcification of dentine and enamel, he thought that the question of 'conversion or secretion' had caused the essential difference in the process as occurring in the two tissues to be overlooked. In enamel the change occurred in connection with the cells, whilst in dentine, as in other connective tissues, the change was effected by the cells on the intercellular matrix. He believed tubular enamel to be more common than was supposed, since in appearance it resembled dentine, though its tubular structure was due to a totally different reason; indeed, tubular enamel was a negative picture of tubular dentine, the tubes being represented by the intercellular matter in enamel and by the cells in dentine.

Another point which has been raised in regard to the enamel organ was the presence of blood-vessels in the enamel jelly. Professors Howes and Poulson have stated that this structure in the rat was vascular. The author had never yet seen a vessel inside the enamel organ. He believed the contrary observation was a mistake, and showed slides to explain how it might have originated. In some animals the stellate-celled connective tissue of the sac is almost indistinguishable from the stellate cells of the enamel organ, whilst the condensed tissue of the outer limit of the sac might easily be mistaken in small animals for the atrophying external enamel epithelium. This connective tissue is, of course, highly vascular, and if assumed to be the enamel jelly would lead to the error.

The structure of Nasmyth's membrane was another moot point. It was, however, readily shown to be an epithelial tissue if unworn fresh teeth were placed in a decalcifying phloroglucin solution for a few minutes, washed, stained in Ehrlich's acid hæmatoxylin and washed again. On now peeling off and mounting the loose bits of membrane in Farrant's solution they would be found to show epithelium with the nuclei well stained. Nasmyth's membrane was without doubt a remnant of the external enamel epithelium.

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6. *The Effect of the Destruction of the Semicircular Canals upon the Movement of the Eyes.* *By* Edgar Stevenson, *M.D., Liverpool.*

The semicircular canals were destroyed on both sides in a small dog, an interval of some weeks being made between the operations on each side. Comparison of the eye movements before and after one ear had been operated on showed a very marked difference in the mobility of the eyes. The right ear was first treated, and it was found that the right eye lost about three-quarters of its power of movement in any direction, the permanent position of the eye being a divergent squint, showing only very slight concomitant movements with the other eye. The results after the left ear had been operated on were even more striking, for now both eyes lost almost altogether the power of movement, the muscles supplied by the third nerve seeming to suffer most, a double divergent squint being now produced. The movements before and after operation were tested both by observation—the dog's head being held fast and food being passed in front of him in various directions—and also graphically by means of Professor

Knoll's ingenious apparatus, by which he recorded the eye movements in brain anæmia. These observations may have some practical significance from the fact that there are some cases on record of impairment of the movements of the eyes in middle ear disease, and also from the fact that certain ophthalmic surgeons hold that Menière's disease, or auditory vertigo, is not due to a primary ear lesion, but to defective balance of the extrinsic muscular innervation of the eye.

MONDAY, SEPTEMBER 21.

The President's Address (see p. 942) was delivered, and was followed by a discussion on the 'Ancestry of the Vertebrata' at a joint meeting of Sections D, H, and I.

TUESDAY, SEPTEMBER 22.

The following Papers were read:—

1. *Photometry and Purkinje's Phenomena. By* Professor J. B. Haycraft.

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2. *The Physical Basis of Life. By* Professor F. J. Allen, *M.D. Cantab.*

The most prominent function of living matter is what may be called *Trading in Energy—i.e.*, the occlusion of radiant energy, storage thereof in the potential form, and subsequent dispersion in the form of heat, mechanical work, &c.

The explanation of this function is to be sought in the peculiar properties of nitrogen. The most salient feature of nitrogen compounds is their liability to change their constitution under slight variations in the energy equilibrium of their surroundings. So wavering is the state of nitrogen under the conditions present on our planet, that it may be called the *Critical Element.*

The importance of carbon must not, however, be underrated. Its main function is the *storing* of energy. In this function it is largely assisted by hydrogen. Oxygen is the medium of exchange between the three other elements just mentioned.

The elements N, O, C, and H may be called the dynamic elements, because they are the chief agents in the trade in energy; but their action may be intimately dependent on the assistance of other elements present in living matter.

The properties of living matter seem to indicate that—

1. Every vital phenomenon is due to a change in a nitrogenous compound, and indeed *in* the nitrogen atoms of that compound.

2. There is no vital action without transfer of oxygen, and the transfer is performed by nitrogen (often assisted by iron).

3. In the anabolic action of light on plants, the nitrogen compounds are affected primarily and the CO_2 and water secondarily.

4. In the living and active molecule the nitrogen is centrally situated and often in the pentad state. In the dead molecule it is usually peripheral and in the triad state.

5. The oxygen store of the living molecule is more or less united with the nitrogen, but passes to some other element at death.

6. The nitrogen of the living molecule is combined in a complex and perhaps changeable manner, the compound resembling in some respects the cyanogen compounds, in other respects the explosives such as nitroglycerine; other analogies are also traceable.

In accounting for the first origin of life on this earth, the nitrogen theory does not require that the planet should have been at a former period, as Pflüger suggests, 'a glowing fire-ball.' The author prefers to believe that the circumstances which support life would also favour its origin.

The theory may, however, be extended to the whole universe. For, even if there be no other world where nitrogen is the critical element, yet other elements may be in the critical state on the moon, or Mars, or the sun, or even in unknown and unimagined regions of the universe.

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3. *The Rôle of Osmosis in Physiological Processes. By* Dr. Lazarus Barlow.

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4. *The Organisation of Bacteriological Research in Connection with Public Health. By* Sims Woodhead, *M.D., Director of the Conjoint Laboratories of the Royal Colleges of Surgeons and Physicians, London.*

Dr. Woodhead pointed out that it was not an easy matter to define accurately where pure science ends and applied science begins, but he maintained that Pasteur, Lister, and Koch had all proved to demonstration that the most notable advances in our knowledge of the causes, prevention, and treatment of disease are extremely closely bound up with the increase in our knowledge of bacteriology, and he maintained that the practical needs in connection with the treatment and prevention of disease had been the prime moving forces in determining the lines on which great scientific advances had been made in the subject of bacteriology. Anyone who had followed the work of Pasteur, Koch, and such investigators would be struck by the fact that in every instance the work carried on and the results obtained were the outcome of a desire to find a means of removing some specific evil which was either commercially or through the public health crippling some section of the community. In the same way the development of the great principle of the antiseptic treatment of surgical wounds was the direct outcome of a desire on the part of Sir Joseph Lister to remedy those evils which had for so long a period crippled surgery, especially in our large hospitals. Turning to the value of bacteriological research in public health questions, he spoke of the work that had been done abroad in connection with the treatment of diphtheria, tetanus, rabies, snake-bite, and numerous other diseases, and pointed out what admirable work was being done in Government and municipally-supported foreign laboratories. In this country we have numerous laboratories in all our large Universities and University Colleges, but all are crippled by want of funds. Speaking of the work that had been done in this country, he mentioned the pathological laboratories of University College, Liverpool, Owens College, Manchester, the British Institute of Preventive Medicine and the Laboratories of the Conjoint Board of the Colleges of Physicians and Surgeons, London, where large numbers of investigations had been going on, and at the same time numerous questions concerning the public health, often raised by medical officers of health, had been worked out. In the University Colleges investigations on cholera, on typhoid, diphtheria, tuberculosis, and similar subjects had been carried on; in the British Institute of Preventive Medicine similar work had been done, and various antitoxic serums had been prepared and distributed to medical men, and several most important questions connected with the bacteriology of water and sewage had been investigated with most satisfactory results. In the laboratories of the Conjoint Board, with the work of which he was of course more specially acquainted, they had examined for the Metropolitan Asylums Board during last year 11,300 specimens from the throats of patients suspected to be suffering from diphtheria, while they had already examined nearly 11,000 specimens during the current year. They had prepared antitoxine for the treatment of these patients with such satisfactory results that he was now in a position to state that, since the figures given by their President in his opening address were published, in one hospital during the first six months of the year, and in one other, and probably two, during the first eight months of the year, several hundreds of cases of post-scarlatinal diphtheria had been treated without the occurrence of a single death, the early diagnosis and the serum treatment combined bringing about this satisfactory result. Dr. Woodhead proceeded to say that bacteriological laboratories were hampered by want of funds, and were thus prevented from attaining their full value to the community. Where assistance had been given from public authorities, as in the case of the Royal Commission on tuberculosis, valuable results had been achieved. Taking the laboratories of the University College, Liverpool, and others, such as Owens College, Manchester, was not the cry there, 'Oh, that they had funds with which they might assist or endow the men they had trained, and who they knew were capable of turning out really good work?' On the other hand, public health authorities were dependent in many respects upon the work of such laboratories. Had not the time arrived for the two sets of authorities to agree on some concerted line of action? Bacteriological laboratories existed for the public good; scientific men used them for the benefit of the community, but the community had not realised the immense possibilities of the work. He suggested that County and City Councils should become patrons of research, as they had in many cases become patrons of teaching. For a certain sum per annum, sufficient to cover expenses and pay salaries, they should have the right, through their medical officers, official veterinary surgeons, or other officials or committees, to submit for bacteriological examination material from hospitals, food stuffs, milk, water, oysters, the carcasses of, or discharges from, animals suffering from infectious diseases; in fact, to call in for consultation the director and obtain from him reports on any subject in which bacteriological examination might be deemed necessary. He would go even further than this, as he maintained that in the present state of the antitoxine question, taking that as an example of the work that had been done for the benefit of the community, it was absolutely necessary that addition to large central laboratories which should be devoted to the testing of the various antitoxic serums offered for sale, there should be facilities in all bacteriological laboratories for the examination of any of the serums that had already been distributed. This opened up a very large question, but it was one which had to be faced, and the sooner that this was recognised the better for all concerned.

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5. *Bacteria and Food.* *By* A. A. KANTHACK, *M.D.*

The author stated that—(1) The quantitative bacteriological analysis is inadequate, since sound food frequently, if not generally, contains as many micro-organisms as suspected or condemned food. This is well illustrated by the results obtained from an examination of milk, sandwiches, oysters, and ice-creams. (2) The qualitative examination of food is also of comparatively little value, since in sound food all the species of bacteria may be found which occur in suspected or in unsound food. Two organisms which have been specially singled out as proof against the soundness or integrity of food are the *Bacterium coli commune* and *proteus* forms. The significance of these microbes is more fully discussed, and the view that the *Bacterium coli* implies fæcal or sewage contamination is assailed. These two organisms occur in food, because their distribution is almost ubiquitous. The *Bacterum coli* is present in the intestines and in fæces because it is ubiquitous, and it is illogical to assume that its presence outside the digestive track signifies direct fæcal or filth contamination. (3) Lastly, the question of obligatory and facultative symbiosis is touched upon, and the question of adaptation between man and bacteria is raised. Many plants do not thrive in sterile surroundings; it is possible that Pasteur's opinion, expressed in 1885, that animals would do badly without the assistance of bacteria, may prove to be correct.

It is well that we should know the bacterial flora of good and unsuspected food, and become familiarised with the idea that many articles of food generally consumed teem with bacteria, described by many bacteriologists as characteristic of fæcal or decomposing matter.

WEDNESDAY, SEPTEMBER 23.

The following Papers and Report were read:—

1. *The Minute Structure of the Cerebellum.* *By* Alexander Hill, *M.D.*

The relations between the various cell-layers were pointed out, and the probable path of the nervous impulses indicated. The final ramifications, under the microscope, appeared to be in anatomical contact, thus getting over the difficulty of physiological action at a distance. Certain new cells were described, and an explanation given of certain granules, seen long ago by Dr. Hill in the molecular layer by the aid of Golgi's method.

2. *The Basis of the Bacteriological Theory, founded upon Observations upon the Fermentation of Milk.* *By* Professor A. P. Fokker.

The author described a previously unrecorded albuminous substance, occurring in the filtrate of sour milk, which takes part in the fermentation of the milk. He also described the quantity of the bacteria present in this filtrate, and discussed the question of their origin.

3. *Report on Oysters under Normal and Abnormal Environments.*

See Reports, p. 663.

4. *The Presence of Iron and of Copper in Green and in White Oysters.* *By* Charles A. Kohn, *Ph.D.*, *B.Sc.*

The object of the experiments undertaken is to show whether the green colour of the gills of certain types of French oysters (*Huitres des Marennes*) is due to iron, which Chatin and Muntz regard as the cause of the colouration. Electrolytic methods of analysis were employed, as these offer special advantages for the determination of minute quantities of metals when derived from organic matter. The results show that white oysters contain quite as much iron, both in their gills and in the rest of their bodies, as green oysters; and, further, that the quantity of iron present in the gills of green oysters is not proportionately sufficient to attribute the colouration to its presence. The total quantity of iron found in French, Dutch, and American oysters varied from 1·8 to 4·0 milligrammes per six oysters.

Copper is also a normal constituent of both green and of white oysters, but the amount present in the gills of the former is quite insufficient to account for their colour. Although iron may be a constituent of the green colouring matter, it is certainly not the cause of the colouration—a conclusion confirmed by Professor Herdman's experiments, in which he showed that no colouration was produced by growing oysters in very dilute saline solutions of iron salts.

5. *Experiments on the Action of Glycerine upon the Growth of Bacteria.* *By* S. Monckton Copeman, *M.A.*, *M.D.* (*Cantab.*), *M.R.C.P.*; *and* Frank R. Blaxall, *M.D.* (*Lond.*), *D.P.H.*

(From the Bacteriological Laboratory of the Westminster Hospital Medical School.)

The paper forms a preliminary account of a series of experiments which are being carried out as an extension of earlier work on the bacteriology of small-pox and vaccinia, and, as an outcome of this, on the question of the purification and preservation of vaccine lymph.

Vaccine lymph as ordinarily obtained and stored is apt to contain, in addition to the specific veins, certain microbes, of which some, when inoculated in the act of vaccination, are liable to be productive of dangerous complications. It was shown, however, in the Transactions of the Congress of Hygiene for 1891, that this difficulty could be avoided by the admixture with the lymph material of an equal quantity of a 50 per cent. solution of pure glycerine in water, prior to storage in capillary tubes. When this process is adopted, and the tubes kept protected from the light for a period of from two to six weeks, it is found, after this lapse of time, that gelatine plates made from such tubes remain absolutely sterile. The lymph, however, is still perfectly active as vaccine, the specific virus being able to withstand the action of the glycerine.

In view of the publication of the Report of the Royal Commission on Vaccination, it appeared to be desirable to investigate more accurately the action of glycerine on various micro-organisms of a pathogenic or non-pathogenic nature respectively.

Method.—This has been done by the addition of known quantities of glycerine to tubes of beef-peptone broth, which are subsequently inoculated with equal quantities of pure cultivations, and incubated at blood-heat and at the room temperature respectively. Control inoculations in ordinary beef broth have also invariably been employed. Subsequently an inoculation is made from the broth-tubes on to solid media, at varying intervals of time, in order to see whether the particular microbe is still capable of growth, or not. In all, some hundreds of inoculations have been made thus far, and the paper includes a table in which are given the maximum limits of substance attained in the different series. Practically, the results of each similar series were found to agree very closely.

The micro-organisms employed for the inoculations comprised *Staphylococcus pyogenes aureus, S. pyogenes albus, Streptococcus pyogenes, Bacillus pyocyaneus, B. subtilis, B. coli communis, B. diphtheriæ* and *B. tuberculosis.* Small-pox and vaccine material in the form of 'crusts' and lymph was also employed.

Results.—1. No visible development of the micro-organisms employed takes place in the presence of more than 30 per cent. of glycerine.

2. All the micro-organisms experimented with are killed out in less than a month in the presence of from 30 per cent. to 40 per cent. glycerine, with the exception of *B. coli communis* and *B. subtilis,* when kept in the cold.

3. *B. coli communis,* unlike *B. typhosus,* resists the action of 50 per cent. glycerine, in the cold, for a considerable period, a fact which is likely to prove a valuable addition to our present methods of differentiating these microbes from one another.

4. Small-pox and vaccine material, whether as 'crusts' or lymph, are sterilised completely, so far as extraneous microbes are concerned, in a week by the presence of glycerine to the extent of 40 per cent. in the broth-tubes.

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6. *Some Points in the Mechanism of Reaction to Peritoneal Infections.* By Herbert E. Durham, Gull Research Student, Bacteriological Laboratory, Guy's Hospital.

Shortly after intra-peritoneal injections of various substances (guinea-pigs), there is a remarkable disappearance of the wandering cells normally present in the peritoneal fluid. Three kinds of wander cells, or leucocytes, are found in normal peritoneal fluid—viz., hyaline cells, coarsely granular oxyphil, or 'megoxyphil' cells as it is proposed to call them, and lymphocytes. The above disappearance affects the hyaline and megoxyphil cells; the lymphocytes remain.

For the period of the paucity of cells in the fluid, the term *leucopenia* or *leucopenic stage,* proposed by Löwit, may be applied.

The onset of leucopenia is described to be instantaneous by Kanthack, and Hardy, and by Issaeff. The author's observations in more than 200 instances (guinea-pigs) show that the onset is never less than 5 minutes after injection. The time of onset varies somewhat according to the nature and temperature of the injected fluid.

Metschnikoff, and Kanthack, and Hardy attribute the leucopenia to a sudden destruction of the cells. Metschnikoff considers that this solution of cells ('phagolyse') imbues the peritoneal fluid with increased bactericidal power.

The author does not agree with these statements; first, because the cells may be found again during the leucopenic stage, and secondly because when inert resistance substances (*e.g.*, carbon particles) are introduced, they disappear in considerable proportion at the same time as the cells. His observations are consequently in accordance with those of Mesnil on the leucopenia which occurs after intra-vascular injections; this observer has shown that the cells are stopped by adhesion to capillary walls—more particularly in the liver. At the beginning of the year (Wiener klin. Wochenschr Nos. 11 and 12, 1896), it was shown by Prof. Gruber, and the author, that large numbers of the cells *become deposited upon the omentum*, though some become adherent to other parts of the peritoneal lining after intra-peritoneal injections.

The mechanism of this deposit appears to be as follows: the hyaline and megoxyphil cells adhere together into masses or 'balls'; these 'balls' are driven by the peristaltic, and other abdominal movements, to the omentum and upper region of the cavity, where they become adherent. In animals killed at recent periods after intra-peritoneal injection, the peristaltic movements are exceptionally active.

At the same time numbers of bacteria, in the case of infections, also become deposited on the omentum, etc.; especially if some serum having a 'clumping' action has been mixed with the bacterial emulsion. By the use of indian ink the phenomenon may be demonstrated to the naked eye by removing samples with capillary tubes. By the action of the abdominal movements the omentum becomes rolled up; it is also intensely injected in acute infections. Soluble substances such as carmine, or potassium ferrocyanide solutions, have a predilection for the omentum apparently independently of the leucocytes. It is suggested that possibly bacterial toxins may be dealt with to some extent in this manner.

The leucopenic stage lasts about an hour, when a cell normally foreign to the peritoneal cavity (the finely granular oxyphil (K. and H.) or 'microxyphil' cell, or polynuclear leucocyte) makes its appearance. The period of leucopenia has been called a 'period of negative chemiotaxis' by Issaeff; however, especially with microbes of a comparatively low degree of virulence, very active phagocytosis is established by the hyaline cells; these cells ingest the microbes without any preliminary intervention on the part of the megoxyphil cells; the microbes attached to the hyaline cells may be almost countless, whilst many of the megoxyphil cells are free from or at any rate only have a few attached microbes. One indubitable instance of phagocytosis by megoxycytes has been observed.

Metschnikoff states that 'phagolyse' does not occur after injections during the leucocytotic condition induced by an injection (*e.g.*, pepton-broth) given twenty-four hours previously. The author does not agree with this statement, for he finds that the cells then present (microxyphil cells and macrophages) '*ball*' together, and disappear by adhesion to the peritoneal linings, in a manner similar to that which occurs in normal (previously untreated) animals. This has been demonstrated to the naked eye by giving coloured injections (*e.g.*, indian ink, or carmine granules) during the leucocytotic period, and seeing the disappearance of the coloured material from capillary samples; also by marking the cells by previous injections (*e.g.*, peptonate of iron, carmine, etc.), and watching their disappearance. The disappearance can also be traced by care after bacterial inoculations; but owing to the abundance of cells, only a proportion of which disappear, the observation is less readily made than when coloured materials are used. The '*increased resistance*' first identified by Issaeff, obtained by producing a leucocytosis by means of simple injections, is suggestive of being of great practical value in the treatment of peritoneal cases in man, where there is some risk of infection (perityphilitic, pelvic abscesses, &c.), if operation is undertaken: these points will be more fully discussed elsewhere in conjunction with a number of observations on peritonitis in man.

Another factor in the production of leucopenia remains to be discussed—the action of the lymph paths. The lymph paths from the peritoneal cavity have received scant attention in the past: recently Starling has observed that the lymph vessels in the anterior mediastinum become filled with coloured material at remote periods after injection of similar material into the peritoneal cavity. The first observation of the author was made in December 1894. It was found that carbon particles began to reach the lymph glands, situated in the first intercostal space (guinea-pigs and rabbits), in eight minutes after injection. Solutions (carmine, pot. ferrocyanide) pass up more rapidly, and these upper glands were filled in three minutes. Though absorption may take place in other regions of the peritoneal lining, and other lymph paths may be utilised, the course through diaphragmatic lymphatics to the vessels and glands of the anterior mediastinum, and so to the blood-vessels, is *par excellence* the route of peritoneal lymph absorption. Bacteria, and cells are carried along these paths from the peritoneal cavity. Bacteria have been seen in the lymph vessels of the diaphragm, and falciform ligament six minutes after injection. Bacteria have been found in the blood capillaries of the liver within half an hour of intra-peritoneal injection. The process is therefore both rapid and early. In man the same lymph paths have been found affected in acute and in chronic (tuberculous, malignant) peritonitis; *they should always be examined in peritonitic cases.* In a case of ruptured tubal gestation these lymphatics were beautifully injected with blood, and could readily be traced into the root of the neck.

Though microxyphil cells do not become free in the peritoneal fluid till about an hour after experimental injections, they begin to make invasion much earlier. In animals killed six to eight minutes after injection the capillaries of the mesentery (especially) are becoming blocked with microxycytes. These cells wander out of the vessels, and eventually through the peritoneal endothelium. Their invasion is associated with an increase in the amount of peritoneal fluid, followed (about sixteen to twenty hours) by diminution of fluid in recovering cases.

The megoxyphil cells do not invade the cavity in significant numbers; they may be almost absent, and are variable and inconstant in numbers.

The microxyphil cells, and macrophages, on the other hand, come in such large numbers in all recovering cases that they must be considered of much significance, in the question of the battle against the microbes.

The presence of microxycytes (and macrophages) in the peritoneal fluid is associated with an increase of bactericidal power of the fluid (*vide* Hahn's similar observations with pleural fluid), apart from phagocytosis. A combination of cellular and humoral theories is necessary for the explanation of the processes of reaction in peritoneal infection.

The rapidity with which the lymph paths are brought into action, and with which intra-vascular changes commence, is an argument against a too rigid theory of coelomic and hæmal white corpuscles.

There would appear to be a definite peritoneal circulation of cells and fluid from (especially the mesenteric) blood-vessels to the anterior mediastinal lymph-vessels, almost from the moment after intraperitoneal injection, until the normal condition has been re-established.

The observations upon which these statements are based, were made in Professor Gruber's laboratory in Vienna, and the Bacteriological Laboratory of Guy's Hospital.

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7. *On the Agglutinating Action of Human Serum on certain Pathogenic Micro-organisms (particularly on the Typhoid Bacillus). By* Albert S. Grünbaum, *M.A., M.B. (Cantab.), M.R.C.P.*

The serum of an animal immunised against the typhoid bacillus or other motile pathogenic micro-organism has a peculiar action on an emulsion (in bouillon) of the bacillus of the corresponding disease. If a drop of serum and a drop of emulsion be mixed, and examined under the microscope, the bacilli will be seen to collect together in clumps, and to lose their motility. This reaction is nearly specific, and can be used to differentiate or identify certain bacteria. The phenomenon, although noticed by Bordet, was first thoroughly studied and its importance recognised by Durham and Gruber. The latter termed the active conglomerating substances 'agglutinines,' and they seem to play an important part in immunisation.

The serum of normal guinea pigs or rabbits does not, as a rule, cause any reaction. Human serum is very different in this respect. In a comparatively large percentage of individuals (particularly those affected with jaundice) the serum has a very distinct agglutinating action on the cholera, coli, and typhoid bacilli, generally more on one than on the other. But the action is so little specific that, in normal individuals, it may be equal on any two or on all three. This does not occur with the serum of immunised animals.

But the strength of action is incomparably smaller with human serum. That of a highly immunised animal can be diluted to one in a thousand or more, and still show a clumping effect, that of man hardly ever more than one in eight.

Only in cases of typhoid fever (and the action is here much more specific) *does it react in a dilution of one to sixteen* (*or more*). *Hence the reaction can be used for purposes of diagnosis.* The agglutination is sometimes more marked with the diluted than with the pure serum, possibly through there being separate substances for the inhibition of movement and the agglutination. Individuals who have had typhoid fever do not, apparently, preserve any excess of typhoid 'agglutinines' in their serum for any great length of time.

Agglutinines present in the maternal blood are not necessarily present in the child's blood (at birth); the former may react strongly, and the latter not at all. But in this case, and generally in man, the immunising power seems to be only very partly dependent on the agglutinating power of the serum.

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8. *The Detection of Lead in Organic Fluids.* *By* JOHN HILL ABRAM, *M.D.* (*Lond*), *M.R.C.P.*, *and* PROSPER H. MARSDEN, *F.C.S.*

[From the Pathological Laboratory, Univ. Coll., Liverpool.]

In the usual methods adopted for the detection of lead in organic fluids, the organic matter is destroyed by means of hydrochloric acid and chlorate of potash, and the solutions or precipitates obtained are then subjected to the ordinary tests, or preferably, as Dr. Kohn has shown, to electrolysis.

With regard to the organic fluids (urine, vomit), with which we (the writers) have more particularly to deal, Dr. Kohn states that the destruction of the organic matter by HCl and $KClO_3$ may be omitted, as the quantity thereof in urine, &c., is small, this is a great gain, and electrolysis is both delicate and accurate.

One of us whilst reading von Jaksch's book on Clinical Diagnosis, was struck by a simple method there described. It is not there claimed by von Jaksch, nor is any reference given, and so far no reference to the process has been discovered by us.

Von Jaksch states that to detect lead the fluid should be partially evaporated on the water bath and the organic matter decomposed, thus apparently not relying on the method to be described.

The details given are as follows:—'A strip of magnesium, free from lead, is placed in the fluid, when metallic lead will be deposited upon it, and can then be dissolved in nitric acid and confirmatory tests applied to the solution.'

We have modified the test slightly by adding ammonium oxalate in the proportion of 1 grm. to 150 c.c. of fluid, and by using acetic acid as the solvent. We have found the addition of the oxalate to be a great advantage, and we have to thank Dr. Kohn for the suggestion.

Coloration is seen on the magnesium within an hour, but we have usually allowed the strip to remain for 24 hours. The magnesium is then taken out, washed with distilled water, and the following confirmatory tests applied:—

1. The slip is warmed gently with a crystal of iodine, when the yellow iodide of lead is formed.

2. The lead is dissolved off with acetic acid and sulphuretted hydrogen passed through the solution.

The magnesium strips can of course be used repeatedly, after carefully washing with acid and distilled water. The method is at bottom an electrolytic one, but its simplicity, and so far as our experiments go, its accuracy strongly recommend it to clinicians.

There is no necessity for any special apparatus, and the actual working time may be safely put as less than one hour.

In aqueous solution we have obtained results when lead has been present in the proportion of 1 part in 50,000.

The results have been equally good in urine. Clinically we have found lead in the urine of two cases under the care of one of us in the Royal Infirmary, and in the vomit from one case.

SECTION K.—BOTANY.

PRESIDENT OF THE SECTION.—D. H. SCOTT, M.A., Ph.D., F.R.S., Honorary Keeper of the Jodrell Laboratory, Royal Gardens, Kew.

THURSDAY, SEPTEMBER 17.

The PRESIDENT delivered the following Address:—

Present Position of Morphological Botany.

THE object of modern morphological botany (the branch of our science to which I propose to limit my remarks) is the accurate comparison of plants, both living and extinct, with the object of tracing their real relationships with one another, and thus of ultimately constructing a genealogical tree of the vegetable kingdom. The problem is thus a purely historical one, and is perfectly distinct from any of the questions with which physiology has to do.

Yet there is a close relation between these two branches of biology; at any rate, to those who maintain the Darwinian position. For from that point of view we see that all the characters which the morphologist has to compare are, or have been, adaptive. Hence it is impossible for the morphologist to ignore the functions of those organs of which he is studying the homologies. To those who accept the origin of species by variation and natural selection there are no such things as morphological characters pure and simple. There are not two distinct categories of characters—a morphological and a physiological category—for all characters alike are physiological. 'According to that theory, every organ, every part, colour, and peculiarity of an organism must either be of benefit to an organism itself, or have been so to its ancestors. . . . Necessarily, according to the theory of natural selection, structures either are present because they are selected as useful, or because they are still inherited from ancestors to whom they were useful, though no longer useful to the existing representatives of those ancestors.'[1]

The useful characters may have become fixed in comparatively recent times, or a long way back in the past. In the latter case the character in question may have become the property of a large group, and thus, as we say, may have become morphologically important.

For instance, parasitic characters, such as the suppression of chlorophyll, are equally adaptive in Dodder and in the Fungi. In Dodder, however, such characters are of recent origin and of little morphological importance, not hindering us from placing the genus in the natural order Convolvulaceæ; while in Fungi equally adaptive characters have become the common property of a great class of plants.

Then, again, the existence of a definite sporophyte generation, which is the great character of all the higher plants, is in certain Fungi inconstant, even among members of the same species.

Although there is no essential difference between adaptive and morphological

[1] Lankester, *Advancement of Science*, p. 307.

characters, there is a great difference in the morphologist's and the physiologist's way of looking at them. The physiologist is interested in the question how organs work; the morphologist asks, what is their history?

The morphologist may well feel discouraged at the vastness of the work before him. The origin of the great groups of plants is perhaps, after all, an insoluble problem, for the question is not accessible either to observation or experiment.

All that we can directly observe or experiment upon is the occurrence of variations—perhaps the most important line of research in biology, for it was the study of variation that led Darwin and Wallace to their grand generalisation. Many observers are working to-day in the spirit of the great masters, and it is certain that their work will be fruitful in results. It is evident, however, that such investigations can at most only throw a side light on the historical question of the origin of the existing orders and classes of living things. The morphologist has to attack such questions by other methods of research.

The embryological method has so far scarcely received justice from botanists. A great deal of what is called embryology in botany is not embryology at all, but relates to pre-fertilisation changes. Of real embryology—that is to say, the development of the young plant from the fertilised ovum—there is much less than we might expect. Thus no comparative investigation of the embryology of either Dicotyledons or Monocotyledons has ever been carried out, our knowledge being entirely based on a few isolated examples.

In the cases which have been investigated perhaps excessive attention has been devoted to the first divisions of the ovum, the importance of which, as Sachs long ago showed, has been overrated, while the later stages, when the differentiation of organs and tissues is actually in progress, have been comparatively neglected.

The law of recapitulation (or repetition of phylogeny in ontogeny) has been very inadequately tested in the vegetable kingdom. Whatever its value may be, it is certainly desirable that the development of plants as well as animals should be considered from this point of view; and this has so far been done in but very few cases. M. Massart, of Brussels, has made some investigations with this object on the development of seedlings and of individual leaves. He is led to the conclusion that examples of recapitulation are rare among plants.[1]

So far, at least, embryological research has only yielded certain proof of recapitulation in a few cases, as in the well-known example of the phyllode-bearing acacias, in which the first leaves of the seedling are normal, while the later formed ones gradually assume the reduced phyllode form.

A less familiar example is afforded by *Gunnera*. Here, as is well known, the mature stem has a structure totally different from that of ordinary Dicotyledons, and much resembling that characteristic of most Ferns. In most species of *Gunnera* there are a number of distinct vascular cylinders in the stem, instead of one only, and there is never the slightest trace, so far as the adult plant is concerned, of the growth by means of cambium, which is otherwise so general in the class. The seedling stem, however, is not only monostelic below the cotyledons, but in this region, though nowhere else, shows distinct secondary growth. Thus, if we were in any doubt as to the general affinities of *Gunnera*, owing to its extraordinary mature structure, we should at once be put on the right track by the study of the embryonic stem, which alone retains the characteristic dicotyledonous mode of growth.

It is only in a few cases, however, and for narrow ranges of affinity, that the doctrine of recapitulation has at present helped in the determination of relationships among plants. Beyond this, conclusions based on embryology alone tend to become merely conjectural and subjective. In fact, all comparative work, in so far as it is limited to plants now living, suffers under the same weakness that it can never yield certain results, for the question whether given characters are relatively primitive or recently acquired is one upon which each naturalist is left to form his own opinion, as the origin of the characters cannot be observed.

[1] La Récapitulation et l'Innovation en Embryologie Végétale,' *Bull. de la Soc. roy. de Bot. de Belgique*, vol. xxxiii., 1894.

To determine the blood-relationships of organisms it is necessary to decipher their past history, and the best evidence we can have (when we can get it) is from the ancient organisms themselves. The problem of the morphologist is an historical one, and contemporary documentary evidence is necessarily the best. It is palæontology alone which can give us the real historical facts.

Anatomical Characters.

In judging of the affinities of fossil plants we are often compelled to make great use of vegetative characters, and more particularly of characters drawn from anatomical structure. It is true that in many cases we do so because we cannot help ourselves, such anatomical features being the only characters available in many of the specimens as at present known. But the value of the method has been amply proved in other cases where the reproductive structures have also been discovered, and are found to fully confirm the conclusions based on anatomy. I need only mention the great groups of the Lepidodendreæ and the Calamites, in each of which the anatomical characters, when accurately known, put us at once on the right track, and lead to results which are only confirmed by the study of the reproductive organs

In this matter fossil botany is likely to react in a beneficial way on the study of recent plants, calling attention to points of structure which have been passed over, and showing us the value of characters of a kind to which systematists had until recently paid but little attention. At present, owing to the work of Radlkofer, Vesque, and others, anatomical characters are gradually coming into use in the classification of the higher plants, and in some quarters there may even be a tendency to over-estimate their importance. Such exaggeration, however, is only a temporary fault incident to the introduction of a comparatively new method. In the long run nothing but good can result from the effort to place our classification on a broader basis. In most cases the employment of additional characters will doubtless serve only to further confirm the affinities already detected by the acumen of the older taxonomists. There are plenty of doubtful points, however, where new light is much needed; and even where the classification is not affected it will be a great scientific gain to know that its divisions are based on a comparison of the whole structure, and not merely on that of particular organs.

The fact that anatomical characters are adaptive is undeniable, but this applies to all characters, such difference as there is being merely one of degree. Cases are not wanting where the vegetative tissues show greater constancy than the organs of reproduction, as, for example, in the Marattiaceæ, where there is a great uniformity in anatomical structure throughout the family, while the sporangia show the important differences on which the distinction of the genera is based. It is in fact a mistake to suppose that anatomical characters are necessarily the expression of recent adaptations. On the contrary, it is easy to cite examples of marked anatomical peculiarities which have become the common property of large groups of plants.

For instance, to take a case in which I happen to have been specially interested, the presence of bast to the inside as well as to the outside of the woody zone is a modification of dicotyledonous structure which is in many groups, at least of ordinal value. The peculiarity is constant throughout the orders Onagraceæ, Lythraceæ, Myrtaceæ, Solanaceæ, Asclepiadaceæ, and Apocynaceæ, not to mention some less important groups. In other families, such as the Cucurbitaceæ and the Gentianeæ, it is nearly constant throughout the order, but subject to some exceptions. Among the Compositæ a similar, if not identical, peculiarity appears in some of the sub-order Cichoriaceæ, but is here not of more than generic value. In *Campanula* the systematic importance of internal phloëm is even less, for it appears in some species and not in others. Lastly, there are cases in which a similar character actually appears as an individual variation, as in *Carum Carvi*, and, under abnormal conditions, in *Phaseolus multiflorus*.

These latter cases seem to me worthy of special study, for in them we can trace, under our very eyes, the first rise of anatomical characters which have elsewhere become of high taxonomic importance. A comparative study of the anatomy of any group of British plants, taking the same species growing under different conditions, would be sure to yield interesting results if any one had the patience to undertake it.

Enough has been said to show that a given anatomical character may be of a high degree of constancy in one group while extremely variable in another, a fact which is already perfectly familiar as regards the ordinary morphological characters. For example, nothing is more important in phanerogamic classification than the arrangement of the floral organs as shown in ground-plan or floral diagram. Yet Professor Trail's observations, which he has been good enough to communicate to me, show that in one and the same species, or even individual, of *Polygonum*, almost every conceivable variation of the floral diagram may be found.

There is, in fact, no 'royal road' to the estimation of the relative importance of characters; the same character which is of the greatest value in one group may be trivial in another; and this holds good equally whether the character be drawn from the external morphology or from the internal structure.

Our knowledge of the comparative anatomy of plants, from this point of view, is still very backward, and it is quite possible that the introduction of such characters into the ordinary work of the Herbarium may be premature; certainly it must be conducted with the greatest judgment and caution. We have not yet got our data, but every encouragement should be given to the collection of such data, so that our classification in the future may rest on the broad foundation of a comparison of the entire structure of plants.

In estimating the relative importance of characters of different kinds we must not forget that characters are often most constant when most adaptive. Thus, as Professor Trail informs me, the immense variability of the flowers of *Polygonum* goes together with their simple method of self-fertilisation. The exact arrangement is of little importance to the plant, and so variation goes on unchecked. In flowers with accurate adaptation to fertilisation by insects such variability is not found, for any change which would disturb the perfection of the mechanism is at once eliminated by natural selection.

Histology.

I propose to say but little on questions of minute histology, a subject which lies on the borderland between morphology and physiology, and which will be dealt with next Tuesday far more competently than I could hope to treat it. Last year my predecessor in the presidency of this Section spoke of a histological discovery (that of the nucleus, by Robert Brown) as 'the most epoch-making of events' in the modern history of botany. The histological questions before us at the present day may be of no less importance, but we cannot as yet see them in proper perspective. The centrosomes, those mysterious protoplasmic particles which have been supposed to preside over the division of the nucleus, and thus to determine the plane of segmentation, if really permanent organs of the cell, would have to rank as co-equal with the nucleus itself. If, on the other hand, as some think, they are not constant morphological entities, but at most temporary structures differentiated *ad hoc*, then we are brought face to face with the question whether the causes of nuclear division lie in the nucleus itself or in the surrounding protoplasm.

Nothing can be more fascinating than such problems, and nothing more difficult. We have, at any rate, reason to congratulate ourselves that English botanists are no longer neglecting the study of the nucleus and its relation to the cell. For a long time little was done in these subjects in our country, or at least little was published, and botanists were generally content to take their information from abroad, not going beyond a mere verification of other men's results. Now we have changed all that, as the communications to this Section sufficiently testify.

Nothing is more remarkable in histology than the detailed agreement in the structure and behaviour of the nucleus in the higher plants and the higher animals, an agreement which is conspicuously manifest in those special divisions which take place during the maturation of the sexual cells. Is this striking agreement the product of inheritance from common ancestors, or is the parallelism dependent solely on similar physical conditions in the cells? This is one of the great questions upon which we may hope for new light from the histological discussion next week.

Alternation of Generations.

We have known ever since the great discoveries of Hofmeister that the development of a large part of the vegetable kingdom involves a regular alternation of two distinct generations, the one, which is sexual, being constantly succeeded—so far as the normal cycle is concerned—by the other which is asexual. This alternation is most marked in the mosses and ferns, taking these words in their widest sense, as used by Professor Campbell in his recent excellent book. In the Bryophyta, the ordinary moss or liverwort plant is the sexual generation, producing the ovum, which, when fertilised, gives rise to the moss-fruit, which here alone represents the asexual stage. The latter forms spores from which the sexual plant is again developed.

In the Pteridophyta the alternation is equally regular, but the relative development of the two generations is totally different, the sexual form being the insignificant prothallus, while the whole fern-plant, as we ordinarily know it, is the asexual generation.

The thallus of some of the lower Bryophyta is quite comparable with the prothallus of a fern, so as regards the sexual generation there is no difficulty in seeing the relation of the two classes; but when we come to the asexual generation or sporophyte the case is totally different. There is no appreciable resemblance between the fruit of any of the Bryophyta and the plant of any vascular Cryptogam.

There is thus a great gap within the Archegoniatæ; there is another at the base of the series, for the regular alternation of the Bryophyta is missing in the Algæ and Fungi, and the question as to what corresponds among these lower groups to the sporophyte and oöphyte of the higher Cryptogams is still disputed.

Now as regards this life-cycle, which is characteristic of all plants higher than Algæ and Fungi, there are two great questions at present open. The one is general: are the two generations, the sporophyte and the oöphyte, homologous with one another, or is the sporophyte a new formation intercalated in the life-history, and not comparable to the sexual plant? The former kind of alternation has been called homologous, the latter antithetic. This question involves the *origin* of alternation; its solution would help us to bridge over the gap between the Archegoniatæ and the lower plants. The second problem is more special: has the sporophyte of the Pteridophyta, which always appears as a complete plant, been derived from the simple and totally different sporophyte of the Bryophyta, or are the two of distinct origin?

At present it is usual, at any rate in England, to assume the antithetic theory of alternation. Professor Bower, its chief exponent, says:[1] 'It will also be assumed that, whatever may have been the circumstances which led to it, antithetic alternation was brought about by elaboration of the zygote [*i.e.* the fertilised ovum] so as to form a new generation (the sporophyte) interpolated between successive gametophytes, and that the neutral generation is not in any sense the result of modification or metamorphosis of the sexual, but a new product having a distinct phylogenetic history of its own.' In his essay on 'Antithetic as distinguished from Homologous Alternation of Generations in Plants,'[2] the author describes the hypothetical first appearance of the sporophyte as follows: 'Once fertilised, a zygote might in these plants [the first land plants] divide up into a number of portions (carpospores), each of which would then serve as a starting-point of a new individual.'

[1] 'Spore-producing Members,' *Phil. Trans.* vol. clxxxv. B. (1894) p. 473.

[2] *Annals of Botany*, vol. iv. (1890), p. 362.

On this view, the sporophyte first appeared as a mere group of spores formed by the division of the fertilised ovum. Consequently the inference is drawn that all the vegetative parts of the sporophyte have arisen by the 'sterilisation of potentially sporogenous tissue.' That is to say, there was nothing but a mass of spores to start with, so whatever other tissues and organs the sporophyte may form must be derived from the conversion of spore-forming cells into vegetative cells. Professor Bower has worked out this view most thoroughly, and as the result he is not only giving us the most complete account of the development of sporangia which we have ever had, but he has also done much to clear up our ideas, and to show us what the course of evolution ought to have been if the assumptions required by the antithetic theory were justified.

Without entering into any detailed criticism of this important contribution to morphology, which is still in progress, I wish to point that we are not, after all, bound to accept the assumption on which the theory rests. There is another view in the field, for which, in my opinion, much is to be said. The antithetic theory is receiving a most severe test at the friendly hands of its chief advocate. Should it break down under the strain we need not despair, for another hypothesis remains which I think quite equally worthy of verification.

This is the theory of Pringsheim, according to which the two generations are *homologous* one with another, the oöphyte corresponding to a sexual individual among Thallophytes, the sporophyte to an asexual individual. To quote Pringsheim's own words:[1] 'The alternation of generations in mosses is immediately related to those phenomena of the succession of free generations in Thallophytes, of which the one represents the neutral, the other the sexual plant.' Further on[2] he illustrates this by saying: 'The moss sporogonium stands in about the same relation to the moss plant as the sporangium-bearing specimens of *Saprolegnia* stand to those which bear oögonia, or as, among the Florideæ, the specimens with tetraspores are related to those with cystocarps.' This gets rid of the intercalation of a new generation altogether; we only require the modification of the already existing sexual and asexual forms of the Thallophytes.

The sudden appearance of something completely new in the life-history, as required by the antithetic theory, has, to my mind, a certain improbability. *Ex nihilo nihil fit.* We are not accustomed in natural history to see brand-new structures appearing, like morphological Melchizedeks, without father or mother. Nature is conservative, and when a new organ is to be formed it is, as every one knows, almost always fashioned out of some pre-existing organ. Hence I feel a certain difficulty in accepting the doctrine of the appearance of an intercalated sporophyte by a kind of special creation.

We can have no direct knowledge of the origin of the sporophyte in the Bryophyta themselves, for the stages, whatever they may have been, are hopelessly lost. In some of the Algæ, however, we find what most botanists recognise as at least a parallel development, even if not phylogenetically identical.[3] In *Œdogonium*, for example, the oöspore does not at once germinate into a new plant, but divides up into four active zoospores, which swim about and then germinate. In *Coleochæte* the oöspore actually becomes partitioned up by cell-walls into a little mass of tissue, each cell of which then gives rise to a zoospore.

In both these genera (and many more might be added) the cell-formation in the germinating oöspore has been generally regarded as representing the formation of a rudimentary sporophyte generation. If we are to apply the antithetic theory of alternation to these cases, we must assume that the zoospores produced on germination are a new formation, intercalated at this point of the life-cycle. But is this assumption borne out by the facts? I think not. In reality nothing new is intercalated at all. The 'zoospores' formed from the oöspore on germination are identical with the so-called 'zoogonidia,' formed on the ordinary vegetative plant at all stages of its growth.

In science, as in every subject, we too easily become the slaves of language.

[1] *Gesammelte Abhandlungen*, II. p. 370. [2] *Ibid.* p. 371.
[3] See Bower, *Antithetic Alternation*, p. 361.

By giving things different names we do not prove that the things themselves are different. In this case, for example, the multiplication of terms serves, in my opinion, merely to disguise the facts. The reproductive cells produced by the ordinary plant of an *Œdogonium* are identical in development, structure, behaviour, and germination with those produced by the oöspore. The term 'zoogonidia' applied to the former is a 'question-begging epithet,' for it assumes that they are not homologous with the 'zoospores' produced by the latter. I prefer to keep the old name zoospore for both, as they are identical bodies.

To my mind the point seems to be this. An *Œdogonium* (to keep to this example) can form zoospores at any stage of its development; there is one particular stage, however, at which they are *always* formed—namely, on the germination of the oöspore. Nothing new is intercalated, but the irregular and indefinite succession of sexual and asexual acts of reproduction is here tending to become regular and definite.

In *Sphæroplea*, as was well pointed out by the late Mr. Vaizey,[1] though his view of alternation was very different from that which I am now putting forward, the alternation is as definite as in a moss, for here, so far as we know, zoospores are only formed on the germination of the fertilised ovum. If *Sphæroplea* stood alone we might believe in the intercalation of these zoospores, as a new stage, but the comparison with *Ulothrix*, *Œdogonium*, *Bulbochæte* and *Coleochæte* shows, I think, where they came from.

The body formed from the oöspore is called by Pringsheim the first neutral generation. In *Œdogonium* this has no vegetative development, for the first thing that the oöspore does is to form the asexual zoospores, and it is completely used up in the process. In other cases it is not in quite such a hurry, and here the first neutral generation has time to show itself as an actual plant. This is so in *Ulothrix*, a much more primitive form than *Œdogonium*, for its sexuality is not yet completely fixed. Here the zygospore actually germinates, forming a dwarf plant, and in this stage passes through the dull season, producing zoospores when the weather becomes more favourable. On Pringsheim's view the dwarf plant is not a new creation, but just a rudimentary *Ulothrix*, which soon passes on to spore-formation. So, too, with the cellular body formed on the germination of the oöspore of *Coleochæte*; this also is looked upon as a reduced form of thallus. On any view this genus is especially interesting, for the sporophyte remains enclosed by the tissue of the sexual generation, thus offering a striking analogy with the Bryophyta.

In the Phycomycetous Fungi—plants which have lost their chlorophyll, but which otherwise in many cases scarcely differ from Algæ—the oöspore in one and the same species may either form a normal mycelium, or a rudimentary mycelium bearing a sporangium, or may itself turn at once into a sporangium (producing zoospores) without any vegetative development. Here it seems certain that Pringsheim's view is the right one, for all stages in the reduction of the first neutral generation lie before our eyes. Nowhere, either here or among the green Algæ, do I see any evidence for the intercalation of a *new* generation or a new form of spore on the germination of the fertilised ovum.

Pringsheim extends the same view to the higher plants. The sporogonium of a moss is for him the highly modified first neutral generation, homologous with the vegetative plant, but here specially adapted for spore-formation. I have elsewhere pointed out[2] that this view has great advantages, for not only does it harmonise exactly with the actual facts observed in the green Algæ and their allies, but it also helps us to understand the astoundingly different forms which the archegoniate sporophyte may assume.

It seems to me that Pringsheim was right in regarding the fruit-formation of Florideæ as totally different from the sporophyte-formation of *Coleochæte* or the Bryophyta. The cystocarp bears none of the marks of a distinct generation, for throughout its whole development it remains in the most complete organic connec-

[1] *Annals of Botany*, vol. iv., p. 373.
[2] *Nature*, February 21, 1895.

tion with the thallus that bears it. The whole Floridean process, often so complicated, appears to be an arrangement for effecting the fertilisation of many female cells as the result of an original impregnation by a single sperm-cell. There is here still a great field for future research; but in the light of our present knowledge there seems to be no real parallelism with the formation of a sporophyte in the higher plants.

The gap between the Bryophyta and the Algæ remains, unfortunately, a wide and deep one, and it is not probable that any Algæ at present known to us lie at all near the line of descent of the higher Cryptogams. *Riccia* is often compared with *Coleochæte*, but it is by no means evident that *Riccia* is a specially primitive form. In *Anthoceros*, which bears some marks of an archaic character, the sporophyte is relatively well developed. To those who do not accept the theory of intercalation it is not necessary to assume that the most primitive Bryophyta must have the most rudimentary sporophyte.

Apart from other differences, Bryophyta differ from most green Algæ in the fact that asexual spores are *only found* in the generation succeeding fertilisation. The spores moreover are themselves quite different from anything in Algæ, and the constancy of their formation in fours among all the higher plants from the liverworts upwards, is a fact which requires explanation. I should like to suggest to some energetic histologist a comparison of the details of spore-formation in the lower liverworts and in the various groups of Algæ, especially those of the green series. It is possible that some light might be thus thrown on the origin of tetrad-spore-formation, a subject as to which Professor Farmer has already gained some very remarkable results. On Pringsheim's view some indications of homology between bryophytic and algal spore-formation might be expected, and anyhow the tetrads require *some* explanation.

The peculiarities of the sporophyte in the Archegoniatæ, as compared with any algal structures, depend, no doubt, on the acquirement of a terrestrial habit, while the oöphyte by its mode of fertilisation remains 'tied down to a semi-aquatic life.'[1] Professor Bower's phrase 'amphibious alternation' expresses this view of the case very happily, and indeed his whole account of the rise of the sporophyte is of the highest value, even though we may not accept his assumption as to its origin *de novo*.

I attach special weight to Professor Bower's treatment of this subject, because he has shown how the most important of all morphological phenomena in plants, namely the alternation of generations in Archegoniatæ, may be explained as purely adaptive in origin. All Darwinians owe him a debt of gratitude for this demonstration, which holds good even if we believe the sporophyte to be the modification of a pre-existing body, and not a new formation.

Apospory and Apogamy.

We must remember that the theory of homologous alternation has twice received the strongest confirmation of which a scientific hypothesis is susceptible—that of verified prediction. In both cases Pringsheim was the happy prophet. Convinced on structural grounds of the homology of the two generations in mosses, he undertook his experiments on the moss-fruits, in the hope, as he says,[2] that he would succeed in producing protonema from the subdivided seta of the mosses, and thus prove the *morphological* agreement of seta and moss-stem. His experiment, as everybody knows, was completely succcessful, and resulted in the first observed cases of *apospory*, *i.e.* the direct outgrowth of the sexual from the asexual generation.

Here he furnished his own verification; in the second case it has come from other hands. In the paper of 1877, so often referred to, he says (p. 391): 'Here, however [*i.e.* in the ferns], the act of generation, that is, the formation of sexual organs and the origin of an embryo, is undoubtedly bound up with the existence of the spore, *until those future ferns are found* which I indicated as conceivable in

[1] Bower, *Antithetic Alternation*.
[2] *Ges. Abh.* II. p. 407.

my preliminary notice, *in which the prothallus will sprout forth directly from the frond.*'

It is unnecessary to remind English botanists that Pringsheim's hypothetical aposporous ferns are now perfectly well known in the flesh; such cases having been first observed by Mr. Druery and then fully investigated by Professor Bower.

A very remarkable case of direct origin of the oöphyte from the sporophyte has lately been described by Mr. E. J. Lowe, in a variety of *Scolopendrium vulgare*. Here the young fern-plant produced prothalli bearing archegonia as direct outgrowths from its second or third frond. The specimen had a remarkable history, for the young plants were produced from portions of a prothallus which had been kept alive and repeatedly subdivided during a period of no less than eight years. I cannot go into the interesting details here, they will be published elsewhere; but I wish to call attention to the fact that in this case the production of the sexual from the asexual generation, occurring so early in life, has no obvious relation to suppressed spore-formation, and so appears to differ essentially from the cases first described, which occurred on mature plants. I believe Mr. Lowe's case is not an altogether isolated one.

The converse phenomenon—that of apogamy—or the direct origin of an asexual plant from the prothallus without the intervention of sexual organs, has now been observed in a considerable number of ferns, the examples already known belonging to no less than four distinct families: Polypodiaceæ, Parkeriaceæ, Osmundaceæ, and Hymenophyllaceæ. In *Trichomanes alatum* Professor Bower found that apospory and apogamy co-exist in the same plant, the sporophyte directly giving rise to a prothallus, which again directly grows out into a sporophyte; the life-cycle is thus completed without the aid either of spores or of sexual organs. Dr. W. H. Lang who has recently made many interesting observations on apogamy, will, I am glad to say, read a paper on the subject before this section, so I need say no more.

I must, however, express my own conviction that the facility with which, in ferns, the one generation may pass over into the other by vegetative growth, and that in both directions, is a most significant fact. It shows that there is no such hard and fast distinction between the generations as the antithetic theory would appear to demand, and in my opinion weighs heavily on the side of the homology of sporophyte and oöphyte. I cannot but think that the phenomena deserve greater attention from this point of view than they have yet received.

A mode of growth which affords a perfectly efficient means of abundant propagation cannot, I think, be dismissed as merely teratological.

Since the foregoing paragraph was first written Dr. Lang has made the remarkable discovery (already communicated to the Royal Society) that in a *Lastræa* sporangia of normal structure are produced on the prothallus itself, side by side with normal archegonia and antheridia. I cannot forbear mentioning this striking observation, of which we shall hear an account from the discoverer himself.

The strongest advocate of the homology of the prothallus with the fern plant could scarcely have ventured to anticipate such a discovery.

Relation between Mosses and Ferns.

Goebel said, in 1882: 'The gap between the Bryophyta and the Pteridophyta is the deepest known to us in the vegetable kingdom. We must seek the starting-point of the Pteridophyta elsewhere than among the Muscineæ: among forms which may have been similar to liverworts, but in which the asexual generations entered from the first on a different course of development.'[1] I cannot help feeling that all the work which has been done since goes to confirm this wise conclusion. Attempts have been made in the most sportsmanlike manner (to adopt a phrase of Professor Bower's) to effect a passage over the gulf, but the gulf is still unbridged. I cannot see anywhere the slightest indication of anything like an intermediate form between the spore-bearing plant of the Pteridophyta and the spore-bearing

[1] Schenk's *Handbuch der Botanik*, vol. ii. p. 401.

fruit of the Bryophyta. The plant of the Pteridophyta is sometimes small and simple, but the smallest and simplest seem just as unlike a bryophytic sporogonium as the largest and most complex. On the side of the moss group, *Anthoceros* has been often cited as a form showing a certain approach towards the Pteridophytes, and Professor Campbell in particular has developed this idea with remarkable ingenuity. An unprejudiced comparison, however, seems to me to show nothing more here than a very remote parallelism, not suggestive of affinity.

There is no reason to believe that the Bryophyta, as we know them, were the precursors of the vascular Cryptogams at all. There is a remarkable paucity of evidence for the geological antiquity of Bryophyta, though many of the mosses at any rate would seem likely to have been preserved if they existed. Brongniart said, in 1849, 'The rarity of fossil mosses, and their complete absence up to now in the ancient strata, are among the most singular facts in geological botany;'[1] and since that time it is wonderful how little has been added. Things seem to point to both Pteridophyta and Bryophyta having had their origin far back among some unknown tribes of the Algæ. If we accept the homologous theory of alternation, we may fairly suppose that the sporophyte of the earliest Pteridophyta always possessed vegetative organs of some kind. The resemblance between the young sporophyte and the prothallus in some lycopods indicates that at some remote period the two generations may not have been very dissimilar. At least some such idea gives more satisfaction to my mind than the attempt to conceive of a fern-plant as derived from a sterilised group of potential spores.

The Bryophyta may have had from the first a more reduced sporophyte, the first neutral generation having, in their ancestors, become more exclusively adapted to spore-producing functions. I must not omit to mention the idea that the Bryophyta, or at any rate the true mosses, are degenerate descendants of higher forms. The presence of typical stomata on the capsule in some cases, and of somewhat reduced stomata in others, has been urged in support of this view. It is possible; but if so, from what have these plants been reduced?

Few people, perhaps, fully realise how absolutely insoluble such a problem as we have been discussing really is. I say nothing as to the mosses, which *may* have arisen relatively late in geological history. The Pteridophyta, at any rate, are known to be of inconceivable antiquity. Not only did they exist in greater development than at present in the far-off Devonian period, but at that time they were already accompanied by highly organised gymnospermous flowering-plants. Probably we are all agreed that Gymnosperms arose somehow from the vascular Cryptogams. Hence, in the Devonian epoch, there had already been time not only for the Pteridophyta themselves to attain their full development, but for certain among them to become modified into complex Phanerogams. It would not be a rash assumption that the origin of the Pteridophyta took place as long before the period represented by the plant-bearing Devonian strata as that period is before our own day. Can we hope that a mystery buried so far back in the dumb past will be revealed?

It will be understood that I do not wish to assume the *rôle* of partisan for the homologous theory of alternation. Possibly the whole question lies beyond human ken, and partisanship would be ridiculous. But I do wish to raise a protest against anything like a dogmatic statement that alternation of generations *must have been* the result of the interpolation of a new stage in the life-history. Let us, in the presence of the greatest mystery in the morphology of plants, at least keep an open mind, and not tie ourselves down to assumptions, though we may use them as working hypotheses.

Histological Characters of the two Generations.

There is one histological question upon which I must briefly touch, because it bears directly on the subject which we have been considering. I shall say very little, however, in view of the discussion next Tuesday.

[1] *Tableau des Genres de Végétaux Fossiles*, p. 13.

It is now well known that in animals and in the higher plants a remarkable numerical change takes place in the constituents of the nucleus shortly before the act of fertilisation. The change consists in the halving of the number of chromosomes, those rod-like bodies which form the essential part of the nucleus, and are regarded by Weismann and most biologists as the bearers of hereditary qualities. Thus in the lily the number of chromosomes in the nuclei of vegetative cells is twenty-four; in the sexual nuclei, those of the male generative cell and of the ovum, the number is twelve. When the sexual act is accomplished the two nuclei unite, and so the full number is restored and persists throughout the vegetative life of the next generation. The absolute figures are of course of no importance; the point is, the reduction to one half during the maturation of the sexual cells, and the subsequent restoration of the full number when their union takes place. I say nothing as to the details or the significance of the process, points which have been fully dealt with elsewhere, notably in an elaborate recent paper by Miss E. Sargant.

Now, in animals (so far as I am aware) and in angiospermous plants the reduction of the chromosomes takes place very shortly before the differentiation of the sexual cells. Thus in a lily the reduction takes place on the male side immediately prior to the first division of the pollen mother-cell, so that four cell-divisions in all intervene between the reduction and the final differentiation of the male generative cells. On the female side the reduction in the same plant takes place in the primary nucleus of the embryo-sac, so that here there are three divisions between the reduction and the formation of the ovum. I believe these facts agree very closely with those observed in the animal kingdom, and so far there is no particular difficulty, for we can easily understand that if the number of chromosomes is to be kept constant from one generation to another, then the doubling involved in sexual fusion must necessarily be balanced by a halving.

There are, however, a certain number of observations on Gymnosperms and archegoniate Cryptogams which appear to put the matter in a different light. Overton[1] first showed that in a Cycad, *Ceratozamia,* the nuclei of the prothallus or endosperm all have the half-number of chromosomes. Here then the reduction takes place in the embryo sac (or rather its mother-cell), but a great number of cell-generations intervene between the reduction and the maturation of the ovum. In fact the whole female oöphyte shows the reduced number, while the sporophyte has the full number. The reduction takes place also in the pollen mother-cell. Further observations have extended this conclusion to some other Gymnosperms.

In *Osmunda* among the ferns there is evidence to show that reduction takes place in the spore mother-cell, and that the sexual generation has the half-number throughout. Professor Farmer has found the same thing in various liverworts, and shown that the reduction of chromosomes takes place in the spore mother-cell; and his observations of cell-division in the two generations have afforded some direct evidence that the oöphyte has the half-number and the sporophyte the full number throughout. Professor Strasburger fully discussed this subject before Section D at Oxford,[2] and came to the conclusion that the difference in number of chromosomes is a difference between the two generations as such, the sexual generation being characterised by the half-number, the asexual by the full number.

The importance of this conception for the morphologist is that an actual histological difference appears to be established between the two generations; a fact which would appear to militate against their homology. Some botanists even go so far as to propose making the number of chromosomes the criterion by which the two generations are to be distinguished. Considering that the whole theory rests at present on but few observations, I venture to think this both premature and objectionable; for nothing can be worse for the true progress of science than to rush hastily to deductive reasoning from imperfectly established premises.

The facts are certainly very difficult to interpret. Those who accept the antithetic theory of alternation suppose the sexual generation to be the older, and

[1] *Annals of Botany*, vol. vii. p. 139.
[2] See *Annals of Botany*, vol. viii. p. 281

that in Thallophytes the plant is always an oöphyte, whether 'actual' or 'potential.' Hence they believe that in Thallophytes the plant should show throughout the reduced number of chromosomes, reduction hypothetically taking place immediately upon the germination of the oöspore. If this were true it would lend some support to the idea of the intercalation of the sporophyte, but at present there is not the slightest evidence for these assumptions. On the contrary, in the only Thallophyte in which chromosome-counting has been successfully accomplished (*Fucus*) Professor Farmer and Mr. Williams find exactly the reverse; the plant has throughout the *full* number of chromosomes; reduction first takes place in the oögonium, immediately before the maturation of the ova, and on sexual fusion the full number is restored, to persist throughout the vegetative life of the plant. *Fucus* is, no doubt, a long way off the direct line of descent of Archegoniatæ, but still it is a striking fact that the only direct evidence we have goes dead against the idea that the sexual generation (and who could call a Fucus-plant anything else but sexual?) necessarily has the reduced number of chromosomes. This fact is indeed a rude rebuff to deductive morphology.

I am disposed to regard the different number of chromosomes in the two generations observed in certain cases among Archegoniatæ not as a primitive but as an acquired phenomenon, perhaps correlated with the definiteness of alternation in the Archegoniatæ as contrasted with its indefiniteness in Thallophytes. In *Fucus*, in flowering plants, and in animals the *soma* or vegetative body has the full number of chromosomes. With these the sporophyte of the Archegoniatæ agrees; it is the oöphyte which appears to be peculiar in possessing the half-number, so that if the evidence points to intercalation at all, it would seem to suggest that the oöphyte is the intercalated generation—obviously a *reductio ad absurdum*. I do not think we are as yet in a position to draw any morphological conclusions from these minute histological differences, interesting as they are.

The question how the number of chromosomes is kept right in cases of apospory and of apogamy is obviously one of great interest, and I am glad to say that it is receiving attention from competent observers.

Sexuality of Fungi.

Only a few years ago De Bary's opinion that the fruit of the ascus-bearing Fungi is normally the result of an act of fertilisation was almost universally accepted, especially in this country. Although the presence of sexual organs had only been recorded in comparatively few cases, and the evidence for their functional activity was even more limited, yet the conviction prevailed that the ascocarp is at least the homologue of a sexually produced fruit. The organ giving rise to the ascus or asci was looked upon as homologous with the oögonium of the Peronosporeæ, the supposed fertilising organ either taking the form of an antheridial branch as in that group, or, as observed by Stahl in the lichen *Collema*, giving rise to distinct male cells, or spermatia. More recently there has been a complete revolution of opinion on this point, and a year ago or less most botanists probably agreed that the question of the sexuality of the Ascomycetes had been settled in a negative sense. This change was due, in the first place, to the influence of Brefeld, who showed, in a great number of laborious investigations, that the ascus-fruit may develop without the presence of anything like sexual organs; while Möller proved that the supposed male cells of lichens are in a multitude of cases nothing but conidia, capable of independent germination.

The view thus gained ground that all the higher Fungi are asexual plants, fertilisation only occurring in the lower forms, such as the Peronosporeæ and Mucorineæ, which have not diverged far from the algal stock. The ascus, in particular, is regarded by this school as homologous with the asexual sporangium of a *Mucor*. This theory has been brilliantly expounded in a remarkable book by Von Tavel, which we cannot but admire as a model of clear morphological reasoning, whether its conclusions be ultimately adopted or not.

Still, it must be admitted that the Brefeld school were rather apt to ignore such pieces of evidence as militated against their views, and consequently their position was insecure so long as these hostile posts were left uncaptured.

Quite recently the whole question has been reopened by the striking observations of Mr. Harper, an American botanist working at Bonn.

Zopf, in 1890,[1] pointed out that up to that time it had not been possible in any Ascomycete to demonstrate a true process of fertilisation by strictly scientific evidence, namely, by observing the fusion of the nuclei of the male and female elements. Exactly the proof demanded has now been afforded by Mr. Harper's observations, for in a simple Ascomycete, *Sphærotheca castagnei,* the parasite causing the hop-mildew, he has demonstrated in a manner which appears to be conclusive the fusion of the nucleus of the antheridium with that of the ascogonium.[2] It is impossible to evade the force of this evidence, for the fungus in question is a perfectly typical Ascomycete, though exceptionally simple, in so far as only a single ascus is normally produced from the ascogonium. It is unnecessary to point out how important it is that Mr. Harper's observations should be confirmed and extended to other and more complex members of the order. In the mean time the few who (unlike your President) had not bowed the knee to Brefeld may rejoice!

It is impossible to pursue the various questions which press upon one's mind in considering the morphology of the Fungi. The occurrence not only of cell-fusion, but of nuclear fusion, apart from any definite sexual process, now recorded in several groups of Fungi, urgently demands further inquiry. Such unions of nuclei have been observed in the basidia of Agarics, the teleutospores of Uredineæ, and even in the asci of the Ascomycetes. That such a fusion is not necessarily, as Dangeard[3] has supposed, of a sexual nature, seems to be proved by the fact that it occurs in the young ascus of *Sphærotheca* long after the true act of fertilisation has been accomplished. It is possible, however, that these phenomena may throw an important side-light on the significance of the sexual act itself.

Another question which is obviously opened up by the new results is that of the homologies of the ascus. The observations of Lagerheim[4] on *Dipodascus* point to the sexual origin of a many-spored sporangium not definitely characterised as an ascus. On the other hand, not only sporangia, but true asci are known to arise in a multitude of cases direct from the mycelium. It is of course possible that as regards the asci these are cases of reduction or apogamy; on the other hand, it is not wholly impossible that the asci may turn out to be really homologous with a sexual sporangia, even though their development may often have become associated with the occurrence of a sexual act. However this may be, there is at present no reason to doubt that a very large proportion of the Fungi are, at least functionally, sexless plants.

CHALAZOGAMY.

Among the most striking results of recent years bearing on the morphology of the higher plants, Treub's discovery of the structure of the ovule and the mode of fertilisation in *Casuarina* must undoubtedly be reckoned. The fact that the pollen-tube in this genus does not enter the micropyle, but travels through the tissues of the ovary to the chalaza, thus reaching the base of the embryo-sac, was remarkable enough in itself, and when considered in connection with the presence of a large sporogenous tissue producing numerous embryo-sacs, appeared to justify the separation of this order from other angiosperms. Then came the work of Miss Benson in England, and of Nawaschin in Russia, showing that these remarkable peculiarities are by no means confined to *Casuarina,* but extend also in various modifications to several genera of the Cupuliferæ and Ulmaceæ. They are not, however, constant throughout these families, so that we are no longer able to attach to these characters the same fundamental systematic importance which their first discoverer attributed to them. It is remarkable, however, that these

[1] 'Die Pilze,' *Schenk's Handbuch der Botanik,* Bd. iv. p. 341.
[2] *Berichte der deutschen bot. Gesellschaft,* vol. xiii., January 29, 1896
[3] *Le Botaniste,* vols. iv. and v.
[4] *Pringsheim's Jahrbuch f. Wiss. Bot.* 1892.

departures from the ordinary course of angiospermous development occur in families some of which have been believed on other grounds to be among the most primitive Dicotyledons.

EVIDENCE OF DESCENT DERIVED FROM FOSSIL BOTANY.

At the beginning of this Address I spoke of the importance of the comparatively direct evidence afforded by fossil remains as to the past history of plants. It may be of interest if I endeavour to indicate the directions in which such evidence seems at present to point.

It was Brongniart who in 1828 first arrived at the great generalisation that 'nearly all of the plants living at the most ancient geological epochs were Cryptogams,'[1] a discovery of unsurpassed importance for the theory of evolution, though one which is now so familiar that we almost take it for granted. Those palæozoic plants which are not Cryptogams are Gymnosperms, for the angiospermous flowering plants only make their appearance high up in the secondary rocks. Even the Wealden flora, recently so carefully described by Mr. Seward, one of the secretaries to this section, has as yet yielded no remains referable to Angiosperms, though this is about the horizon at which we may expect their earliest trace to be found.

Attention has already been called to the enormous antiquity of the higher Cryptogams—the Pteridophyta—and to the striking fact that they are accompanied, in the earliest strata in which they have been demonstrated with certainty, by well-characterised Gymnosperms. The Devonian flora, so far as we know it, though an early, was by no means a primitive one, and the same statement applies still more strongly to the plants of the succeeding Carboniferous epoch. The palæozoic Cryptogams, as is now well known, being the dominant plants of their time, were in many ways far more highly developed than those of our own age; and this is true of all the three existing stocks of Pteridophyta, Ferns, Lycopods, and Equisetineæ.

We cannot, therefore, expect any *direct* evidence as to the origin of these groups from the palæozoic remains at present known to us, though it is, of course, quite possible that the plants in question have sometimes retained certain primitive characters, while reaching in other respects a high development. For example, the general type of anatomical structure in the young stems of the Lepidodendreæ was simpler than that of most Lycopods at the present day, though in the older trunks the secondary growth, correlated with arborescent habit, produced a high degree of complexity. On the whole, however, the interest of the palæozoic Cryptogams does not consist in the revelation of their primitive ancestral forms, but rather in their enabling us to trace certain lines of evolution further upward than in recent plants. From the Carboniferous rocks we first learn what Cryptogams are capable of. In descending to the early strata we do not necessarily trace the trunk of the genealogical tree to its base; on the contrary, we often light on the ultimate twigs of extensive branches which died out long before our own period.

In a lecture which I had the honour of giving last May before the Liverpool Biological Society, I pointed out how futile the search for 'missing links' among fossil plants is likely to be. The lines of descent must have been so infinitely complex in their ramification that the chances are almost hopelessly great against our happening upon the direct ancestors of living forms. Among the collateral lines, however, we may find invaluable indications of the course of descent.

Fossil botany has revealed to us the existence in the Carboniferous epoch of a fourth phylum of vascular Cryptogams quite distinct from the three which have come down—more or less reduced—to our own day. This is the group of Sphenophylleæ, plants with slender ribbed stems, superposed whorls of more or less wedge-shaped leaves, and very complex strobili with stalked sporangia. The group to a certain extent combines the characters of Lycopods and Horsetails, resembling the former in the primary anatomy, and the latter, though remotely, in external habit and fructification. Like so many of the early Cryptogams, *Spheno-*

[1] Williamson, *Reminiscences of a Yorkshire Naturalist*, 1896, p. 198.

phyllum possessed well-marked cambial growth. One may hazard the guess that this interesting group may have been derived from some unknown form lying at the root of both Calamites and Lycopods. The existence of the Sphenophylleæ certainly suggests the probability of a common origin for these two series.

In few respects is the progress made recently in fossil botany more marked than in our knowledge of the affinities of the Calamarieæ. Even so recently as the publication of Count Solms-Laubach's unrivalled introduction to 'Fossil Botany,' the relation of this family to the Horsetails was still so doubtful that the author dealt with the two groups in quite different parts of his book. This is never likely to happen again. The study of vegetative anatomy and morphology on the one hand, and of the perfectly preserved fructifications on the other, can leave no doubt that the fossil Calamarieæ and the recent Equiseta belong to one and the same great family, of which the palæozoic representatives are, generally speaking, by far the more highly organised. This is not only true of their anatomy, which is characterised by secondary growth in thickness just like that of a Gymnosperm, but also applies to the reproductive organs, some of which are distinctly heterosporous. In the genus *Calamostachys* we are, I think, able to trace the first rise of this phenomenon.

The external morphology of the cones is also more varied and usually more complex than that of recent Equiseta, though in some Carboniferous forms, as in the so-called *Calamostachys tenuissima* of Grand' Eury, we find an exactly Equisetum-like arrangement.

The position of the Sigillariæ as true members of the Lycopod group is now well established. The work of Williamson proved that there is no fundamental distinction between the vegetative structure of *Lepidodendron*, which has always been recognised as lycopodiaceous, and that of *Sigillaria*. Secondary growth in thickness, the character which here, as in the case of the Calamodendreæ, misled Brongniart, is the common property of both genera. Then came Zeiller's discovery of the cones of *Sigillaria*, settling beyond a doubt that they are heterosporous Cryptogams. A great deal still remains to be done, more especially as to the relation of *Stigmaria* to the various types of lycopodiaceous stem. At present we are perhaps too facile in accepting *Stigmaria ficoides* as representing the underground organs of almost any carboniferous Lycopod.

We are now in possession of a magnificent mass of data for the morphology of the palæozoic lycopods, and have perhaps hardly yet realised the richness of our material. I refer more especially to specimens with structure, on which, here as elsewhere, the scientific knowledge of fossil plants primarily depends.

It is scarcely necessary to repeat what has been said so often elsewhere, that the now almost universal recognition of the cryptogamic nature of Calamodendreæ and Sigillariæ is a splendid triumph for the opinions of the late Professor Williamson, which he gallantly maintained through a quarter of a century of controversy.

Perhaps, however, the keenest interest now centres in the Ferns and fern-like plants of the carboniferous epoch. No fossil remains of plants are more abundant, or more familiar to collectors, than the beautiful and varied fern-fronds from the older strata. The mere form, and even the venation of these fronds, however, really tell us little, for we know how deceptive such characters may be among recent plants. In a certain number of cases, discovery of the fructification has come to our aid, and where sori are found we can have no more doubt as to the specimens belonging to true Ferns. The work of Stur and Zeiller has been especially valuable in this direction, and has revealed the interesting fact that a great many of these early Ferns showed forms of fructification now limited to the small order Marattiaceæ. I think perhaps the predominance of this group has been somewhat exaggerated, but at least there is no doubt that the marattiaceous type was much more important then than now, though it by no means stood alone. In certain cases the whole fern-plant can be built up. Thus Zeiller and Renault have shown that the great stems known as *Psaronius*, the structure of which is perfectly preserved, bore fronds of the *Pecopteris* form, and that similar *Pecopteris* fronds produced the fructification of *Asterotheca*, which is of a marattraceous character. Hence, for a good many Carboniferous and Permian forms there is not the slightest doubt as to their fern-nature, and we can even form an idea of the particular group of Ferns to which the affinity is closest.

I will say nothing more as to the true Ferns, though they present innumerable points of interest, but will pass on at once to certain forms of even greater importance to the comparative morphologist.

A considerable number of palæozoic plants are now known which present characters intermediate between those of Ferns and Cycadeæ. I say *present intermediate characters*, because that is a safe statement; we cannot go further than this at present, for we do not yet know the reproductive organs of the forms in question.

In *Lyginodendron*, the vegetative organs of which are now completely known, the stem has on the whole a cycadean structure; the anatomy, which is preserved with astonishing perfection, presents some remarkable peculiarities, the most striking being that the vascular bundles of the stem have precisely the same arrangement of their elements as is found in the leaves of existing Cycads, but nowhere else among living plants. The roots also, though not unlike those of certain ferns in their primary organisation, grew in thickness by means of cambium, like those of a Gymnosperm. On the other hand, the leaves of *Lyginodendron* are typical fern-fronds, having the form characteristic of the genus *Sphenopteris*, and being probably identical with the species *S. Hœninghausi*. Their minute structure is also exactly that of a fern-frond, so that no botanist would doubt that he had to do with a Fern if the leaves alone were before him.

This plant thus presents an unmistakable combination of cycadean and fern-like characters. Another and more ancient genus, *Heterangium*, agrees in many details with *Lyginodendron*, but stands nearer the ferns, the stem in its primary structure resembling that of a *Gleichenia*, though it grows in thickness like a cycad. These intermediate characters led Professor Williamson and myself to the conclusion that these two genera were derived from an ancient stock of Ferns, combining the characters of several of the existing families, and that they had already considerably diverged from this stock in a cycadean direction. I believe that recent investigations, of which I hope we shall hear more from Mr. Seward, tend to supply a link between *Lyginodendron* and the more distinctly cycadean stem known as *Cycadoxylon*.

Heterangium first appears in the Burntisland beds, at the base of the carboniferous system; from a similar horizon in Silesia, Count Solms-Laubach has described another fossil, *Protopitys Bucheana*, the vegetative structure of which also shows, though in a different form, a striking union of the characters of Ferns and Gymnosperms. Count Solms shows that this genus cannot well be included among the Lyginodendreæ, but must be placed in a family of its own, which, to use his own words, 'increases the number of extinct types which show a transition between the characters of Filicineæ and of Gymnosperms, and which thus might represent the descendants in different directions of a primitive group common to both.'[1]

Another intermediate group, quite different from either of the foregoing, is that of the Medulloseæ, fossils most frequent in the Upper Carboniferous and Permian strata. The stems have a remarkably complicated structure, built up of a number of distinct rings of wood and bast, each growing by its own cambium. Whether these rings represent so many separate primary cylinders, like those of an ordinary polystelic Fern, or are entirely the product of anomalous secondary growth, is still an open question, on which we may expect more light from the investigations of Count Solms. In any case, these curious stems (which certainly suggest in themselves some relation to Cycadeæ) are known to have borne the petioles known as *Myeloxylon* which have precisely the structure of cycadean petioles.[2]

Renault has further brought forward convincing evidence that these *Myeloxylon* petioles terminated in distinctly fern-like foliage, referable to the form-genera

[1] *Bot. Zeitung*, 1893, p. 207.
[2] Seward, *Annals of Botany*, vol. vii. p. 1.

Alethopteris and *Neuropteris.* Hence it is evident that the fronds of these types, like some specimens of *Sphenopteris*, cannot be accepted as true Ferns, but may be strongly suspected of belonging to intermediate groups between Ferns and Cycads.

It is not likely (as has been repeatedly pointed out elsewhere) that any of these intermediate forms are really direct ancestors of our existing Cycads, which certainly constitute only a small and insignificant remnant of what was once a great class, derived, as I think the evidence shows, from fern-like ancestors, probably by several lines of descent.

One of the greatest discoveries in fossil botany was undoubtedly that of the Cordaiteæ—a fourth family of Gymnosperms, quite distinct from the three now existing, though having certain points in common with all of them. They are much the most ancient of the four stocks, extending back far into the Devonian. Nearly all the wood of Carboniferous age, formerly referred to Coniferæ under the name of *Dadoxylon* or *Araucarioxylon*, belonged to these plants. Thanks chiefly to the brilliant researches of Renault and Grand' Eury, the structure of these fine trees is now known with great completeness. The roots and stems have a coniferous character, but the latter contain a large, chambered pith different from anything in that order. The great simple lanceolate or spatulate leaves, sometimes a yard long, were traversed by a number of parallel vascular bundles, each of which has the exact structure of a foliar bundle in existing Cycadeæ. This type of vascular bundle is evidently one of the most ancient and persistent of characters. Both the male and female flowers (*Cordaianthus*) are well preserved in some cases. The morphology of the former has not yet been cleared up, but the stamen, consisting of an upright filament bearing 2–4 long pollen-sacs at the top, is quite unlike anything in Cycadeæ; a comparison is possible either with *Gingko* or with the Gnetaceæ.

In the female flowers—small cones—the axillary ovules appear to have two integuments, a character which resembles Gnetaceæ rather than any other Gymnosperms. Renault's famous discovery of the prothallus in the pollen-grains of *Cordaites* indicates the persistence of a cryptogamic character; but it cannot be said that the group as a whole bears the impress of primitive simplicity, though it certainly combines in a remarkable way the characters of the three existing orders of the Gymnosperms.

There is one genus, *Poroxylon*, fully and admirably investigated by Messrs. Bertrand and Renault, which from its perfectly preserved vegetative structure (and at present nothing else is known) appears to occupy an intermediate position between the Lyginodendreæ and the Cordaiteæ. The anatomy of the stem is almost exactly that of *Lyginodendron*, the resemblance extending to the minutest details, while the leaves seem to closely approach those of *Cordaites. Poroxylon* is at present known only from the Upper Carboniferous, so we cannot regard it as in any way representing the ancestors of the far more ancient Cordaiteæ. The genus suggests, however, the possibility that the Cordaiteæ and the Cycadeæ (taking the latter term in its wide sense) may have had a common origin among forms belonging to the filicinean stock. It is also possible that the Cordaiteæ, or plants allied to them, may in their turn have given rise to both Coniferæ and Gnetaceæ.

It is unfortunate that at present we do not know the fructification of any of the fossil plants which appear to be intermediate between ferns and Gymnosperms. Sooner or later the discovery will doubtless be made in some of these forms, and most interesting it will be. M. Renault's *Cycadospadix* from Autun appears to show that very cycad-like fructifications already existed in the later Carboniferous period, and numerous isolated seeds point in the same direction, but we do not know to what plants they belonged.

I think we may say that such definite evidence as we already possess decidedly points in the direction of the origin of the Gymnosperms generally from plants of the Fern series rather than from a lycopodiaceous stock.

I must say a few words before concluding on the cycad-like fossils which are so striking a feature of mesozoic rocks, although I feel that this is a subject with which my friend Mr. Seward is far more competent to deal. Both leaves and trunks of an unmistakably cycadean character are exceedingly common in many mesozoic strata, from the Lias up to the Lower Cretaceous. In some cases the structure of the stem is preserved, and then it appears that the anatomy as well as the external morphology is, on the whole, cycadean, though simpler, as regards the course of the vascular bundles, than that of recent representatives of the group.

Strange to say, however, it is only in the rarest cases that fructifications of a truly cycadean type have been found in association with these leaves and stems. In most cases, when the fructification is accurately known, it has turned out to be of a type totally different from that of the true Cycadeæ, and much more highly organised. This is the form of fructification characteristic of *Bennettites*, a most remarkable group, the organisation of which was first revealed by the researches of Carruthers, afterwards extended by those of Solms-Laubach and Lignier. The genus evidently had a great geological range, extending from the Middle Oölite (or perhaps even older strata) to the Lower Greensand. Probably, all botanists are agreed in attributing cycadean affinities to the Bennettiteæ, and no doubt they are justified in this. Yet the cycadean characters are entirely vegetative and anatomical; the fructification is as different as possible from that of any existing cycad, or, for that matter, of any existing Gymnosperm. At present, only the female flower is accurately known, though Count Solms has found some indications of anthers in certain Italian specimens. The fructification of the typical species, *B. Gibsonianus,* which is preserved in marvellous perfection in the classical specimens from the Isle of Wight, terminates a short branch inserted between the leaf-bases, and consists of a fleshy receptacle bearing a great number of seeds seated on a long pedicel with barren scales between them. The whole mass of seeds and intermediate scales is closely packed into a head, and is enclosed by a kind of pericarp formed of coherent scales, and pierced by the micropylar terminations of the erect seeds. Outside the pericarp, again, is an envelope of bracts which have precisely the structure of scale-leaves in cycads. The internal structure of the seeds is perfectly preserved, and strange to say, they are nearly, if not quite, exalbuminous, practically the whole cavity being occupied by a large dicotyledonous embryo.

This extraordinary fructification is entirely different from that of any other known group of plants, recent or fossil, and characterises the Bennettiteæ, as a family perfectly distinct from the Cycadeæ, though probably, as Count Solms-Laubach suggests, having a common origin with them at some remote period. The Bennettiteæ, while approaching Angiosperms in the complexity of their fruit, retain a filicinean character in their ramenta, which are quite like those of ferns, and different from any other form of hair found in recent Cycadeæ. Probably the bennettitean and cycadean series diverged from each other at a point not far removed from the filicinean stock common to both.

I hope that the hasty sketch which I have attempted of some of the indications of descent afforded by modern work on fossil plants may have served to illustrate the importance of the questions involved and to bring home to botanists the fact that phylogenetic problems can no longer be adequately dealt with without taking into account the historical evidence which the rocks afford us.

Before leaving this subject I desire to express the great regret which all botanists must feel at the recent loss of one of the few men in England who have carried on original work in fossil botany. At the last meeting of the Association we had to lament the death, at a ripe old age, of a great leader in this branch of science, Professor W. C. Williamson. Only a few weeks ago we heard of the premature decease of Thomas Hick, for many years his demonstrator and colleague. Mr Hick profited by his association with his distinguished chief, and made many valuable original contributions to palæobotany (not to mention other parts of botanical science), among which I may especially recall his work, in conjunction with Mr. Cash, on *Astromyelon* (now known to be the root of Calamites), on the leaves and on the primary structure of the stem in Calamites, on the structure of *Calamostachys,* on the root of *Lyginodendron,* and on a new fossil probably allied to *Stigmaria.* His loss will leave a gap in the too thin ranks of fossil-botanists; but we may hope that the subject, now that its importance is beginning to be appreciated, will be taken up by a new generation of enthusiastic investigators.

Conclusion.

To my mind there is a wonderful fascination in the records of the far-distant past in which our own origin, like that of our distant cousins the plants, lies hidden. If any fact is brought home to us by the investigations of modern biology, it is the conviction that all life is one: that, as Nägeli said, the distance from man to the lowest bacterium is less than the distance from the lowest bacterium to non-living matter.

In all studies which bear on the origin and past history of living things there is an element of human interest—

'Hence, in a season of calm weather,
Though inland far we be,
Our souls have sight of that immortal sea
Which brought us hither,'

The problems of descent, though strictly speaking they may often prove insoluble, will never lose their attraction for the scientifically guided imagination.

The following Report and Papers were read :—

1. *Report on Methods of Preparing Vegetable Specimens for Museums.*

See Reports, p. 684.

2. *On some Species of the Chytridiaceous Genus* Urophlyctis. *By* P. Magnus, *Professor of Botany in the University of Berlin.*

The author maintains the genus *Urophlyctis,* established by J. Schroeter, in opposition to the opinion of Alfred Fischer. He describes the development of the species *Urophlyctis Kriegeriana,* occurring in *Carum carvi,* established by him some years ago, and shows that its spores are formed by the conjugation of two cells, arising from different filaments, and that the development of the fungus takes place within a single cell of the host, namely, the central cell of the gall produced by it, which is of limited growth. The author proves that the fungus observed by Trabut in Algiers, which causes large swellings on beetroots, also belongs to this genus *Urophlyctis.* It was described by Trabat and also by Saccardo and Mattirolo as one of the Ustilagineæ, *Œdomyces leproides* (Trab.). The author proves that its spores are likewise formed by the conjugation of two cells, arising from different filaments, exactly as in *Urophlyctis.* While these observers state that the fungus developes in individual cells of the tumours caused by it, the author shows that the cells containing the fungus are connected with one another by canals of variable length and width, and that hence the cells containing the fungus are only outgrowths and branches of one and the same cell. The species only differs from *Urophlyctis Kriegeriana* in the unlimited growth of the gall, which corresponds to the continued ramification of the cell attacked by the fungus.

Finally, the author deals with the development of the gall of *Urophlyctis pulposa,* which differs from that of the species already described.

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3. *A Parasitic Disease of* Pellia epiphylla. *By* W. G. P. Ellis, *M.A., Cambridge.*

A disease extending over a pan of *Pellia epiphylla* at the University Botanic Garden, Cambridge, during May and June, 1896, was found to be caused by a

Mould allied to, if not identical with, *Ascotricha,* which has become endoparasitic. The fungus was isolated, cultivated in hanging drops, gelatine tubes and flasks; and conidia from a pure culture when applied to fresh Pellia plants reproduced the disease. The germ tube from the conidia was traced into the superficial cells, whose walls were browned in the neighbourhood of the germinating spores or their germ tubes.

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4. *On* Corallorhiza innata *R. Br. and its associated Fungi. By* A. VAUGHAN JENNINGS, *F.L.S., F.G.S., Demonstrator of Botany and Geology in the Royal College of Science, Dublin.*

The orchid genus *Corallorhiza* has long been of interest to botanists on account of the peculiar rhizome from which it derives its name, the absence of roots, and that loss of chlorophyll associated with a saprophytic habit which it shares with such forms as *Epipogon* and *Monotropa.* During recent years considerable modification of the views of botanists as to the nutrition of saprophytes, as well as of other plants, has taken place owing to their frequently observed connection with fungoid elements; and from this point of view any additional information as to the habit of so specialised a type as *Corallorhiza* may prove of value.

The writer has had some growing plants of this species under observation during July and August in the pine-woods near Davos Platz, and the results may be roughly stated as follows:—

1. The parenchymatous tissue of the rhizome contains numerous hyphæ of a 'Mycorhiza.' These may be colourless, yellow, or brown, are distinctly septate, and show the character of the mycelium of the higher fungi, not of the 'moulds,' &c. Though most abundant in the middle cortex, the hyphæ are present in all layers external to this, and their distribution is often correlated with the presence of a large quantity of starch.

2. The rhizome of the growing plant is invariably surrounded by a web of white, yellow, and brown hyphæ, which spread out for a long distance into the surrounding soil. These hyphæ present the same characters under the microscope as those of the mycorhiza in the tissue cells.

3. Though in hurriedly gathered specimens the rhizome seems to separate readily from the soil and its mycelium, a careful examination shows that the growing shoots bear small papillæ crowned with tufts of long hairs, which serve for the collection and transmission of the fungous hyphæ. The latter may be traced in great numbers from the surrounding mycelium down the hairs and through the epidermal cells into the ground tissue.

4. The presence of these specialised hairs seems to indicate that, whatever may be the case in other plants, the mycorhiza has here a distinct physiological value to the orchid, and is not a merely tolerated symbiote.

5. Attempts to discover whether the mycelium forming the mycorhiza can be referred to any one species of fungus have not as yet proved conclusive, but the following observations may be noted:—

(*a*) The general and microscopic characters of the hyphæ point to the Basidiomycetes as the group to which the fungus belongs.

(*b*) Several young agaricoid sporophores have been found growing from the mycelium round the rhizome. These refused to develop further in cultivation, but comparison with the early stages of *Clitocybe infundibuliformis* Sch., found a few feet distant, indicates that this is the species to which they belong.

(*c*) In another locality *Tricholoma ionides* Bull. was found growing from the hole from which a plant of Corallorhiza had been removed three days before.

(*d*) In a third case a subterranean hymenomycete, probably a species of *Hymenogaster*, was found between the lobes of the rhizome with its mycelium spreading over the branches.

So far, then, as this district is concerned, it seems that the 'mycorhiza' of Corallorhiza is a hymenomycete, and commonly an agaric; and that the species of *Tricholoma* and *Clitocybe* mentioned above are those commonly observed. The only other forms yet noted in proximity to Corallorhiza are *Cortinarius subferrugineus* Batsch. and *Mycena umbellifera* Sch., but further evidence with regard to these is at present wanting.

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5. *On a New Genus of* Schizomycetes, *showing Longitudinal Fission.* (Astrobacter Jonesii.) *By* A. Vaughan Jennings, *F.L.S., F.G.S., Demonstrator of Geology and Botany in the Royal College of Science, Dublin.*

The great section of lower fungoid organisms known as the Schizomycetes is characterised by the predominance of reproduction by the simple method of fission. In almost all cases the direction of division is transverse to the longer axis of the cell, and this is, in fact, commonly regarded as constant throughout the group.

One exception has, however, been described by Metschnikoff in the form named by him *Pasteuria ramosa*, a pear-shaped organism in which longitudinal division produces more or less radiate groups of pyriform cells.

The object of the present note is to record the existence of a second genus, in which longitudinal fission results in the formation of a still more distinctly stellate structure.

The organism in question was found by Mr. A. Coppen Jones, F.L.S., in fresh water in the neighbourhood of Tübingen, associated with large quantities of *Spirillum undula.* It was, in fact, only after staining the material to demonstrate the cilia in the latter that it was first observed, unfortunately too late for investigation in the living condition.

Simple rod-like forms may be found, but more frequently V-shaped or Y-shaped cells resulting from their longitudinal fission. After division the new segments become more and more widely separated at the ends till regular three- or four-rayed stars are produced. In later stages symmetrical six- and eight-rayed stars are formed, but older individuals with ten or more rays are less regular in structure. There is no tendency to the pear-shaped swelling seen in Pasteuria, and no spores have been observed. Owing to the intensity of the staining, little can be said at present as to their internal structure, and details as to the life-history await further investigation.

There is no doubt, however, that the organism is allied to the bacteria, and that its peculiar shape is the result of longitudinal division. It may in future be desirable to divide the Schizomycetes into two sections, those in which the division is transverse (*Diaschizæ*), and those in which it is longitudinal (*Paraschizæ*).

The generic name proposed is at once suggested by its form; the specific name is in honour of the discoverer, whose valuable work on the tubercle bacillus is now being recognised by all bacteriologists.

FRIDAY, SEPTEMBER 18.

The following Papers were read:—

1. *On the Arrangement of the Vascular Bundles in certain* Nymphæaceæ. *By* D. T. Gwynne-Vaughan, *B.A. Cantab.*

One of the most remarkable characteristics of this order is the very extensive prevalence of the astelic system in the arrangement of the vascular bundles of their stems; however, during an examination into the structure of various members of the order, the fact that other systems of arrangement also are present came to light. Thus in *Nymphæa flava* and *N. tuberosa* the plants produce small tubers at the ends of stalks or stolons of greater or less length, and in these stalks or stolons the vascular bundles are not arranged in an astelic manner, but are grouped around three to five different centres, forming thus so many separate steles, or at least so many groups possessing all the characteristics of definite steles. Each of these is surrounded by its own endodermis, and is composed of three to four vascular bundles with very distinct and prominent phloëms, while a small canal in the centre of the stele represents their disintegrated xylems.

The tubers formed at the end of these stolons bear buds which grow out into resh rhizomes, the first internodes of which are very narrow and much elongated; in these, again, the vascular bundles (four to seven in number) exhibit a different arrangement, for they present none of the confusion found in the mature rhizome, but run perfectly longitudinally; either they all keep separate, or a varying number of them may be united to form pairs. When six of them are present and these are arranged in three pairs, the section presents a remarkable resemblance to that of the floral peduncle of *Cabomba aquatica.*

Again, in the rhizome itself the arrangement is not altogether astelic, for by the aggregation of the separated bundles of the stem a number of steles are formed, one in the region below the point of insertion of each leaf. These groups of bundles appear to be set apart for the especial purpose of bearing the adventitious roots, and they are to be found in varying degrees of perfection throughout the order. I found *Victoria regia* and certain species of *Nymphæa* to possess the most perfect root-bearing steles; they are composed of ten to twenty bundles arranged in a ring, and are perfectly distinct and well defined. On the other hand, in other species of *Nymphæa* and in *Nuphar* the bundles set apart for bearing the adventitious roots are not arranged in a sufficiently regular manner to be considered as a stele, or are only laterally fused together to form an arc of greater or less extent.

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2. *The Influence of Habitat upon Plant-Habit.* *By* G. F. Scott Elliot, *B.Sc., F.L.S., F.R.G.S.*

The paper is an attempt to tabulate and compare the habits and habitats of the Ranunculaceæ, Papaveraceæ, and Cruciferæ in the Kew and British Museum Herbaria, or those from the European and Mediterranean floras practically. There were only 230 plants in which such tabulation of both habit and habitat was possible. The author's tables are given below, and the paper is explanatory of them, giving the result of recent literature and experiment so far as it illustrates or explains the tables. The dependence of habit upon habitat is shown to be very clear throughout. In conclusion, the author anticipates the objections of those who hold the original hypothesis of Professor Weismann (that acquired characters can by no means be inherited) by pointing to the most recent publication of this writer, wherein use-inheritance of a kind is admitted. In any case the correspondence must be explained by those who deny any relation between habit and habitat on purely theoretical grounds.

Table I.—*Rosette Plants.*

Cerastium macranthum	Rocks Algiers	Alyssum, 5, 6, 7	Athens
„ scaposum	Rocks Crete	Diplotaxis 3, 5, 6 (only if grown in	Exposed places)
„ campanulatum	Sand Naples	„ 10	Sandy waysides
Iberis 19	Dry places	„ 11	Seaside
Lychnis alpina	Rocks ?	„ 13	Midian desert
Thlaspi 6,[1] 8, 10, 20, 21, 23	Rocks	Sinapis 10	Calcaire aride
Sisymbrium 32	Desert	Brassica 24	Algeria
Arabis 6, 10, 21, 12, 13.	Rocks	Lepidium 21, 22, 23	Stony mountains
Cardamine 13, 14, 15	Alpine rocks		

Table II.—*Rock Plants.*

Farsetia, 1, 2, 3.	Very woolly plants	Euromodendron	An ericoid shrub
Sinapis 4	More hairy than usual	Matthiola 7	Very woody
Fumaria 27	Fleshy leaves	Turritis	Near water in sheltered glens
Iberis 18	Fleshy leaves	Arabis 1, 2, 3, 4, 5	

Table III.—*Downy, Hairy, or Woolly Plants.*

Ranunculus 6 (variety)	Desert	Alyssum 5, 6, 7	Athens
Delphinium 14	Desert	„ 8	Fragments calcaireux
„ 7	Greece	Sisymbrium 32	Deserts
„ nanum	Stony places	Malcolmia 9, 10	Spain, Algiers
Matthiola 5	Desert	„ 11	Maritime sands
Vella	Mont. calcar., Spain	Cerastium latifolium	Alpine
Farsetia 1, 2, 3	Dry rocks	„ tomentosum	Mountains, Greece
Aubrietia	Syria, arid places	„ pedunculatum	„ „

[1] The numbers correspond to those in Nyman's Conspectus.

TABLE IV.—*Types of Sonchus spinosus or Zilla myagroides.*

Lepidium 15	Palestine	Sisymbrium 17	Australia
Matthiola 11	Greece and arid countries	Zilla	Egyptian desert
Oudneya	Algerian deserts	Delphinium 10	Waste places, Dardanelles
Farsetia linearis	Egyptian desert	„ antheroideum	Dry sandy places
„ ægyptiaca	„ „		

TABLE V.—*The Aptosimum Type.*

Sisymbrium 20, 21	Spain, Syria	Matthiola humilis	Egyptian desert
Alyssum 26, 27	Sunny places, Orient	Fumaria 20	Greece
Matthiola acaulis	Egyptian desert		

TABLE VI.—*Small-leaved or Retama-like Plants.*

Delphinium 14	Leaves reduced	Desert
„ nanum	„ „	Stony places
„ Balansæ	„ absent	Desert
„ virgatum	„ few	Sandy waysides
„ 9	„ very few	Desert
Lepidium 15	„ „	Palestine
Farsetia linearis	„ reduced	Egyptian desert
„ ægyptiaca	„ „	„ „
Cardamine 12	„ „	Plaines marécageuses
Sisymbrium 3	„ few	Syria
„ 9, 11	Rigid virgate shrub	Spain
„ 25	„ „ „	Arabia, Palestine
Iberis, 23	Nearly leafless variety	Calcareous soil in hot countries

3. A Discussion on the Movement of Water in Plants was opened by Mr. FRANCIS DARWIN, F.R.S. Mr. Darwin's Paper was ordered by the General Committee to be printed *in extenso*. See Reports, p. 674.

SATURDAY, SEPTEMBER 19.

The following Papers were read:—

1. *Changes in the Tentacle of* Drosera rotundifolia, *produced by Feeding with Egg Albumen. By* LILY H. HUIE, *Physiol. Labor., Oxford.*

[Communicated by Dr. Gustav Mann.]

In unfed leaves fixed in watery picro-corrosive (sp. gr. 1·020) and stained with Eosin-Toluidin blue, the apical and lateral glands of the first or outer layer and also all the cells of the second or middle layer show a deep-blue cytoplasm, with nuclei possessing little chromatin proper, but large nucleoli and a granular nucleoplasm. Within one minute after feeding the blue cytoplasm becomes purple; after one hour it is greatly vacuolated and reddish purple; after twenty-four hours the blue material has disappeared, and only a few strands of a pink cytoplasm are to be seen. The nucleus after feeding loses the granular cytoplasm, the nuclear chromatin segments enlarge enormously, reminding one of the early stages of mitosis. The nucleolus has lost its red chromatin, and is not easy to see.

Recuperation of the cytoplasm is the result of nuclear activity, for the chromosomes enlarge during the period preceding the appearance of the granular nucleoplasm, which latter in every respect resembles the granular deposit of cytoplasm in immediate contact with the outer surface of the nuclear membrane. The cytoplasm is at first purple in colour, but becomes blue after 6–7 days. After the 'secretion' of the cytoplasm the nuclear chromatin segments diminish in size, while the nucleoli become more and more evident, and the nucleoplasm has the same appearance as in a leaf which has never been fed. The third layer of gland-cells, perhaps concerned in the secretion of mucus, also shows marked changes; for the long spindle-shaped nuclei of the resting condition shorten within one minute, after ten minutes they are more or less globular, then pass through changes similar to those described above, and after some days resume their spindle shape—an indication of rest.

2. *On the so-called Tubercle Bacillus.* By A. Coppen Jones, *F.L.S.*

[Communicated by A. Vaughan Jennings, F.L.S., F.G.S., &c.]

Since the demonstration by Robert Koch in 1882 of a specific micro-organism constantly associated with and capable of producing tuberculous disease, the *Bacillus tuberculosis* has been the object of a great amount of investigation, which has resulted in a vast accumulation of literature. The minute rod-like organism which bears the name is better known to pathologists than any other pathogenic fungus, and may be easily diagnosed by the characteristic and unique appearance of its pure cultures on solid media, by the difficulty of staining it with the ordinary aniline dyes, and by the resistance it offers when stained to the decolorising action even of mineral acids.

Its claim to be regarded as a true bacillus has only very recently been questioned, but there are several considerations which tend to modify our views with respect to its biological status; and the following observations, made during the last few years, and continued up to the present time, are, from this point of view, not without interest:—

1. While the well-known simple rod-like form is by far the commonest, and, n fact, the only form to be found in the vast majority of cases, whether in the tissues, in sputum, or in cavity contents, there may be observed, not infrequently, elongated examples which develop lateral outgrowths, twigs, or incipient branching.

2. In rarer cases this process results in the formation of definite threads or hyphæ, which exhibit true branching, and often contain one or more spores, forming oval, highly refracting, deeply stained swellings on the course of the filaments. It is to be particularly noted, first, that these spores have far more resemblance to the chlamydospores of the true filamentous fungi than to the typical endospores of bacteria; and, secondly, that they must on no account be confounded with the unstained intervals on the course of the rods or filaments of the tubercle organism. These were formerly described by Koch as spores, but are really vacuoles in the cell contents, or, in some cases, spaces caused by the plasmolytic shrinkage of the protoplasm. Occasionally, in cavity contents, densely matted mycelial growths have been observed.

3. When old cultures are examined by means of sections it is found that the growth does not consist of separated rod-like forms, isolated from one another and lying at all angles, but of strands of parallel filaments, frequently showing dichotomous branching

4. These facts indicate that the so-called 'tubercle bacillus' is really a stage in the life-history of some higher form of fungus with a definite mycelial growth. From a systematic point of view, it cannot be regarded as coming within any definition of the genus *Bacillus*, and it is suggested that a more appropriate name would be *Tuberculomyces*.

Pathologists, who for the most part believe strongly in the constancy of form of the species of bacteria, may not be inclined at first to accept these conclusions. Bearing in mind the controversies of the past on the specific distinctness of micro-organisms and the many erroneous observations which have led to false statements as to polymorphism, such scepticism is both natural and desirable; but in the present case the tracing of all stages between the short rods and the branched hyphal filaments, their identical behaviour towards reagents, and the occurrence of all these forms in pure cultures, place their genetic relationship beyond a doubt.

Brefeld has proved that a number of the higher thallus-forming fungi may, under certain conditions, multiply for innumerable generations as mere unicellular rods or spheres ('oidia,' &c.), and yet retain the power of again forming, when placed under suitable conditions, the mycelium from which they arose. It is therefore no far-fetched supposition to regard the rod-like form of the tubercle parasite as an adaptive modification of some higher fungus, existing perhaps as a saprophyte outside the animal body. Further support for such a view may be seen in the fact that the tubercle fungus occupies a unique position among the pathogenic micro-organisms resembling only the well-known hyphomycete *Actinomyces.* The resembance of these two forms was pointed out in 1892 by Fischel, and the present writer has been able to show that the tubercle organism is accompanied in a large proportion of cases by club-shaped growths identical with those so characteristic of Actinomycosis. Now it has been placed beyond a doubt that *Actinomyces* is primarily a parasite saprophytic on cereal plants, and that its occurrence as an animal parasite can only be regarded as secondary and accidental.

Whether the change in our view as to the real nature of the tubercle fungus will in the future be of any diagnostic value it is impossible to say, as comparatively few cases showing the filamentous growth have yet been observed; but there is some evidence in support of the idea that the hyphal type may be correlated with more chronic stages of the disease, where actual tissue destruction is relatively slight.

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3. *Preliminary Notes on Floral Deviations in some Species of* Polygonum. *By* J. W. H. TRAIL, *F.R.S., Professor of Botany in the University of Aberdeen.*

The genus has long been known to show considerable departures from the arrangement and number of parts accepted as most typical (Per. 5. St. 5 + 3, C. $\underline{3}$), such as is found in *P. convolvulus.* Eichler's 'Blüthendiagramme,' for example, shows diagrams of several species as if characterised by constant differences of structures. Observation shows that in some species (*e.g. Convolvulus*) variations are comparatively infrequent and slight, but that in most (*e.g. Persicaria* and *aviculare*) they are extremely frequent, and lead to very great changes in floral structure. Often it is scarcely possible in such species to find two flowers alike on the same branch, or even on the same plant. Within a species individual plants show wide differences in the frequency and extent of variations.

A comparison of different species shows that while each varies, so as in the more variable species to cover almost the whole range observed in the genus, each shows a tendency to certain lines of variation. These tendencies are more alike usually in the more nearly allied species, so as to correspond in the main with the groups based on habit, and they lead from group to group.

The modes of variation commonly observed include almost all the recognised modes of departure from floral symmetry. They affect all the whorls. The *perianth* in some species is very constant. In others it habitually shows cohesion of two or more segments, or abortion in different degrees, or suppression of one or two (usually the inner) segments. Chorisis of a segment is less frequent. Enations from one or more segments are frequent in certain species, rare or absent in others. The *outer stamens* often show cohesion of the two in each pair, varying from the slightest union of the bases of the filaments to absolute union of even the anthers. Abortion (in all degrees to complete suppression) of one or more stamens is not rare, frequently reducing this whorl to 3 (less often to 2) in *aviculare.* Chorisis is not rare, especially of the unpaired stamen. The *inner stamens* seldom show cohesion (except in *aviculare* and its allies) with stamens of the outer whorl. Abortion (in all degrees to complete suppression) is very frequent, and in certain species (*amphibium*) this whorl has completely disappeared. In *aviculare* and allied species the inner whorl shows abortion less than the outer. Chorisis in the inner whorl most frequently shows itself in the posterior stamen. Adhesions of stamens to perianth segments and petalody of stamens are not frequent.

(In *P. amphibium* the land form near Aberdeen very generally has the anthers very small or abortive, and the stamens hidden within the perianth, while the form growing in water has the anthers well developed, and some or all exserted; neither form appears to seed habitually.)

The *pistil* in some species is very constant, while in others it shows all stages of cohesion and reduction to two carpels, this being the almost invariable number in certain species. Abortion is less frequent, and complete suppression cannot be distinguished from complete cohesion. Chorisis is very frequent in *aviculare* and some other species, in all degrees from a mere enlargement of one or more stigmas to an increase in number (up to seven), with corresponding modifications in structure in the ovary. Only one ovule has been observed in each ovary.

Markedly teratological forms have been met with, but are not included in this summary.

No very definite relation has been traced between the position of a flower on the axis and deviations in structure, though pressure tends to abortion or suppression of parts, especially of the sexual organs. (The flowers examined have chiefly been those sufficiently open to allow the natural arrangement to be noted without manipulation, to avoid displacement of parts, hence cleistogamous flowers are scarcely included.) The variability appears rather to express the result of an innate tendency to vary where not subject to the check of loss of fertility, the variations in *Polygonum* not leading to this loss.

The same number of parts in a whorl may be due to very different causes, and still more may the same number of stamens express very different arrangements in the flower; hence such a statement in a specific description as 'stamens usually six' is insufficient.

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4. *On the Singular Effect produced on certain Animals in the West Indies by feeding on the Young Shoots, Leaves, Pods, and Seeds of the Wild Tamarind or Jumbai Plant* (Leucæna glauca, *Benth.*). *By* D. Morris, *C.M.G., M.A., D.Sc., F.L.S., Assistant Director of the Royal Gardens, Kew.*

The seeds of many species of *Leguminosæ* are well known to be poisonous. The most striking instance is the Calabar bean of West Tropical Africa (*Physostigma venenosum*). This plant closely resembles a *Phaseolus*, but the poisonous character of the seeds is so well recognised that it has been long used by the people of West Africa as an ordeal in state trials. The seeds of *Abrus precatorius*, popularly called Crab's Eyes, are harmless when eaten, but rapidly produce fatal effects when introduced beneath the skin in very small quantity. Even the seeds of the common Laburnum (*Laburnum vulgare*) are responsible for more than one death amongst children in this country every summer; and recently ten cattle were poisoned in Mid-Lothian by eating the leaves of this plant. The most remarkable effects are produced on horses in the Western States of America by feeding on species of *Astragalus* and *Oxytropis*, locally known as Crazy or Loco plants. The animals pass through a stage of temporary intoxication and act as if attacked with blind staggers, and ultimately die. Lastly, there is paralysis of the hinder extremities produced in horses (also in human beings) by feeding on the seeds of the Bitter Vetch (*Lathyrus sativus*). This has occurred very widely in India. The condition so induced is known as 'lathyrismus.'

The subject of this note is a plant that has received little or no attention. As far as I am aware, its singular properties have not been placed on record in this country. The Wild Tamarind of Jamaica and the Jumbai or Jumbie of the Bahamas (*Leucæna glauca*, Benth.) is commonly found along roadsides and in waste places in Tropical America. It presents the appearance of a weedy-looking Acacia, and belongs to the tribe *Eumimoseæ* of the N. O. *Leguminosæ*. The plant is now so widely distributed in tropical countries that its native habitat, according to Bentham, is unknown. There is, however, no doubt of its American origin. The extensive distribution of so unattractive a plant is probably due: (1) to the facility with which the small flat seeds are carried about by man or animals; (2) to the use to which the seeds are put in making ornamental articles such as artificial flowers, bracelets, brooches, baskets, &c. A set of these is shown in the Kew Museums. The following is a brief description of the species:—

Leucæna glauca, Benth. in 'Hook. Journ. Bot.' IV. 1842, 416. A small unarmed tree or shrub, extremities, young leaves, and inflorescence puberulous. Pinnæ 3-6-jugate, occasionally a sessile gland between the lowest pair; leaflets linear, glaucous beneath, often sub-falcate, acute, $\frac{1}{3}$–$\frac{1}{2}$ inch long. Heads globose, white, $\frac{3}{4}$ inch in diameter, on peduncles of $\frac{3}{4}$–$1\frac{1}{2}$ inch from the upper axils. Legume flat, thinly coriaceous 4–6 inches long, $\frac{2}{3}$–$\frac{3}{4}$ inch broad, narrowed at the base into the stipes $\frac{1}{3}$–$\frac{3}{4}$ inch. Acacia glauca, Willd., A. leucocephala, Link.

Distribution:—West Indies, Bahamas, Demerara; Brazil, Peru; gardens of S. Europe and North Africa; widely found in tropical Africa, East Indies, Ceylon, Mauritius, Java, and China. Probably introduced into Africa and Asia.

Thirteen years ago I drew attention to the properties of this plant in a few words that appeared in the 'Report of the Botanical Department, Jamaica,' 1883, p. 19, as follows: *Wild Tamarind.*—'Mr. Robert Russell, of St. Ann's, informs me that horses feeding on the leaves of this plant completely lose the hair from their manes and tails. He adds, "Horses from Llandovery, Richmond, and that side of the parish where the Wild Tamarind abounds, are frequently to be seen tail-less and mane-less."' This statement was supported by the testimony of so many people acquainted with the facts that there was no reason to doubt it. Many years afterwards (in December 1895) I renewed my acquaintance with the plant in the Bahamas. The plant was much more plentiful there than in Jamaica; it was, in fact, distinctly encouraged in the former islands as a fodder plant. The people were fully aware of the singular effect it produced on horses, and added that it also affected mules and donkeys. Its effect on pigs was still more marked. These animals assumed a completely naked condition, and appeared without a single hair on their body. Horses badly affected by Jumbai were occasionally seen in the streets of Nassau, where they were known as 'cigar-tails.' Such depilated animals, although apparently healthy, were considerably depreciated in value. They were said to recover when fed exclusively on corn and grass. The new hair was, however, of a different colour and texture, 'so the animals were never quite the same.' One animal was cited as having lost its hoofs as well, and in consequence it had to be kept in slings until they grew again and hardened. The effects of the Jumbai on horses, mules, donkeys, and pigs were regarded as accidental—due to neglect or ignorance. The plant was really encouraged to supply food for cattle, sheep, and goats. The latter greedily devoured it and were not perceptibly affected by it. It will be noticed that the animals affected were non-ruminants, while those not affected were ruminants. The probable explanation is that the ruminants, by thoroughly mixing the food with saliva and slowly digesting it, were enabled to neutralise the action of the poison and escape injury. The seeds probably contain the deleterious principle in a greater degree than any other part of the plant. It was a common experience that animals introduced from other localities suffered more than the native animals. The latter were either immune or had learnt to avoid the plant as noxious to them. The active principle in *Leucæna glauca* has not yet been investigated. There is abundant material at hand for this purpose in almost every part of the world. It is probable that the active principle may consist of a volatile alkaloid somewhat similar to that found in *Lathyrus sativus.* A certain amount of parallelism is to be noticed in the effects produced by these two plants. In 'lathyrismus' (ignoring the effect on man) the chief sufferer is undoubtedly the horse. The effect on mules and donkeys is not given, but is probably the same. Although pigs fatten on *Lathyrus,* they lose the use of their hinder extremities, as in the horse. Hence the non-ruminating animals as a class suffer from *Lathyrus* as they do from *Leucæna.* The similarity in ruminants is also very close. For instance, cattle are reported to grow lean if fed exclusively on *Lathyrus,* but are not otherwise affected. Sheep are not affected at all.

I am not disposed to attach much importance to the parallelism here noticed. It is possible that ruminants generally are less susceptible to the action of certain poisons than non-ruminants. It is evident, however, that in *Leucæna glauca* we possess a plant with singular properties. It is a vegetable depilatory of a very decided character. No other plant appears to produce exactly identical results.

MONDAY, SEPTEMBER 21.

The following Papers were read:—

1. *On the Number of Spores in Sporangia. By* Professor F. O. Bower, *F.R.S.*

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2. *The Polymorphism of the Green Algæ, and the Principles of their Evolution. By* R. Chodat, *Professor of Botany in the University of Geneva.*

The paper treats of the following subjects: Primitive and Nodal Types; Preponderance of Fluctuating Characters in the different Series; Specialisation of Characters and their Fixation; Sexuality: its Origin and Tendencies; supposed Relations with the Archegoniatæ.

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3. *On some Peculiar Cases of Apogamous Reproduction in Ferns. By* William H. Lang, *M.B., B.Sc., Robert Donaldson Scholar, Glasgow University.*

In order to ascertain to what extent apogamy in *Nephrodium filix-mas,* Desv., is correlated with the cresting of the fern plant, from which the spores were derived, cultures of normal and crested forms were made. Of the three cultures of normal forms one was unsuccessful; one of the others was exclusively apogamous, while the other has, as yet, reproduced in the ordinary way. Seven crested varieties were sown; five of these were apogamous and the other two normal. Three of the crested varieties were known with certainty to be wild finds; two of these were apogamous. From these results it appears that apogamy in *N. filix-mas* stands in no definite relation to cresting. When the ferns sown were divided into Wollaston's species, *N. filix mas, N. pseudo-mas,* and *N. propinquum,* it was found that all the varieties of the two former were apogamous, while both normal and crested forms of *N. propinquum* were normally reproduced. The basis of observation is, however, too limited to allow of any general conclusion being drawn as to the constancy of this difference.

Cultures were also made of crested varieties of other species. In all in which young plants were produced their development was at first normal. After the cultures had continued for nine months young plants, developed apogamously, were found in *Scolopendrium vulgare, Athyrium filix fœmina* and *Aspidium aculeatum,* var. *angulare.* It is impossible at present to decide how far the result can be ascribed to cresting of the parent plant. Possibly the prolonged cultivation of unfertilised prothalli is the more important factor in these cases, the cresting aiding as a predisposing cause.

Unfertilised prothalli of *Scolopendrium vulgare* formed a cylindrical, fleshy prolongation of the midrib, the tip of which became in time covered with ramenta, and was continued directly as the axis of the young sporophyte. Archegonia were present just below the ramenta.

In some prothalli of a fern from Mr. Druery's collection, which was labelled *Lastræa dilatata,* var. *cristato-gracilis,* a similar prolongation of the median region was found. Upon this sporangia were borne, sometimes singly, in other cases grouped together so as to resemble a sorus. The sporangia had a well-developed annulus which sometimes showed the characteristic reddish-brown thickenings of the wall. The prolongation on which the sporangia were situated bore archegonia and antheridia which sometimes intervened between two groups of sporangia. Its prothallial nature was, therefore, beyond doubt. The sporangia were borne on prothalli on which no trace of a young sporophyte could be detected.

Consideration of the theoretical bearings of these facts is deferred until they have been investigated in detail.

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4. A Lecture on the Geographical Distribution of Plants was delivered by Mr. W. T. THISELTON-DYER, F.R.S., C.M.G., C.I.E., Director of the Royal Gardens, Kew.

TUESDAY, SEPTEMBER 22.

The following Papers were read:—

1. A Discussion on the Cell was opened by the reading of the following Paper:—

Some Current Problems connected with Cell-Division.
By Professor J. BRETLAND FARMER.

The great mass of information concerning the phenomena of cell-structure forms the excuse for attempting to test some of the leading hypotheses and theories as to the meaning of the observed facts.

And firstly, it is necessary to exercise great care in laying the foundations of our knowledge, since these depend so much on material which has been subjected to an elaborate technical treatment before it can be appropriately examined.

Secondly, there is a widespread tendency to generalise from a study, exhaustive it may be, of a few types. But there is so much variety, that, save in the broadest outlines, it is hardly possible to speak of a type at all.

This is illustrated by the present position of the centrosome question. Few people are agreed as to what its very nature actually is, and perhaps still fewer as to the part which it plays in the cell. Some regard it as the active agent in bringing about nuclear division, whilst others believe it to be a transient structure, called into existence by the forces which are at work during karyokinesis. The occurrence and behaviour of centrosomes during karyokinesis (nutosis) require a comparative treatment. Whilst it is quite possible that in the cells of some organisms the centrosome may possess a marked individuality, it does not therefore necessarily follow that it must occur universally, or that it is concerned, as a principal, with the process; and this latter remark applies even to those instances in which it appears most prominently. *Post hoc* does not always imply *propter hoc*.

The present position of the question as to the origin and nature of the achromatic spindle, also, is a very uncertain one. Does the spindle arise as the result of an onward development of a pre-existing rudiment, or is it a new formation in the protoplasm? In the answer to this question, no less than in the conclusion to which we arrive as to the nature of the centrosome, an important principle is involved. It is, doubtless, simpler to admit a variety of 'organs' in the cell, but does such an admission bring us any nearer to understanding the actual processes of cell life?

Again, the chromosomes themselves present abundant difficulties, when one tries to arrive at a rational account which shall embrace the facts which even yet have been ascertained respecting them. If individuality be conceded to the chromosomes, how can this be reconciled with the facts of reduction and fertilisation? It would seem that the reduction can be effected in various and radically different ways. But this touches very nearly their claims to the possession of that complicated structure which has been regarded as probable by some writers, and which is supposed by them to be intimately associated with different hereditary properties.

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2. *On the Heterotype Divisions of* Lilium Martagon. *By* Ethel Sargant.

There are two series of nuclear divisions in the life-history of *Lilium Martagon* which exhibit twelve chromosomes in place of twenty-four.

I. Spermatogenesis:—

1. First division of pollen mother-cell nucleus.
2. Second division of pollen mother-cell nucleus.
3. Division of pollen-grain nucleus into vegetative and generative nuclei.
4. Division of generative nucleus in pollen-tube.

II. Oögenesis:—

1. Division of primary embryo-sac nucleus into micropylar and chalazal nuclei.
2. Division of micropylar daughter nucleus.
3. Division of both daughter nuclei of the micropylar nucleus.

My preparations include the whole oögenetic series and the first three divisions of the spermatogenetic series. The second and third divisions in both are precisely similar to vegetative nuclear divisions except in possessing only half the number of chromosomes. They are called *homotype.*

The first nuclear division on either side is called *heterotype*, because the process of karyokinesis differs from that of the vegetative nucleus. The chief points which distinguish it are:—

1. The resting nucleus, after some increase in size, passes into a contracted state called *synapsis.*
2. The chromatic ribbon of the spirem is not homogeneous, but is composed of an erythrophilous ribbon bearing a double row of cyanophilous dots.
3. Longitudinal fission appears in the spirem ribbon before its division into chromosomes.
4. A second longitudinal fission appears in each segment of the immature chromosomes.
5. The segments of each chromosome are tightly twisted on each other, and separate from near the middle or from either end. The untwisting of the segments from each other as they separate gives a contorted appearance to each chromosome of the nuclear plate, and adjacent chromosomes are often of totally different shape. The appearance of the heterotype spindle is therefore much less regular than that of the homotype spindle.
6. The chromosomes of the diaster stage are usually V-shaped.

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3. *On the Cells of the Cyanophyceæ. By* Professor E. Zacharias.

My recent researches on the Cyanophyceæ have confirmed and extended my former statements. Cell protoplasm, containing the coloured matter, surrounds a central body which is colourless. This body is not homogeneous in the living state; when treated with reagents, it shows apparently a spongy structure; in its surface, in certain cases outside of it, are distributed granules of different shape and size, becoming deeply stained, when treated with methylen-blue. These granules ('Centralsubstanz,' as I have named them formally) agree, as stated some years ago, in their reactions with the chromatin of the nucleus of other organisms. However, I recently found slight differences, which, combined with certain considerations, render it doubtful whether the 'Centralsubstanz' contains nuclein like the Chromosomes or not.

Iodine reactions observed in *Gloiotrichia pisum* render it probable that the central body of the spore and of those cells immediately above it contains glycogen.

The cell protoplasm contains in different stages of cell-life different quantities of granules, which are chemically different from the central substance. Both kinds of granules are stored in the spores of Gloiotrichia.

By certain methods of culture the granulations can be made to vanish entirely out of the cells.

The whole of my experiments lead me to suppose that the granules in the cell-protoplasm are increased in size and number when the cells are able to assimilate carbon, although under conditions that do not allow them to grow.

The cell-division takes place, as I have stated previously, without showing karyokinetic processes. Sometimes the disposition of the constituents of the central body may remind one of karyokinetic stages; nevertheless this disposition is entirely variable and without rule.

Reviewing the facts which we know at the present time, we are obliged to admit that the central body of the Cyanophyceæ differs in important points from the nucleus of other organisms. It is highly remarkable that often nuclein has not been found in the dividing cells of Cyanophyceæ, while in other organisms, as far as we know, the nuclein augments when the cells begin to divide.

In connection with the previous statements, I wish to add some words on micro-chemical methods. A mixture of methylen-blue and fuchsin S. may be used with great advantage to study the distribution of nuclein in the cell. If one treats tissues of different origin with diluted hydrochloric acid and afterwards adds the said mixture, the constituents of the cell which contain nuclein are stained deeply blue, the parts without that substance being red. Sperm cells of the Rhine-salmon were treated by me with diluted hydrochloric acid to remove protamin. Afterwards I stained them with the methylen-blue fuchsin S. mixture. Instantly the envelopes of the heads which contain the nucleic acid were beautifully dyed bright blue, the inner part of the heads seemed to be colourless, the tails were dyed red. Similarly treated, the chromatin bodies of all the nuclei, which as yet have been examined, are stained blue, the rest of the nuclei and the cell protoplasms red. That the chromatin bodies contain nuclein had also been proved by their other reactions. However, it is easily understood, but often not sufficiently attended to, that it is necessary to treat the tissues quite similarly if one wishes to obtain comparable results. Lilienfeld states that white of an egg coagulated by alcohol cannot be stained, and removes the colour from the dye-mixture. I, on the contrary, have stated that white of an egg coagulated by alcohol is stained red by the above-mentioned mixture. I recently made out that this difference of results must have been caused by the different ways in which Lilienfeld and I have obtained the coagulated white of an egg. If one squeezes some white of an egg through a cloth, and then adds just enough alcohol to coagulate it, the substance thus obtained cannot be stained red, but removes the colour from the dye-mixture. But if the coagulate is washed with water, it can now be stained reddish blue, and after washing it with alcohol, pure red. The water used for washing has an alkaline reaction, and removes the colour from the dye-mixture.

4. *On a New Hybrid Passion Flower.* *By* Dr. J. Wilson.

5. *Observations on the Loranthaceæ of Ceylon.* *By* F. W. Keeble, *B.A. Cantab.*

I. Emergences on the Embryo of Loranthus neelgherensis.—The hypocotyl of the fully developed embryo is densely covered with green columnar emergences, whose cortical cells contain chlorophyll, starch, tannin, and a substance giving the reactions of a fat. Irregular masses of a similarly reacting material are frequently found covering the cuticle.

A *single* stoma occurs on the free surface of each emergence, and in the embryo of this species stomata are confined to the emergences.

The cuticle covering the general epidermis is continuous over the guard-cells of each stoma, except for a small oval slit which allows of communication between the intercellular space and the air. The stomata thus suggest either a xerophytic habit for the plant or an abnormal function for themselves.

The emergences flourish during the germinating (epiphytic) stage, and later, when semi-parasitism is achieved, cease to be functional.

II. Mode of penetration into the host of L. neelgherensis.—Unlike many species, *L. neelgherensis* develops no well-marked organ of attachment (suctorial disc) at the free end of its hypocotyl.

Where much resistance to the entry of the sucker is offered by the host, there are formed at the edges of the attached surface of the hypocotyl a series of acropetally arising, hair-bearing cortical ridges. The later-formed ridges, wedging themselves in between the older ones and the bark, force these older ridges away. The firmly attached hairs of each ridge so forced away tear off masses of the bark, and thus the softer tissues, through which the sucker readily and cleanly bores, are exposed by instalments. Where the sucker comes in contact with lignified structures, dissolution is more gradual, and stages of disintegration (erosion figures) are to be observed.

In *L. loniceroides*, where a well-marked suctorial disc is formed, attachment occurs once for all. This attachment is maintained (1) by the growth of the edge of the disc hard against the bark; (2) by the outgrowing hairs forming a matted sclerotic mass firmly fixed into the outer layers of the host.

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6. Specimens of Recent and Fossil Plants were demonstrated in the Zoological Laboratory by Dr. D. H. SCOTT, Professor MAGNUS, Professor ZACHARIAS, Miss E. SARGANT, Mr. A. C. SEWARD, Mr. W. H. LANG, and others.

WEDNESDAY, SEPTEMBER 23.

The following Papers were read:—

1. *On Latent Life in Seeds. By* M. CASIMIR DE CANDOLLE.

In this paper M. de Candolle gave an account of some experiments which he has recently carried out on the power of germination of seeds exposed for different periods to low temperatures. He also recorded striking instances of the development of normal seedlings from seeds which have been kept for a great number of years. From seeds of *Nelumbium speciosum*, more than a hundred years old, Robert Brown obtained perfect seedlings. Similar results were recorded from experiments made on very old seeds in the Tournefort Herbarium, Paris. Plants buried under rubbish-heaps collected by the Greeks have been found to grow and develop flowers from seeds which must have been at least 1,500 years old. To test the condition of a dormant seed, M. de Candolle exposed the seeds of several plants to a temperature too low to admit of the continuance of the process of respiration. Seeds of corn, oats, *Fœniculum officinale*, *Mimosa pudica*, *Gloxinia*, and other plants were exposed for 118 days to a temperature of 40°F. below zero. The means of carrying out these experiments was afforded by refrigerating machines placed at the disposal of M. de Candolle by a Liverpool firm of meat importers. The machines worked about eight hours a day, and during that time the temperature often fell considerably below 40°F. below zero. Nearly all the seeds of corn, oat, and *Fœniculum* germinated, and a great many in the case of *Mimosa*. The Gloxinias did not develop, but there is reason to suppose that they were not good seeds, as others from the same lot did not germinate freely even under normal conditions. The conclusion to be drawn from the experiments seems to be this: In resting seeds the protoplasm is not actually living, but has reached a stage of inaction in which, although not dead, it is endowed with potential life. In other words, protoplasm in resting seeds is not analogous to a smouldering fire, but rather to those chemical mixtures made up of bodies capable of combining when certain conditions of temperature and illumination are realised. A good example of this condition is afforded by a mixture of chlorine and hydrogen, which can be preserved indefinitely without combining if kept in the dark, but under the influence of certain rays of light combine with explosive violence.

2. *On some Carboniferous Fossils referred to Lepidostrobus.* *By* D. H. Scott, *M.A., Ph.D., F.R.S.*

1. The specimens described by the late Professor W. C. Williamson under the name of *Lepidodendron Spenceri*[1] consist entirely of pedunculate strobili, and therefore, if their Lepidodendroid affinities were established, would be placed in the genus *Lepidostrobus.* Under the name *L. Spenceri* two distinct species are included, differing in the dimensions of the axis, the arrangement of the sporophylls, and the size, arrangement, and forms of the spores.

The smaller kind, which is the more frequent, is alone figured in Williamson's memoirs, and must retain the specific name of *Spenceri.* The structure is preserved with great perfection. The anatomy of the peduncle and axis is consistent with the attribution of the species to *Lepidostrobus*; but in several points, notably the form of the sporophylls and the insertion of the sporangia, the cone differs from all known *Lepidostrobi.* It agrees most nearly with a form described by M. Zeiller as *Sigillariostrobus Crepini.*[2] If the latter be a true *Sigillariostrobus* then *L. Spenceri* should also be placed in that genus. In that case it would be the first fructification of *Sigillaria* discovered with structure preserved.

The second and larger species appears to be co-generic with the former.

2. A fragment of stem from the Burntisland beds at the base of the Carboniferous formation was described by Williamson in 1872[3] as possibly forming part of the axis of the *Lepidostrobus* found in the same deposits. A renewed examination of the specimen has shown that it differs in many respects from any Lepidodendroid axis, as shown by the pitted, as distinguished from scalariform tracheides, by the di- or trichotomous leaf-traces, and by the presence of a ventral lobe on the leaf. The specimen represents a new type of stem, having some points in common with *Sphenophyllum,* but so far of uncertain affinity.

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3. *A New Cycad from the Isle of Portland.* *By* A. C. Seward, *M.A., F.G.S.*

Dr. Woodward lately obtained an exceedingly fine specimen of a cycadean stem from the Purbeck beds of Portland, which is now in the fossil plant gallery of the British Museum. The stem, which is probably the largest known, has a height of 1 m. 18·5 cm., and measures 1 m. 7 cm. in girth at the broadest part. A striking feature of the specimen is the conical apical bud enclosed by tapered bud scales, bearing numerous ramental outgrowths on the exposed surface. The surface of the stem presents the appearance of a prominent reticulum of projecting ridges, of which the meshes were originally occupied by the persistent petiole bases. The substance of the leafstalks has for the most part disappeared, while the interpetiolar ramental tissue has been mineralised and so preserved as a projecting framework. In structure the ramenta are practically identical with those of *Bennettites,* as described by Carruthers and other writers. The petiole bases also agree very closely with those of *Bennettites,* consisting of a mass of parenchymatous tissue traversed by numerous vascular bundles and secretory canals, with a distinct band of cork at the periphery. No trace of any inflorescence has been found. It is proposed to name the plant *Cycadeoidea gigantea.*

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4. *Note on a Large Specimen of Lyginodendron.* *By* A. C. Seward, *M.A., F.G.S.*

The specimens on which this description is based are in the Botanical Department of the British Museum and in the recently acquired Williamson Collection.

[1] 'Organization of the Fossil Plants of the Coal-measures,' parts ix., x., xvi., and xix., 1878–93, *Phil. Trans.*

[2] *Flore fossile du Bassin Houiller de Valenciennes,* pl. lxxvii. fig. 3.

[3] 'Organization,' &c, part iii.

The block, from which several sections have been prepared, is a striking example of the preservation of the minute structure of a Coal Measure plant on a large scale; it consists of a mass of wood at least 6 cm. thick in a radial direction, and a pith about 3 cm. in diameter, but without any trace of cortical tissue. Sections obtained from this block, and included in the Williamson Collection, were described at some length in the recently published memoir by Williamson and Scott on *Lyginodendron* and *Heterangium*. The examination of additional specimens has led to a somewhat fuller diagnosis of the structure and a more detailed comparison with *Lyginodendron Oldhamium* and other plants. The main mass of the wood possesses a structure practically identical with that of *Lyginodendron Oldhamium* and recent cycadean stems; internal to the centrifugally developed secondary wood there is a fairly complete and narrow ring of centripetally developed xylem. In the pith there are numerous secretory canals and nests of dark-coloured sclerous cells. No definite traces of primary xylem like that of *Lyginodendron Oldhamium* have been detected. As a matter of convenience the specimen may be designated *Lyginodendron robustum*.

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5. *A New Species of Albuca* (A. prolifera, *Wils.*). *By* Dr. J. Wilson.

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6. *Observations on Hybrid Albucas*. *By* Dr. J. Wilson.

INDEX.

References to reports and papers printed in extenso *are given in Italics.*
*An Asterisk * indicates that the title only of the communication is given.*
The mark † indicates the same, but a reference is given to the Journal or Newspaper where the paper is published in extenso.

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1879. *Allen, Rev. A. J. C. The Librarian, Peterhouse, Cambridge.
1887. **Allen, Arthur Ackland. Overbrook, Kersal, Manchester.*
1887. **Allen, Charles Peter. Overbrook, Kersal, Manchester.*
1888. §Allen, F. J., M.A., M.B., Professor of Physiology, Mason College, Birmingham.
1884. ‡Allen, Rev. George. Shaw Vicarage, Oldham.
1891. ‡Allen, Henry A., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1887. ‡Allen, John. Kilgrimol School, St. Anne's-on-the-Sea, viâ Preston.
1878. ‡Allen, John Romilly. 28 Great Ormond-street, London, W.C.
1887. **Allen, Russell. 2 Parkwood, Victoria Park, Manchester.*
1891. ‡Allen, W. H. 24 Glenroy-street, Roath, Cardiff.
1889. ‡Allhusen, Alfred. Low Fell, Gateshead.
1889. §Allhusen, Frank E. The School, Harrow.
*ALLMAN, GEORGE J., M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. Ardmore, Parkstone, Dorset.
1886. ‡Allport, Samuel, F.G.S. 50 Whittall-street, Birmingham.
1896. §Alsop, J. W. 16 Bidston-road, Oxton.
1887. ‡Alward, G. L. 11 Hamilton-street, Grimsby, Yorkshire.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1891. ‡Ambrose, D. R. Care of Messrs. J. Evans & Co., Bute Docks, Cardiff.
1883. §Amery, John Sparke. Druid, Ashburton, Devon.
1883. §Amery, Peter Fabyan Sparke. Druid, Ashburton, Devon.
1884. ‡Ami, Henry, F.G.S. Geological Survey, Ottawa, Canada.
1885. ‡*Anderson, Charles Clinton. 4 Knaresborough-place, Cromwell-road, London, S.W.*
1883. ‡Anderson, Miss Constance. 17 Stonegate, York.
1885. *Anderson, Hugh Kerr. Caius College, Cambridge.
1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.
1892. ‡Anderson, Joseph, LL.D. 8 Great King-street, Edinburgh.
1888. *Anderson, R. Bruce. 35A Great George-street, London, S.W.
1887. ‡Anderson, Professor R. J., M.D. Queen's College, Galway.
1889. ‡Anderson, R. Simpson. Elswick Collieries, Newcastle-upon-Tyne.
1880. *ANDERSON, TEMPEST, M.D., B.Sc., F.G.S. 17 Stonegate, York.
1886. *ANDERSON, WILLIAM, C.B., D.C.L., F.R.S., M.Inst.C.E., Director-General of Royal Ordnance Factories. Lesney House, Erith, Kent.
1880. ‡Andrew, Mrs. 126 Jamaica-street, Stepney, London, E.
1883. ‡Andrew, Thomas, F.G.S. 18 Southernhay, Exeter.
1895. §§Andrews, Charles W. British Museum (Natural History), London, S.W.
1891. ‡Andrews, Thomas. 163 Newport-road, Cardiff.
1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
1886. §Andrews, William, F.G.S. Steeple Croft, Coventry.
1883. ‡Anelay, Miss M. Mabel. Girton College, Cambridge.
1877. §ANGELL, JOHN, F.C.S. 5 Beacons-field, Derby-road, Fallowfield, Manchester.
1886. ‡Annan, John, J.P. Whitmore Reans, Wolverhampton.

Year of Election.

1896. §Annett, R. C. F. 11 Greenhey-road, Liverpool.
1886. ‡Ansell, Joseph. 38 Waterloo-street, Birmingham.
1878. ‡Anson, Frederick H. 15 Dean's-yard, Westminster, S.W.
1890. §Antrobus, J. Coutts. Eaton Hall, Congleton.
1896. §Appleton, C. 31A King-street, Wigan.
1874. ‡ARCHER, W., F.R.S., M.R.I.A. 52 Lower Mount-street, Dublin.
1894. §Archibald, A. Bank House, Ventnor.
1884. *Archibald, E. Douglas. Care of Mr. F. Tate, 28 Market-street, Melbourne.
1851. ‡ARGYLL, His Grace the Duke of, K.G., K.T., D.C.L., F.R.S., F.R.S.E., F.G.S. Argyll Lodge, Kensington, London, W.; and Inverary.
1883. §Armistead, Richard. 33 Chambres-road, Southport.
1883. *Armistead, William. 15 Rupert-street, Compton-road, Wolverhampton.
1887. ‡Armitage, Benjamin. Chomlea, Pendleton, Manchester.
1857. *ARMSTRONG, The Right Hon. Lord, C.B., LL.D., D.C.L., F.R.S. Cragside, Rothbury.
1879. *ARMSTRONG, Sir ALEXANDER, K.C.B., M.D., LL.D., F.R.S., F.R.G.S. The Elms, Sutton Bonnington, Loughborough.
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., LL.D., F.R.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.
1889. ‡Armstrong, Thomas John. 14 Hawthorn-terrace, Newcastle-upon-Tyne.
1893. ‡Arnold-Bemrose, H., M.A., F.G.S. 56 Friar-gate, Derby.
1870. ‡Arnott, Thomas Reid. Bramshill, Harlesden Green, London, N.W.
1886. ‡Ascough, Jesse. Patent Borax Company, Newmarket-street, Birmingham.
1870. *Ash, Dr. T. Linnington. Penroses, Holsworthy, North Devon.
1874. ‡Ashe, Isaac, M.B. Dundrum, Co. Dublin.
1889. §Ashley, Howard M. Airedale, Ferrybridge, Yorkshire.
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, Stockport.
Ashworth, Henry. Turton, near Bolton.
1888. *Ashworth, J. Jackson. Hillside, Wilmslow, Cheshire.
1890. ‡Ashworth, J. Reginald, B.Sc. 105 Freehold-street, Rochdale.
1887. ‡Ashworth, John Wallwork, F.G.S. Thorne Bank, Heaton Moor, Stockport.
1887. ‡Aspland, Arthur P. Werneth Lodge, Gee Cross, near Manchester.
1875. *Aspland, W. Gaskell. Birchwood-grove, Burgess Hill, Sussex.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1896. *Assheton, Richard. Birnam, Cambridge.
1861. ‡Aston, Theodore. 11 New-square, Lincoln's Inn, London, W.C.
1896. §Atkin, George, J.P. Egerton Park, Rockferry.

Year of Election.

1887.§§Atkinson, Rev. C. Chetwynd, M.A. Fairfield House, Ashton-on-Mersey.
1865. *Atkinson, Edmund, Ph.D., F.C.S. Portesbery Hill, Camberley Surrey.
1884. ‡Atkinson, Edward, Ph.D., LL.D. Brookline, Massachusetts, U.S.A.
1894. §Atkinson, George M. 28 St. Oswald's-road, London, S.W.
1894. *Atkinson, Harold W. Erwood, Beckenham, Kent.
1861. ‡Atkinson, Rev. J. A. The Vicarage, Bolton.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1881. ‡Atkinson, Robert William, F.C.S. 44 Loudoun-square, Cardiff.
1894. §Atkinson, William. Erwood, Beckenham, Kent.
1863. *Attfield, J., M.A., Ph.D., F.R.S., F.C.S. 111 Temple-chambers, London, E.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. Kincraig, Winchester.
1888. ‡Ayre, Rev. J. W., M.A. 30 Green-street, Grosvenor-square, 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.

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, 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. 114 Eaton-square, London, S.W.
1877. ‡Badock, W. F. Badminton House, Clifton Park, Bristol.
1883. ‡Baildon, Dr. 65 Manchester-road, Southport.
1892.§§Baildon, H. Bellyse. Duncliffe, Murrayfield, Edinburgh.
1883. *Bailey, Charles, F.L.S. Ashfield, College-road, Whalley Range, Manchester.
1893. §Bailey, Colonel F., Sec. R.Scot.G.S., F.R.G.S. Edinburgh.
1870. ‡Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1887. *Bailey, G. H., D.Sc., Ph.D. Owens College, Manchester.
1865. ‡Bailey, Samuel, F.G.S. Ashley House, Calthorpe-road, Edgbaston, Birmingham.
1855. ‡Bailey, W. Horseley Fields Chemical Works, Wolverhampton.
1887. ‡Bailey, W. H. Summerfield, Eccles Old-road, Manchester.
1866. ‡Baillon, Andrew. British Consulate, Brest.
1894. *Baily, Francis Gibson, M.A. University College, Liverpool.
1878. ‡Baily, Walter. 4 Roslyn-hill, London, N.W.
1885. ‡Bain, Alexander, M.A., LL.D. Ferryhill Lodge, Aberdeen.
1873. ‡Bain, Sir James, M.P. 3 Park-terrace, Glasgow.
1896.§§Bain, James, jun. (Local Treasurer). Toronto.
1885. ‡Bain, William N. Collingwood, Pollokshields, Glasgow.
1882. *Baker, Sir Benjamin, K.C.M.G., LL.D., F.R.S., M.Inst.C.E. 2 Queen Square-place, Westminster, S.W.
1891. ‡Baker, J. W. 50 Stacey-road, Cardiff.
1881. ‡Baker, Robert, M.D. The Retreat, York.
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, The Right Hon. G. W., M.P. Whittinghame, Prestonkirk, N.B.

Year of Election.

1894. ‡Balfour, Henry, M.A. 11 Norham-gardens, Oxford.
1875. ‡BALFOUR, ISAAC BAYLEY, M.A., D.Sc., M.D., F.R.S., F.R.S.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. 24 Merrion-square, Dublin.
1866. *BALL, Sir ROBERT STAWELL, LL.D., F.R.S., F.R.A.S., Director of the Observatory and Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1886. ‡Ballantyne, J. W., M.B. 24 Melville-street, Edinburgh.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1890. ‡Bamford, Professor Harry, B.Sc. McGill University, Montreal, Canada.
1882. ‡Bance, Colonel Edward, J.P. Limewood, The Avenue, Southampton.
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.
1894. §Barclay, Arthur. 29 Gloucester-road, South Kensington, London, S.W.
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.
1881. ‡Barfoot, William, J.P. Whelford-place, Leicester.
1882. ‡Barford, J. D. Above Bar, Southampton.
1886. ‡Barham, F. F. Bank of England, Birmingham.
1890. ‡Barker, Alfred, M.A., B.Sc. Aske's Hatcham School, New Cross, London, S.E.
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. The Vicarage, Yatton, Bristol.
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.
1886. ‡Barling, Gilbert. 85 Edmund-street, Edgbaston, Birmingham.
1873. ‡Barlow, Crawford, B.A., M.Inst.C.E. 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. 5 Great George-street, Dublin.
1885. *BARLOW, WILLIAM, F.G.S. Hillfield, Muswell Hill, London, N.
1873. ‡BARLOW, WILLIAM HENRY, F.R.S., M.Inst.C.E. High Combe, Old Charlton, Kent.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.

Year of Election.

1881. ‡Barnard, William, LL.B. 3 New-court, Lincoln's Inn, W.C.
1889. ‡Barnes, J. W. Bank, Durham.
1868. §Barnes, Richard H. Heatherlands, Parkstone, Dorset.
1884. ‡Barnett, J. D. Port Hope, Ontario, Canada.
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E. The University, Glasgow.
1890. ‡Barr, Frederick H. 4 South-parade, Leeds.
1895. §§*Barr, James Mark. Central Technical College, London, E.C.*
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1891. §Barrell, Frank R., M.A., Professor of Mathematics in University College, Bristol.
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. Abbotsgate, Huyton, 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.
1893. ‡Barrow, George, F.G.S. Geological Survey Office, 28 Jermyn-street, London, S.W.
1886. ‡Barrow, George William. Baldraud, Lancaster.
1886. ‡Barrow, Richard Bradbury. Lawn House, 13 Ampton-road, Edgbaston, Birmingham.
1896. §Barrowman, James. Stanacre, Hamilton, N.B.
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. The Cloisters, Windsor.
1862. *Barry, Charles. 1 Victoria-street, London, S.W.
1883. ‡Barry, Charles E. 1 Victoria-street, London, S.W.
1875. ‡Barry, John Wolfe, C.B., F.R.S., M.Inst.C.E. 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.
1892. ‡Bartholomew, John George, F.R.S.E., F.R.G.S. 12 Blacket-place, Edinburgh.
1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Hyde Park, Leeds.
1884. ‡Bartlett, James Herbert. 148 Mansfield-street, Montreal, Canada.
1873. ‡Bartley, G. C. T., M.P. St. Margaret's House, Victoria-street, S.W.
1892. ‡Barton, Miss. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1893. ‡Barton, Edwin H., B.Sc. University College, Nottingham.
1884. ‡Barton, H. M. Foster-place, Dublin.
1852. ‡Barton, James. Farndreg, Dundalk.
1892. ‡Barton, William. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1887. ‡Bartrum, John S. 13 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1876. ‡Bassano, Alexander. 12 Montagu-place, London, W.

Year of Election.

1876. ‡Bassano, Clement. Jesus College, Cambridge.
1888. *BASSET, A. B., M.A., F.R.S. Fledborough Hall, Holyport, Berkshire.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *BASSETT, HENRY. 26 Belitha-villas, Barnsbury, London, N.
1889. ‡BASTABLE, Professor C. F., M.A., F.S.S. 6 Trevelyan-terrace, 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., C.M.G. Board of Trade, London, S.W.
1868. ‡Bateman, Sir F., M.D., LL.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.
1884. ‡BATESON, WILLIAM, M.A., F.R.S. St. John's College, Cambridge.
1881. *Bather, Francis Arthur, M.A., F.G.S. 135 Kensington High-street, W.; and British Museum (Natural History), S.W.
1836. ‡Batten, Edmund Chisholm. Thorn Falcon, near Taunton, Somerset.
1863. §BAUERMAN, H., F.G.S. 14 Cavendish-road, Balham, London, S.W.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1892. §§Bayly, F. W. Royal Mint, London, E.
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. 2 Norham-gardens, Oxford.
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.
1886. ‡Beale, Charles G. Maple Bank, Edgbaston, Birmingham.
1860. *BEALE, LIONEL S., M.B., F.R.S. 61 Grosvenor-street, London, W.
1882. §Beamish, Lieut.-Colonel A. W., R.E. 27 Philbeach-gardens, S.W.
1884. ‡Beamish, G. H. M. Prison, Liverpool.
1872. ‡Beanes, Edward, F.C.S. Moatlands, Paddock Wood, Brenchley, Kent.
1883. ‡Beard, Mrs. Oxford.
1889. §Beare, Prof. T. Hudson, F.R.S.E., M.Inst.C.E. University College, W.C.
1887. ‡*Beaton, John, M.A.* 219 *Upper Brook-street, Chorlton-on-Medlock, Manchester.*
1842. *Beatson, William. Ash Mount, Rotherham.
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. Emmanuel College, Cambridge.
1885. *BEAUMONT, W. W., M.Inst.C.E., F.G.S. Outer Temple, 222 Strand, London, W.C.
1896. §Beazer, C. Hindley, near Wigan.
1871. *Beazley, Lieut.-Colonel George G. 74 Redcliffe-square, S.W.
1887. *BECKETT, JOHN HAMPDEN. Corbar Hill House, Buxton, Derbyshire.

Year of Election.

1885. §§BEDDARD, FRANK E., M.A., F.R.S., F.Z.S., Prosector to the Zoological Society of London, Regent's Park, London, N.W.
1870. §BEDDOE, JOHN, M.D., F.R.S. The Chantry, Bradford-on-Avon.
1896. §Bedford, F. S. King's College, Cambridge.
1858. §Bedford, James. Woodhouse Cliff, near Leeds.
1890. ‡Bedford, James E., F.G.S. Shireoak-road, Leeds.
1891. §Bedlington, Richard. Gadlys House, Aberdare.
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.
1891. *Belinfante, L. L., B.Sc., Assist.-Sec. G.S. Burlington House, W.
1892. ‡Bell, A. Beatson. 143 Princes-street, Edinburgh.
1873. ‡*Bell, Asahel P. 32 St. Anne's-street, Manchester.*
1871. ‡Bell, Charles B. 6 Spring-bank, Hull.
1884. ‡Bell, Charles Napier. Winnipeg, Canada.
1896. §BELL, DUGALD, F.G.S. 27 Lansdowne-crescent, Glasgow.
1894. §§BELL, F. JEFFREY, M.A., F.Z.S. 35 Cambridge-street, Hyde Park, London, W.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.
1862. *BELL, Sir ISAAC LOWTHIAN, Bart., LL.D., 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. Howell Hill Lodge, Ewell, Surrey.
1896. §Bell, James. 38 Russian Drive, Stoneycroft, Liverpool.
1891. ‡Bell, James. Bangor Villa, Clive-road, Cardiff.
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.*
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1893. ‡BELPER, The Right Hon. Lord, LL.M. Kingston, Nottinghamshire.
1884. ‡Bemrose, Joseph. 15 Plateau-street, Montreal, Canada.
1886. §Benger, Frederick Baden, F.I.C., F.C.S. The Grange, Knutsford.
1885. ‡BENHAM, WILLIAM BLAXLAND, D.Sc. The Museum, Oxford.
1891. §Bennett, Alfred Rosling. 22 St. Alban's-road, Harlesden, London, N.W.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1896. §Bennett, George W. West Ridge, Oxton.
1836. ‡Bennett, Henry. Bedminster, Bristol.
1881. §Bennett, John R. 16 West Park, Clifton, Bristol.
1883. *Bennett, Laurence Henry. Bedminster, Bristol.
1896. §Bennett, Richard. 19 Brunswick-street, Liverpool.
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's-square, Manchester.*
1889. ‡Benson, John G. 12 Grey-street, Newcastle-upon-Tyne.
1848. ‡Benson, Starling. Gloucester-place, Swansea.
1887. *Benson, Mrs. W. J. Care of Standard Bank of South Africa, Stellenbosch, S. Africa.

Year of Election.

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.
1896. *Bergin, William, M.A., Professor of Natural Philosophy in Queen's College, Cork.
1894. §§Berkeley, The Right Hon. the Earl of. The Heath, Boarshill, near Abingdon.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1886. ‡Bernard, W. Leigh. Calgary, Canada.
1894. §Berridge, Douglas. The Laboratory, The College, Malvern.
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.
1880. *Bevan, Rev. James Oliver, M.A., F.G.S. 55 Gunterstone-road, London, W.
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1885. ‡Beveridge, R. Beath Villa, Ferryhill, Aberdeen.
1890. §Bevington, Miss Mary E. Merle Wood, Sevenoaks, Kent.
1863. ‡Bewick, Thomas John, M.Inst.C.E., F.G.S. Broad-street House, Old Broad-street, London, E.C.
1870. ‡Bickerton, A.W., F.C.S. Christchurch, Canterbury, New Zealand.
1888. *Bidder, George Parker. The Zoological Station, Naples.
1885. *BIDWELL, SHELFORD, M.A., LL.B., F.R.S. Riverstone Lodge, Southfields, Wandsworth, Surrey, S.W.
1882. §Biggs, C. H. W., F.C.S. Glebe Lodge, Champion Hill, S.E.
1891. ‡Billups, J. E. 29 The Parade, Cardiff.
1886. ‡Bindloss, G. F. Carnforth, Brondesbury Park, London, N.W.
1887. *Bindloss, James B. Elm Bank, Eccles, Manchester.
1884. *Bingham, Lieut.-Colonel John E., J.P. West Lea, Ranmoor, 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.
1888. *Birley, Miss Caroline. 14 Brunswick-gardens, Kensington, London, W.
1887. *Birley, H. K. 13 Hyde-road, Ardwick, Manchester.
1871. *BISCHOF, GUSTAV. 4 Hart-street, Bloomsbury, London, W.C.
1892. ‡*Bishop, Arthur W., Ph.D. Heriot Watt College, Edinburgh.*
1883. ‡*Bishop, John le Marchant.* 100 *Mosley-street, Manchester.*
1894. §§Bisset, James. 5 East India-avenue, London, E.C.
1885. ‡Bissett, J. P. Wyndem, Banchory, N.B.
1886. *Bixby, Captain W. H. War Department, Washington, U.S.A.
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.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1855. *BLACKIE, W. G., Ph.D., F.R.G.S. 1 Belhaven-terrace, Kelvinside, Glasgow.
1896. §Blackie, Walter W., B.Sc. 17 Stanhope-street, Glasgow.
1884. ‡Blacklock, Frederick W. 25 St. Famille-street, Montreal, Canada.

Year of Election.

1883. ‡Blacklock, Mrs. Sea View, Lord-street, Southport.
1896. §Blackwood, J. M. 16 Oil-street, Liverpool.
1895.§§Blaikie, W. B. 6 Belgrave-crescent, Edinburgh.
1888. ‡Blaine, R. S., J.P. Summerhill Park, Bath.
1883. ‡Blair, Mrs. Oakshaw, Paisley.
1892. ‡Blair, Alexander. 35 Moray-place, Edinburgh.
1892. ‡Blair, John. 9 Ettrick-road, Edinburgh.
1863. ‡Blake, C. Carter, D.Sc. 6 St. Edmund's-terrace, St. John's Wood, London, N.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. 43 Clifton Hill, London, N.W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1891. ‡Blakesley, Thomas H., M.A., M.Inst.C.E. Royal Naval College, Greenwich, London, S.E.
1886. ‡Blakie, John. The Bridge House, Newcastle, Staffordshire.
1894. ‡Blakiston, Rev. C. D. Exwick Vicarage, Exeter.
1887. ‡Blamires, George. Cleckheaton.
1881.§§Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1895. §Blamires, William. Oak House, Taylor Hill, 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. 12 King's Parade, Cambridge.
1887. *Bles, Edward J. 12 King's-parade, Cambridge.
1887. ‡Bles, Marcus S. The Beeches, Broughton Park, Manchester.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1880. ‡Bloxam, G. W., M.A. 11 Presburg-street, Clapton, London, N.E.
1888. §Bloxsom, Martin, B.A., Assoc.M.Inst.C.E. Hazelwood, Crumpsall Green, Manchester.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
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. 27 Mansion House-road, Edinburgh.
1867. *Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1887. ‡Blythe, William S. 65 Mosley-street, Manchester.
1870. ‡Boardman, Edward. Oak House, Eaton, Norwich.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1889. ‡Bodmer, G. R., Assoc.M.Inst.C.E. 30 Walbrook, London, E.C.
1884. ‡Body, Rev. C. W. E., M.A. Trinity College, Toronto, Canada.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1881. ‡*Bojanowski, Dr. Victor de. 27 Finsbury-circus, London, E.C.*
1876. ‡Bolton, J. C. Carbrook, Stirling.
1894. §Bolton, John. Clifton-road, Crouch End, London, N.
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.
1893.§§Boot, Jesse. Carlyle House, 18 Burns-street, Nottingham.

Year of Election.

1890. *Booth, Charles, F.S.S. 2 Talbot-court, Gracechurch-street, London, E.C.

1883. §Booth, James. Hazelhurst, Turton.

1883. ‡Booth, Richard. 4 Stone-buildings, Lincoln's Inn, London, W.C.

1876. ‡Booth, Rev. William H. Mount Nod-road, Streatham, London, S.W.

1883. ‡Boothroyd, Benjamin. Solihull, Birmingham.

1876. *Borland, William. 260 West George-street, Glasgow.

1882. §Borns, Henry, Ph.D., F.C.S. 19 Alexandra-road, Wimbledon, Surrey.

1876. *Bosanquet, R. H. M., M.A., F.R.S., F.R.A.S., F.C.S. New University Club, St. James's-street, London, S.W.

1896. §Bose, Dr. J. C. Calcutta, India.

*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.

1881. §Bothamley, Charles H., F.I.C., F.C.S., Director of Technical Instruction, Somerset County Education Committee. Wentworth, Weston-super-Mare.

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., D.Sc., F.R.S., F.R.S.E., F.C.S. The University, Glasgow.

1884. *Bottomley, Mrs. The University, Glasgow.

1892. ‡Bottomley, W. B., B.A., Professor of Botany, King's College, London.

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.

1883. †Bourne, A. G., D.Sc., F.R.S., F.L.S., Professor of Biology in the Presidency College, Madras.

1893.§§Bourne, G. C., M.A., F.L.S. New College, Oxford.

1889. ‡Bourne, R. H. Fox. 41 Priory-road, Bedford Park, Chiswick.

1866. §Bourne, Stephen, F.S.S. 5 Lansdown-road, Lee, S.E.

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.

1881. *Bower, F. O., D.Sc., F.R.S., F.L.S., Regius Professor of Botany in the University of Glasgow.

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., F.L.S. Mayfield, Knutsford, Cheshire.

1887. §Box, Alfred Marshall. 68 Huntingdon-road, Cambridge.

1895. *Boyce, Rubert, M.B., Professor of Pathology, University College, Liverpool.

1884. *Boyd, M. A., M.D. 30 Merrion-square, Dublin.

1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.

1865. ‡Boyle, The Very Rev. G. D., M.A. The Deanery, Salisbury.

1884. *Boyle, R. Vicars, C.S.I. Care of Messrs. Grindlay & Co., 55 Parliament-street, London, S.W.

Year of Election.

1892.§§Boys, Charles Vernon, F.R.S., Assistant Professor of Physics in the Royal College of Science, London, S.W.
1872. *Brabrook, E. W., F.S.A. 178 Bedford-hill, Balham, London, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1894. *Braby, Ivon. Bushey Lodge, Teddington, Middlesex.
1893. §Bradley, F. L. Bel Air, Alderley Edge, Cheshire.
1892. §Bradshaw, W. Carisbrooke House, The Park, Nottingham.
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, S.O., Essex.
1864. ‡Braham, Philip. 3 Cobden-mansions, Stockwell-road, London, S.E.
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., LL.D., 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. The Rectory, Dickleburgh.
1885. *Bratby, William, J.P. Oakfield Hale, Altrincham, Cheshire.
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. Goldsmith-buildings, Temple, London, E.C.
1866. ‡Brettell, Thomas. Dudley.
1891. ‡Brice, Arthur Montefiore, F.G.S., F.R.G.S. 159 Strand, London, W.C.
1886.§§Bridge, T. W., M.A., D.Sc., Professor of Zoology in the Mason Science College, Birmingham.
1870. *Bridson, Joseph R. Bryerswood, 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, M.P. Kildwick Hall, Keighley, Yorkshire.
1890. ‡Brigg, W. A. Kildwick Hall, Keighley, Yorkshire.
1893. ‡Bright, Joseph. Western-terrace, The Park, Nottingham.
1868. ‡Brine, Admiral Lindesay, F.R.G.S. United Service Club, Pall Mall, London, S.W.
1893.§§Briscoe, Albert E., A.R.C.Sc., B.Sc. Battersea Polytechnic, London, S.W.
1884. ‡Brisette, M. H. 424 St. Paul-street, Montreal, Canada.
1879. *Brittain, W. H., J.P., F.R.G.S. Alma Works, 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. 9 Vanbrugh Hill, Blackheath, London, S.E.
1896. *Brocklehurst, S. Olinda, Sefton Park, Liverpool.
1859. *Brodhurst, Bernard Edward, F.R.C.S. 20 Grosvenor-street, Grosvenor-square, London, W.
1883. *Brodie, David, M.D. 12 Patten-road, Wandsworth Common, London, S.W.
1865. ‡Brodie, Rev. Peter Bellinger, M.A., F.G.S. Rowington Vicarage, near Warwick.

Year of Election.

1884. ‡Brodie, William, M.D. 64 Lafayette-avenue, Detroit, Michigan, U.S.A.
1883. *Brodie-Hall, Miss W. L. The Gore, Eastbourne.
1881. §§Brook, Robert G. Raven-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.
1887. §Brooks, James Howard. Elm Hirst, Wilmslow, near Manchester.
1863. ‡Brooks, John Crosse. 14 Lovaine-place, Newcastle-on-Tyne.
1887. ‡Brooks, S. H. Slade House, Levenshulme, Manchester.
1887. *Bros, W. Law. Sidcup, Kent.
1883. §§Brotherton, E. A. Fern Cliffe, Ilkley, Yorkshire.
1883. *Brough, Mrs. Charles S. Rosendale Hall, West Dulwich, S.E.
1886. §Brough, Professor Joseph, LL.M., Professor of Logic and Philosophy in University College, Aberystwith.
1885. *Browett, Alfred. 29 Wheeley's-road, Birmingham.
1863. *Brown, Alexander Crum, M.D., LL.D., F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1892. ‡Brown, Andrew, M.Inst.C.E. Messrs. Wm. Simons & Co., Renfrew, near Glasgow.
1896. §Brown, A. T. The Nunnery, St. Michael's Hamlet, Liverpool.
1867. ‡Brown, Charles Gage, M.D., C.M.G. 88 Sloane-street, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. ‡Brown, David. Willowbrae House, Midlothian.
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.
1883. ‡Brown, George Dransfield. Henley Villa, Ealing, Middlesex, W.
1884. ‡Brown, Gerald Culmer. Lachute, Quebec, Canada.
1883. ‡Brown, Mrs. H. Bienz. 62 Stanley-street, Aberdeen.
1883. ‡Brown, Mrs. Helen. Canaan-grove, Newbattle-terrace, Edinburgh.
1870. §Brown, Horace T., F.R.S., F.C.S., F.G.S. 52 Nevern-square, London, S.W.
Brown, Hugh. Broadstone, Ayrshire.
1883. ‡Brown, Miss Isabella Spring. Canaan-grove, Newbattle-terrace, Edinburgh.
1895. §§Brown, J. Allen, J.P., F.R.G.S., F.G.S. 7 Kent-gardens, Ealing, London, W.
1870. *Brown, Professor J. Campbell, D.Sc., F.C.S. University College, Liverpool.
1876. §Brown, John. Longhurst, Dunmurry, Belfast.
1881. *Brown, John, M.D. 68 Bank-parade, Burnley, Lancashire.
1882. *Brown, John. 7 Second-avenue, Sherwood Rise, Nottingham.
1895. *Brown, John Charles. 7 Second-avenue, Nottingham.
1859. ‡Brown, Rev. John Crombie, LL.D. Haddington, N.B.
1894. ‡Brown, J. H. 6 Cambridge-road, Brighton.
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.
1896. §Brown, Stewart H. Quarry Bank, Allerton, Liverpool.
1891. §Brown, T. Forster, M.Inst.C.E., F.G.S. Guildhall Chambers, Cardiff.
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.

Year of Election.

1863. ‡Browne, Sir Benjamin Chapman, M.Inst.C.E. Westacres, Newcastle-upon-Tyne.
1892. ‡Browne, Harold Crichton. Crindon, Dumfries.
1895. *Browne, Henry Taylor. 10 Hyde Park-terrace, London, W.
1879. ‡BROWNE, Sir J. CRICHTON, M.D., LL.D., F.R.S., F.R.S.E. 61 Carlisle-place-mansions, Victoria-street, London, S.W.
1891. §BROWNE, MONTAGU, F.G.S. Town Museum, Leicester.
1862. *Browne, Robert Clayton, M.A. Sandbrook, Tullow, Co. Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Redcot, Bradbourne, Sevenoaks, Kent.
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.
1892. ‡Bruce, James. 10 Hill-street, Edinburgh.
1893.§§Bruce, William S. University Hall, Riddle's-court, Edinburgh.
1863. *Brunel, H. M., M.Inst.C.E. 21 Delahay-street, Westminster, S.W.
1863. ‡Brunel, J. 21 Delahay-street, Westminster, S.W.
1875. ‡Brunlees, John. 5 Victoria-street, Westminster, S.W.
1896. *Brunner, Sir J. T., Bart., M.P. Druid's Cross, Wavertree, Liverpool.
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., D.Sc., F.R.S. Thornlea, Trumpington-road, Cambridge.
1894. §Bryan, Mrs. R. P. Thornlea, Trumpington-road, Cambridge.
1884. ‡Bryce, Rev. Professor George. The College, Manitoba, Canada.
1894.§§Brydone, R. M. Petworth, Sussex.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1871. §BUCHAN, ALEXANDER, M.A., LL.D., F.R.S.E., Sec. Scottish Meteorological Society. 42 Heriot-row, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡BUCHANAN, JOHN YOUNG, M.A., F.R.S., F.R.S.E., F.R.G.S., F.C.S. 10 Moray-place, Edinburgh.
1884. ‡Buchanan, W. Frederick. Winnipeg, Canada.
1883. ‡Buckland, Miss A. W. 5 Beaumont-crescent, West Kensington, London, W.
1886. *Buckle, Edmund W. 23 Bedford-row, London, W.C.
1864. ‡BUCKLE, Rev. GEORGE, M.A. Wells, Somerset.
1865. *Buckley, Henry. 8 St. Mary's-road, Leamington.
1886. §Buckley, Samuel. Merlewood, Beaver Park, Didsbury.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, London, W.
1880. ‡Buckney, Thomas, F.R.A.S. 53 Gower-street, London, W.C.
1869. ‡BUCKNILL, Sir 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.
1893. §BULLEID, ARTHUR. Glastonbury.
1871. ‡Bulloch, Matthew. 48 Prince's-gate, London, S.W.
1881. ‡Bulmer, T. P. Mount-villas, York.
1883. ‡Bulpit, Rev. F. W. Crossens Rectory, Southport.
1865. ‡Bunce, John Thackray. 'Journal' Office, New-street, Birmingham.

Year of Election.

1895. §§Bunte, Dr. Hans. Karlsruhe, Baden.
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.
1891. ‡Burge, Very Rev. T. A. Ampleforth Cottage, near York.
1894. §Burke, John. Owens College, Manchester.
1884. *Burland, Lieut.-Col. Jeffrey H. 287 University-street, Montreal, Canada.
1888. ‡Burne, H. Holland. 28 Marlborough-buildings, Bath.
1883. *Burne, Major-General Sir Owen Tudor, K.C.S.I., C.I.E., F.R.G.S. 132 Sutherland-gardens, Maida Vale, London, W.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1885. *Burnett, W. Kendall, M.A. 11 Belmont-street, Aberdeen.
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.
1883. *Burrows, Abraham. Russell House, Rhyl, North Wales.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1894. ‡Burstall, H. F. W. 76 King's-road, Camden-road, London, N.W.
1891. ‡Burt, J. J. 103 Roath-road, Cardiff.
1888. ‡Burt, John Mowlem. 3 St. John's-gardens, Kensington, London, W.
1888. ‡Burt, Mrs. 3 St. John's-gardens, Kensington, London, W.
1894. §§Burton, Charles V. 24 Wimpole-street, London, W.
1866. *BURTON, FREDERICK M., F.L.S., F.G.S. Highfield, Gainsborough.
1889. ‡Burton, Rev. R. Lingen. Little Aston, Sutton Coldfield.
1892. ‡Burton-Brown, Colonel Alexander, R.A., F.R.A.S., F.G.S. St. George's Club, Hanover-square, London, W.
1887. *Bury, Henry. Trinity College, Cambridge.
1895. §Bushe, Colonel C. K., F.G.S. Bramhope, Old Charlton, Kent.
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.
1888. ‡Buttanshaw, Rev. John. 22 St. James's-square, Bath.
1884. *Butterworth, W. Greenhill, Church-lane, Harpurhey, Manchester.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1883. ‡Buxton, Miss F. M. Newnham College, Cambridge.
1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1881. ‡Buxton, Sydney. 15 Eaton-place, London, S.W.
1872. ‡Buxton, Sir Thomas Fowell, Bart., K.C.M.G., F.R.G.S. Warlies, Waltham Abbey, Essex.
1854. ‡BYERLEY, ISAAC, F.L.S. 22 Dingle-lane, Toxteth-park, Liverpool.
1885. ‡Byres, David. 63 North Bradford, Aberdeen.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1883. ‡Byrom, John R. Mere Bank, Fairfield, near Manchester.

1889. ‡Cackett, James Thoburn. 60 Larkspur-terrace, Newcastle-upon-Tyne.
1892. ‡Cadell, Henry M., B.Sc., F.R.S.E. Grange, Bo'ness, N.B.
1894. ‡Caillard, Miss E. M. Wingfield House, near Trowbridge, Wilts.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.

Year of Election.

1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1886. *Caldwell, William Hay. 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. 35 Huskisson-street, Liverpool.
1892. ‡*Calvert, A. F., F.R.G.S. The Mount, Oseney-crescent, Camden-road, London, N.*
1884. ‡Cameron, Æneas. Yarmouth, Nova Scotia, Canada.
1876. ‡Cameron, Sir Charles, Bart., M.D., LL.D. 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.
1896. §Cameron, J. H. 307 Sherbourne-street, Toronto, Canada.
1884. ‡Campbell, Archibald H. Toronto, Canada.
1876. ‡Campbell, James A., LL.D., M.P. Stracathro House, Brechin.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
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. 27 Kensington Court-gardens, London, W.
1894. §Capper, D. S., M.A., Professor of Mechanical Engineering in King's College, London, W.C.
1880. ‡Capper, Robert. 18 Parliament-street, Westminster, S.W.
1883. ‡Capper, Mrs. R. 18 Parliament-street, Westminster, S.W.
1887. ‡Capstick, John Walton. University College, Dundee.
1873. *CARBUTT, Sir EDWARD HAMER, Bart., M.Inst.C.E. 19 Hyde Park-gardens, London, W.
1896. *Carden, H. V. Surbiton.
1877. ‡Carkeet, John. 3 St. Andrew's-place, Plymouth.
1867. ‡Carmichael, David (Engineer). Dundee.
1884. ‡Carnegie, John. Peterborough, Ontario, Canada.
1884. ‡Carpenter, Louis G. Agricultural College, Fort Collins, Colorado, U.S.A.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1889. ‡Carr, Cuthbert Ellison. Hedgeley, Alnwick.
1893. ‡Carr, J. Wesley, M.A., F.L.S., F.G.S., Professor of Biology in University College, Nottingham.
1889. †Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. Central House, Central Hill, London, S.E.
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. 1 Trinity College, 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.
1896. §Cartwright, Miss Edith G. 69 Gloucester-road, Kew, Surrey.
1878. *Cartwright, Ernest H., M.A., M.D. 1 Courtfield-gardens, S.W.
1870. §Cartwright, Joshua, M.Inst.C.E., F.S.I., Borough and Water Engineer. Albion-place, Bury, Lancashire.

Year of Election.

1862. ‡Carulla, F. J. R. 84 Argyll-terrace, Derby.
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.
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.
1896. *Casey, James. 10 Philpot-lane, London, E.C.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 35 Commercial-street, Halifax.
1888. ‡Cater, R. B. Avondale, Henrietta Park, Bath.
1874. ‡Caton, Richard, M.D. Lea Hall, Gateacre, Liverpool.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1886. *Cave-Moyles, Mrs. Isabella. Devonshire House, New Malden, Surrey.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1883. ‡Chadwick, James Percy. 51 Alexandra-road, Southport.
1859. ‡*Chadwick, Robert. Highbank, Manchester.*
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, Mrs. Colába Observatory, Bombay.
1883. ‡Chambers, Charles, jun., Assoc.M.Inst.C.E. Colába Observatory, Bombay.
*Champney, Henry Nelson. 4 New-street, York.
1881. **Champney, John E. Woodlands, Halifax.*
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. 1 Grand Avenue, Brighton.
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. Firbank, Hereford.
1874. ‡Charles, J. J., M.D., Professor of Anatomy and Physiology in Queen's College, Cork. Newmarket, Co. Cork.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1866. ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A. Crichton Club, Adelphi-terrace, London, W.C.
1886. ‡Chate, Robert W. Southfield, Edgbaston, Birmingham.
1884. *Chatterton, George, M.A., M.Inst.C.E. 46 Queen Anne's-gate, London, S.W.
1886. §Chattock, A. P. University College, Bristol.
1867. *Chatwood, Samuel, F.R.G.S. High Lawn, Broad Oak Park, Worsley, Manchester.
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.
1896. §Chenie, John. Charlotte-street, Edinburgh.

Year of Election.

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.
1896. §Cherry, R. B. 92 Stephen's Green, Dublin.
1879. *Chesterman, W. Belmayne, Sheffield.
1865. *Child, Gilbert W., M.A., M.D., F.L.S. Holywell Lodge, Oxford.
1883. ‡Chinery, Edward F. Monmouth House, Lymington.
1884. ‡Chipman, W. W. L. 957 Dorchester-street, Montreal, Canada.
1889. ‡Chirney, J. W. Morpeth.
1894. ‡Chisholm, G. G., M.A., B.Sc., F.R.G.S. 26 Dornton-road, Balham, London, S.W.
1842. **Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.*
1882. ‡Chorley, George. Midhurst, Sussex.
1887. ‡Chorlton, J. Clayton. New Holme, Withington, Manchester.
1893. *CHREE, CHARLES, D.Sc., Superintendent of the Kew Observatory, Richmond, Surrey.
1861. ‡*Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.*
1884. *Christie, William. 29 Queen's Park, Toronto, Canada.
1875. *Christopher, George, F.C.S. 3 Tankerville-road, Streatham, London, S.W.
1876. *CHRYSTAL, GEORGE, M.A., LL.D., 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. Shelsley, Ennerdale-road, Kew, Surrey.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, E.C.
1857. ‡*Churchill, F., M.D. Ardtrea Rectory, Stewartstown, Co. Tyrone.*
1896. §Clague, Daniel. 5 Sandstone-road, Stoneycroft, Liverpool.
1890. ‡*Clark, E. K. 81 Caledonian-road, Leeds.*
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
Clark, George T. 44 Berkeley-square, London, W.
1876. ‡Clark, George W. 31 Waterloo-street, Glasgow.
1892. §Clark, James, M.A., Ph.D. Yorkshire College, Leeds.
1892. ‡Clark, James. Chapel House, Paisley.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1881. ‡Clark, J. Edmund, B.A., B.Sc., F.G.S. 12 Feversham-terrace, York.
1861. ‡CLARK, LATIMER, F.R.S., F.R.A.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. Ingleside, Elm-grove, Peckham, S.E.
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.
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.*
1883. ‡Clarke, W. P., J.P. 15 Hesketh-street, Southport.
1896. §Clarke, W. W. Albert Dock Office, Liverpool.
1884. ‡Claxton, T. James. 461 St. Urbain-street, Montreal, Canada.
1889. §CLAYDEN, A. W., M.A., F.G.S. St. John's, Polsloe-road, Exeter.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1890. *Clayton, William Wikely. Gipton Lodge, Leeds.
1859. ‡Cleghorn, John. Wick.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.

Year of Election.

1861.§§CLELAND, JOHN, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 The University, Glasgow.
1886. ‡*Clifford, Arthur. Beechcroft, Edgbaston, Birmingham.*
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. 3 Bardwell-road, Banbury-road, Oxford.
1893. ‡Clofford, William. 36 Mansfield-road, Nottingham.
Clonbrock, Lord Robert. Clonbrock, Galway.
1878. §Close, Rev. Maxwell H., F.G.S. 38 Lower Baggot-street, Dublin.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1892. ‡Clouston, T. S., M.D. Tipperlinn House, Edinburgh.
1883. *CLOWES, FRANK, D.Sc., F.C.S., Professor of Chemistry in University College, Nottingham. 99 Waterloo-crescent, Nottingham.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1881. *Clutton, William James. The Mount, York.
1885. ‡Clyne, James. Rubislaw Den South, Aberdeen.
1891. *Coates, Henry. Pitcullen House, Perth.
Cobb, Edward. Falkland House, St. Ann's, Lewes.
1884. §Cobb, John. Summerhill, Apperley Bridge, Leeds.
1895. *COBBOLD, FELIX T., M.A. The Lodge, Felixstowe, Suffolk.
1889. ‡Cochrane, Cecil A. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1889. ‡Cochrane, William. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1892. ‡Cockburn, John. Glencorse House, Milton Bridge, Edinburgh.
1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1861. *Coe, Rev. Charles C., F.R.G.S. Whinsbridge, Grosvenor-road, Bournemouth.
1881. *COFFIN, WALTER HARRIS, F.C.S. 94 Cornwall-gardens, South Kensington, London, S.W.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1896. *Coghill, Percy de G. Camster, Cressington.
1884. *Cohen, B. L., M.P. 30 Hyde Park-gardens, London, W.
1887. ‡Cohen, Julius B. Yorkshire College, Leeds.
1894. *Colby, Miss E. L. Carreg-wen, Aberystwith.
1895. *Colby, James George Ernest, M.A., F.R.C.S. Malton, Yorkshire.
1895. *Colby, William Henry. Carreg-wen, Aberystwith.
1853. ‡Colchester, William, F.G.S. Burwell, Cambridge.
1893. ‡Cole, Grenville A. J., F.G.S. Royal College of Science, Dublin.
1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.
1894. ‡Colefax, H. Arthur, Ph.D., F.C.S. 14 Chester-terrace, Chester-square, London, S.W.
1893. ‡Coleman, J. B., F.C.S., A.R.C.S. University College, Nottingham.
1878. ‡Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, London, W.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1892.§§Collet, Miss Clara E. 7 Coleridge-road, London, N.
1892. §Collie, Alexander. Harlaw House, Inverurie.
1887. ‡COLLIE, J. NORMAN, Ph.D., F.R.S. University College, Gower-street, London, W.C.
1887. ‡Collier, Thomas. Ashfield, Alderley Edge, Manchester.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1893.§§Collinge, Walter E. Mason College, Birmingham.
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. 60 Heber-road, Dulwich Rise, London, S.E.

Year of
Election.

1892. ‡Colman, H. G. Mason College, Birmingham.
1868. *Colman, J. J. 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.
1896. *Comber, Thomas. Leighton, Parkgate, Chester.
1888. ‡Commans, R. D. Macaulay-buildings, Bath.
1884. ‡Common, A. A., LL.D., F.R.S., F.R.A.S. 63 Eaton-rise, Ealing, Middlesex, W.
1891. ‡Common, J. F. F. 21 Park-place, Cardiff.
1892. §§Comyns, Frank, M.A., F.C.S. The Grammar School, Durham.
1884. ‡Conklin, Dr. William A. Central Park, New York, U.S.A.
1896. §Connacher, W. S. Birkenhead Institute, Birkenhead.
1890. ‡Connon, J. W. Park-row, Leeds.
1871. *Connor, Charles C. Notting Hill House, Belfast.
1881. ‡Conroy, Sir John, Bart., M.A., F.R.S. Balliol College, Oxford.
1893. ‡Conway, Sir W. M., M.A., F.R.G.S. The Red House, Hornton-street, London, W.
1876. ‡*Cook, James. 162 North-street, Glasgow.*
1895. §Cooke, Miss Janette E. Holmwood, Thorpe, Norwich.
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. 28 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, N.
1884. ‡Cooke, R. P. Brockville, Ontario, Canada.
1878. ‡Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
1881. ‡Cooke, Thomas. Bishopshill, York.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1896. §Cookson, E. H. Kiln Hey, West Derby.
1888. ‡Cooley, George Parkin. Cavendish Hill, Sherwood, Nottingham.
1884. ‡Coon, John S. 604 Main-street, Cambridge Pt., Massachusetts, U.S.A.
1895. §§Cooper, Charles Friend, M.I.E.E. 68 Victoria-street, Westminster, S.W.
1893. ‡Cooper, F. W. 14 Hamilton-road, Sherwood Rise, Nottingham.
1883. ‡Cooper, George B. 67 Great Russell-street, London, W.C.
1868. ‡Cooper, W. J. New Malden, Surrey.
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.
1842. Corbett, Edward. Grange-avenue, Levenshulme, Manchester.
1891. §Corbett, E. W. M. Y Fron, Pwllypant, Cardiff.
1887. *Corcoran, Bryan. 9 Alwyne-square, London, N.
1894. §Corcoran, Miss Jessie R. The Chestnuts, Sutton, Surrey.
1881. §Cordeaux, John. Great Cotes House,.R.S.O., Lincoln.
1883. *Core, Professor Thomas H., M.A. 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.
1893. *Corner, Samuel, B.A., B.Sc. 95 Forest-road West, Nottingham.

Year of Election.

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.
1891. ‡Cory, John, J.P. Vaindre Hall, near Cardiff.
1891. ‡Cory, Alderman Richard, J.P. Oscar House, Newport-road, Cardiff.
1883. ‡Costelloe, B. F. C., M.A., B.Sc. 33 Chancery-lane, London, W.C.
1891. *Cotsworth, Haldane Gwilt. G.W.R. Laboratory, Swindon, Wilts.
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 Mallet, Somerset.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1889. ‡Courtney, F. S. 77 Redcliffe-square, South Kensington, London, S.W.
1896. §§Courtney, Right Hon. Leonard, M.P. 15 Cheyne Walk, Chelsea, S.W.
1890. ‡Cousins, John James. Allerton Park, Chapel Allerton, Leeds.
1896. §Coventry, J. 19 Sweeting-street, Liverpool.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William, F.L.S., F.G.S. 31 Belsize Park-gardens, London, N.W.
Cowie, The Very Rev. Benjamin Morgan, M.A., D.D., Dean of Exeter. The Deanery, Exeter.
1895. *Cowell, Philip H. Royal Observatory, Greenwich, London, S.E.
1871. ‡Cowper, C. E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. Cardean, Meigle, N.B.
1867. *Cox, George Addison. Beechwood, Dundee.
1892. ‡Cox, Robert. 34 Drumsheugh-gardens, Edinburgh.
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.
1888. ‡Cox, Thomas W. B. The Chestnuts, Lansdowne, Bath.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1883. §§Crabtree, William, M.Inst.C.E. 126 Manchester-road, Southport.
1890. ‡Cradock, George. Wakefield.
1892. *Craig, George A. 66 Edge-lane, Liverpool.
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.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Slateford, Edinburgh.
1871. *Crawford and Balcarres, The Right Hon. the Earl of, K.T., LL.D., F.R.S., F.R.A.S. Dun Echt, Aberdeen.
1846. *Crawshaw, The Right Hon. Lord. Whatton, Loughborough.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, London, N.
1870. *Crawshay, Mrs. Robert. Caversham Park, Reading.

Year of Election.

1885. §CREAK, Captain E. W., R.N., F.R.S. 36 Kidbrooke Park-road, Blackheath, London, S.E.
1896. §Cregeen, A. C. 21 Prince's-avenue, Liverpool.
1879. ‡Creswick, Nathaniel. Chantry Grange, near Sheffield.
1876. *Crewdson, Rev. George. St. Mary's Vicarage, Windermere.
1887. *Crewdson, Theodore. Norcliffe Hall, Handforth, Manchester.
1896. §Crewe, W. Outram. 121 Bedford-street, Liverpool.
1896. §Crichton, H. 6 Rockfield-road, Anfield, Liverpool.
1880. *Crisp, Frank, B.A., LL.B., F.L.S., F.G.S. 5 Lansdowne-road, Notting Hill, London, W.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. ‡Croke, John O'Byrne, M.A. University College, Stephen's Green, Dublin.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1885. ‡Crombie, Charles W. 41 Carden-place, Aberdeen.
1885. ‡Crombie, John, jun. Daveston, Aberdeen.
1885. ‡CROMBIE, J. W., M.A., M.P. Balgownie Lodge, Aberdeen.
1885. ‡Crombie, Theodore. 18 Albyn-place, Aberdeen.
1887. ‡*Crompton, A.* 1 *St. James's-square, Manchester.*
1887. §CROOK, HENRY T. 9 Albert-square, Manchester.
1865.§§CROOKES, W., F.R.S., F.C.S. 7 Kensington Park-gardens, W.
1879. ‡Crookes, Mrs. 7 Kensington Park-gardens, London, W.
1870. ‡Crosfield, C. J. Gledhill, Sefton Park, Liverpool.
1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
1870. *CROSFIELD, WILLIAM. Annesley, Aigburth, Liverpool.
1890. ‡Cross, E. Richard, LL.B. Harwood House, New Parks-crescent, Scarborough.
1887.§§Cross, John. Beaucliffe, Alderley Edge, Cheshire.
1861. ‡Cross, Rev. John Edward, M.A., F.G.S. Halecote, Grange-over-Sands.
1886. ‡*Crosskey, Cecil.* 117 *Gough-road, Birmingham.*
1853. ‡Crosskill, William. Beverley, Yorkshire.
1870. *Crossley, Edward, F.R.A.S. Bemerside, Halifax.
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1894. *Crosweller, William Thomas, F.Z.S., F.I.Inst. Kent Lodge, Sidcup, Kent.
1894. §Crow, C. F. Home Lea, Woodstock-road, Oxford.
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-upon-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., M.A. 40 Trinity College, Dublin.
1878. ‡Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
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. 20 Essex-villas, Kensington, London, W.

Year of
Election.

1887. ‡Cunningham, David, M.Inst.C.E., F.R.S.E., F.S.S. Harbour-chambers, Dundee.
1877. *CUNNINGHAM, D. J., M.D., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy in Trinity College, Dublin.
1891. ‡Cunningham, J. H. 4 Magdala-crescent, Edinburgh.
1852. ‡Cunningham, John. Macedon, near Belfast.
1892. ‡*Cunningham, Very Rev. John. St. Bernard's College, Edinburgh.*
1885. ‡CUNNINGHAM, J. T., B.A. Biological Laboratory, Plymouth.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S., F.G.S., Professor of Natural History in Queen's College, Belfast.
1883. *CUNNINGHAM, Rev. WILLIAM, D.D., D.Sc. Trinity College, Cambridge.
1892. ‡*Cunningham, William. 14 Inverleith-gardens, Edinburgh.*
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1892. §Cunningham-Craig, E. H. 14A Dublin-street, Edinburgh.
1885. ‡*Curphey, William S. 15 Bute-mansions, Hill Head, Cardiff.*
1892. *Currie, James, jun., M.A. Larkfield, Golden Acre, Edinburgh.
1884. ‡Currier, John McNab. Newport, Vermont, U.S.A.
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. Endon, Staffordshire.
1854. ‡Daglish, Robert. Orrell Cottage, near Wigan.
1883. ‡Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1889. *Dale, Miss Elizabeth. Westbourne, Buxton, Derbyshire.
1863. ‡Dale, J. B. South Shields.
1867. ‡Dalgleish, W. Dundee.
1894. ‡Dalgleish, W. Scott, M.A., LL.D. 25 Mayfield-terrace, Edinburgh.
1870. ‡DALLINGER, Rev. W. H., LL.D., F.R.S., F.L.S. Ingleside, Newstead-road, Lee, London, S.E.
Dalton, Edward, LL.D. Dunkirk House, Nailsworth.
1862. ‡DANBY, T. W., M.A., F.G.S. The Crouch, Seaford, Sussex.
1876. ‡Dansken, John. 4 Eldon-terrace, Partickhill, Glasgow.
1896. §Danson, F. C. Liverpool and London Chambers, Dale-street, Liverpool.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1894. ‡Darbishire, B. V., M.A., F.R.G.S. 1 Savile-row, London, W.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A., F.G.S. 26 George-street, Manchester.
1896. §Darbishire, W. A. Nantlle, Penygroes, R.S.O. North Wales.
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.
1894. §DARWIN, Major LEONARD, Sec. R.G.S. 18 Wetherby-place, South Kensington, London, S.W.
1882. ‡Darwin, W. E., B.A., F.G.S. Bassett, Southampton.
1888. ‡Daubeny, William M. 1 Cavendish-crescent, Bath.
1872. ‡Davenport, John T. 64 Marine-parade, Brighton.

Year of Election.

1880. *DAVEY, HENRY, M.Inst.C.E., F.G.S. 3 Prince's-street, Westminster, S.W.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, E.C.
1870. ‡Davidson, Alexander, M.D. 2 Gambier-terrace, Liverpool.
1885. ‡Davidson, Charles B. Roundhay, Fonthill-road, Aberdeen.
1891. ‡Davies, Andrew, M.D. Cefn Parc, Newport, Monmouthshire.
1890. ‡*Davies, Arthur. East Brow Cottage, near Whitby.*
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1887. §Davies, David. 55 Berkley-street, Liverpool.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1893. *Davies, Rev. T. Witton, B.A. Midland Baptist College, Nottingham.
1896. *Davies, W. V. 3 Burn's-avenue, Liscard.
1887. ‡Davies-Colley, T. C. Hopedene, Kersal, Manchester.
1873. *Davis, Alfred. 13 St. Ermin's-mansions, London, S.W.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
1842. Davis, Rev. David, B.A. Almswood, Evesham.
1882. ‡Davis, Henry C. Berry Pomeroy, Springfield-road, Brighton.
1883. ‡Davis, R. Frederick, M.A. Earlsfield, Wandsworth Common, S.W.
1885. *Davis, Rev. Rudolf. Almswood, Evesham.
1891. ‡Davis, W. 48 Richmond-road, Cardiff.
1886. ‡Davis, W. H. Hazeldean, Pershore-road, Birmingham.
1886. ‡DAVISON, CHARLES, M.A. 373 Gillott-road, Birmingham.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡DAVY, E. W., M.D. Kimmage Lodge, Roundtown, 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.S.A., F.G.S., Professor of Geology and Palæontology in the Victoria University, Owens College, Manchester. Woodhurst, Fallowfield, Manchester.
1886. ‡Dawson, Bernard. The Laurels, Malvern Link.
1891. ‡Dawson, Edward. 2 Windsor-place, Cardiff.
1885. *Dawson, Lieut.-Colonel H. P., R.A. East Holt, Alverstoke, Gosport.
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. 293 University-street, Montreal, Canada.
1859. *Dawson, Captain William G. The Links, Plumstead Common, Kent.
1892. ‡Day, J. C., F.C.S. 36 Hillside-crescent, Edinburgh.
1870. *DEACON, G. F., M.Inst.C.E. 19 Warwick-square, London, S.W.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1887. ‡Deakin, H. T. Egremont House, Belmont, near Bolton.
1861. ‡Dean, Henry. Colne, Lancashire.
1884. *Debenham, Frank, F.S.S. 1 Fitzjohn's-avenue, London, N.W.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S. 4 Schlangenweg, Cassel, Hessen.
1884. ‡Deck, Arthur, F.C.S. 9 King's-parade, Cambridge.
1893. §Deeley, R. M. 10 Charnwood-street, Derby.
1878. ‡Delany, Rev. William. St. Stanislaus College, Tullamore.
1884. *De Laune, C. De L. F. Sharsted Court, Sittingbourne.
1870. ‡De Meschin, Thomas, B.A., LL.D. Dublin.
1896. §Dempster, John. Tynron, Noctorum, Birkenhead.
1889. ‡Dendy, Frederick Walter. 3 Mardale-parade, Gateshead.
1896. §Denison, Miss Louisa E. 16 Chesham-place, London, S.W.
1889. §DENNY, ALFRED, F.L.S., Professor of Biology in the Firth College, Sheffield.

Year of Election.

Dent, William Yerbury. 5 Caithness-road, Brook Green, London, W.
1874. §De Rance, Charles E., F.G.S. 55 Stoke-road, Shelton, Stoke-upon-Trent.
1896. §Derby, The Right Hon. the Earl of, G.C.B. Knowsley, Prescot, Lancashire.
1874. *Derham, Walter, M.A., LL.M., F.G.S. 63 Queensborough-terrace, London, W.
1878. ‡De Rinzy, James Harward. Khelat Survey, Sukkur, India.
1894. *Deverell, F. H. 13 Lawn-terrace, Blackheath, London, S.E.
1868. ‡Dewar, James, M.A., LL.D., F.R.S., F.R.S.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, W.
1887. ‡De Winton, Major-General Sir F., G.C.M.G., C.B., D.C.L., LL.D., F.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.
1896. §D'Hemry, P. 136 Prince's-road, Liverpool.
1889. ‡Dickinson, A. H. The Wood, Maybury, Surrey.
1863. ‡Dickinson, G. T. Lily-avenue, Jesmond, 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, M.A., F.G.S. 11 West Cliff-road, Birkdale, Southport.
1887. §Dickson, H. N., F.R.S.E. 2 St. Margaret's-road, Oxford.
1885. ‡Dickson, Patrick. Laurencekirk, Aberdeen.
1883. ‡Dickson, T. A. West Cliff, Preston.
1862. *Dilke, The Right Hon. Sir Charles Wentworth, Bart., M.P., F.R.G.S. 76 Sloane-street, London, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1884. ‡Dix, John William H. Bristol.
1874. *Dixon, A. E., M.D., Professor of Chemistry in Queen's College, Cork. Mentone Villa, Sunday's Well, Cork.
1883. ‡Dixon, Miss E. 2 Cliff-terrace, Kendal.
1888. §Dixon, Edward 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. Birch Hall, Rusholme, Manchester.
1885. ‡Dixon, John Henry. Inveran, Poolewe, Ross-shire, N.B.
1896. §Dixon-Nuttall, F. R. Ingleholme, Ecclestone Park, Prescot.
1887. ‡Dixon, Thomas. Buttershaw, near Bradford, Yorkshire.
1885. ‡Doak, Rev. A. 15 Queen's-road, Aberdeen.
1890. ‡Dobbie, James J., D.Sc. University College, Bangor, North Wales.
1885. §Dobbin, Leonard. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. 34 Westbourne-park, London, W.
1892. ‡Dobie, W. Fraser. 47 Grange-road, Edinburgh.
1891. ‡Dobson, G. Alkali and Ammonia Works, Cardiff.
1893. ‡Dobson, W. E., J.P. Lenton-road, The Park, Nottingham.
1894. ‡Dockar-Drysdale, Mrs. 39 Belsize-park, London, N.W.
1875. *Docwra, George, jun. 108 London-road, Gloucester.

Year of Election.

1870. *Dodd, John. Nunthorpe-avenue, York.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1889. ‡Dodson, George, B.A. Downing College, Cambridge.
1893. ‡Donald, Charles W. Kinsgarth, Braid-road, Edinburgh.
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, M.Inst.C.E. The Mount, Wray Park, Reigate.
1889. ‡Donkin, R. S., M.P. Campville, North Shields.
1896. §Donnan, F. E. Ardenmore-terrace, Holywood, Ireland.
1861. ‡Donnelly, Major-General Sir J. F. D., R.E., K.C.B. South Kensington Museum, London, S.W.
1881. ‡Dorrington, John Edward. Lypiatt Park, Stroud.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1863. *Doughty, Charles Montagu. Henwick, Newbury.
1877. *Douglass, Sir James N., F.R.S., M.Inst.C.E. Stella House, Dulwich, London, S.E.
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. ‡Dowe, John Melnotte. 69 Seventh-avenue, New York, U.S.A.
1876. ‡Dowie, Mrs. Muir. Golland, by Kinross, N.B.
1894. ‡Dowie, Robert Chambers. 13 Carter-street, Higher Broughton, Manchester.
1884. *Dowling, D. J. Bromley, Kent.
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, J. Emerson, M.Inst.C.E. 3 Great Queen-street, S.W.
1887. ‡Doxey, R. A. Slade House, Levenshulme, Manchester.
1894. §§Doyne, R. W., F.R.C.S. 28 Beaumont-street, Oxford.
1883. ‡Draper, William. De Grey House, St. Leonard's, York.
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1868. ‡Dresser, Henry E., F.Z.S. 110 Cannon-street, London, E.C.
1890. ‡Drew, John. 12 Harringay-park, Crouch End, Middlesex, N.
1892. ‡Dreyer, John L. E., M.A., Ph.D., F.R.A.S. The Observatory, Armagh.
1887. ‡*Dreyfus, Dr. Daisy Mount, Victoria Park, Manchester.*
1893. §Druce, G. Claridge, M.A., F.L.S. 118 High-street, Oxford.
1889. ‡Drummond, Dr. 6 Saville-place, Newcastle-upon-Tyne.
1892. ‡Du Bois, Dr. H. Mittelstrasse, 39, Berlin.
1889. ‡Du Chaillu, Paul B. Care of John Murray, Esq., 50A Albemarle-street, London, W.
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.
1895. *Duddell, William. Kensington Infirmary, Marloes-road, London, W.
1867. *Duff, The Right Hon. Sir Mountstuart Elphinstone Grant-, G.C.S.I., F.R.S., F.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.

Year of Election.

1890. ‡Dufton, S. F. Trinity College, Cambridge.
1884. ‡Dugdale, James H. 9 Hyde Park-gardens, London, W.
1883. §Duke, Frederic. Conservative Club, Hastings.
1892. ‡Dulier, Colonel E., C.B. 27 Sloane-gardens, London, S.W.
1866. *Duncan, James. 9 Mincing-lane, London, E.C.
1891. *Duncan, John, J.P. 'South Wales Daily News' Office, Cardiff.
1880. ‡Duncan, William S. 143 Queen's-road, Bayswater, London, W.
1896. §Duncanson, Thomas. 16 Deane-road, Birkenhead.
1881. ‡Duncombe, The Hon. Cecil, F.G.S. Nawton Grange, York.
1893. *Dunell, George Robert. 9 Grove Park-terrace, Chiswick, Middlesex.
1892. ‡Dunham, Miss Helen Bliss. Messrs. Morton, Rose, & Co., Bartholomew House, London, E.C.
1881. ‡Dunhill, Charles H. Gray's-court, York.
1896. §Dunkerley, S. 23 Kelvin-grove, Prince's-road, Liverpool.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1882. ‡Dunn, J. T., M.Sc., F.C.S. Northern Polytechnic Institute, Holloway-road, N.
1883. ‡Dunn, Mrs. Northern Polytechnic Institute, Holloway-road, N.
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 Station, Charlottesville, Virginia, U.S.A.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1893. *Dunstan, M. J. R. Newcastle-circus, Nottingham.
1891. ‡Dunstan, Mrs. Newcastle-circus, Nottingham.
1885. *DUNSTAN, WYNDHAM R., M.A., F.R.S., Sec.C.S., Director of the Scientific Department of the Imperial Institute, London, S.W.
1869. ‡D'Urban, W. S. M., F.L.S. Moorlands, Exmouth, Devon.
1895. *Dwerryhouse, Arthur R. 8 Livingston-avenue, Sefton Park, Liverpool.
1887. ‡Dyason, John Sanford, F.R.G.S. Boscobel-gardens, N.W.
1884. ‡Dyck, Professor Walter. The University, Munich.
1885. *Dyer, Henry, M.A., D.Sc. 8 Highburgh-terrace, Dowanhill, Glasgow.
1869. *Dymond, Edward E. Oaklands, Aspley Guise, Bletchley.
1895. §Dymond, Thomas S., F.C.S. County Technical Laboratory, Chelmsford.

1868. ‡Eade, Sir Peter, M.D. Upper St. Giles's-street, Norwich.
1895. §§Earle, Hardman H. 29 Queen Anne's-gate, Westminster, S.W.
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.
1871. *EASTON, EDWARD. 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.
1893. §Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, E.C.
1887. *Eccles, Mrs. S. White Coppice, Chorley, Lancashire.
1884. ‡Eckersley, W. T. Standish Hall, Wigan, Lancashire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1870. *Eddison, John Edwin, M.D., M.R.C.S. 6 Park-square, Leeds.
*Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1887. ‡Ede, Francis J., F.G.S. Silchar, Cachar, India.
1884. *Edgell, Rev. R. Arnold, M.A., F.C.S. The College House, Leamington.

Year of Election.

1887. §EDGEWORTH, F. Y., M.A., D.C.L., F.S.S., Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1870. *Edmonds, F. B. 6 Furnival's Inn, London, E.C.
1883. ‡Edmonds, William. Wiscombe Park, Colyton, Devon.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, London, S.W.
1884. *Edmunds, James, M.D. 29 Dover-street, Piccadilly, London, W.
1883. ‡Edmunds, Lewis, D.Sc., LL.B., F.G.S. 1 Garden-court, Temple, London, E.C.
1867. *Edward, Allan. Farington Hall, 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.
1896. §Ekkert, Miss Dorothea. 95 Upper Parliament-street, Liverpool.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1890. §Elford, Percy. St. John's College, Oxford.
1885. *ELGAR, FRANCIS, LL.D., F.R.S., F.R.S.E., M.Inst.C.E. 113 Cannon-street, London, E.C.
1868. ‡Elger, Thomas Gwyn Empy, F.R.A.S. Manor Cottage, Kempston, Bedford.
1885. ‡Ellingham, Frank. Thorpe St. Andrew, Norwich.
1883. ‡Ellington, Edward Bayzand, M.Inst.C.E. Palace-chambers, Bridge-street, Westminster, S.W.
1891. ‡Elliott, A. C., D.Sc., Professor of Engineering in University College, Cardiff. 2 Plasturton-avenue, Cardiff.
1864. ‡*Elliott, E. B. Washington, U.S.A.*
1883. *ELLIOTT, EDWIN BAILEY, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. 4 Bardwell-road, Oxford.
Elliott, John Fogg. Elvet Hill, Durham.
1879. ‡Elliott, Joseph W. Post Office, Bury, Lancashire.
1886. ‡Elliott, Thomas Henry, F.S.S. Board of Agriculture, 4 Whitehall-place, London, S.W.
1877. ‡Ellis, Arthur Devonshire. Thurnscoe Hall, Rotherham, Yorkshire.
1875. *Ellis, H. D. 6 Westbourne-terrace, Hyde Park, London, W.
1880. *ELLIS, JOHN HENRY. Woodland House, Plymouth.
1891. §Ellis, Miss M. A. 2 Southwick-place, London, W.
1884. ‡Ellis, W. Hodgson. Toronto, Canada.
1869. ‡ELLIS, WILLIAM HORTON. Hartwell House, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1887. ‡Elmy, Ben. Congleton, Cheshire.
1862. ‡Elphinstone, Sir H. W., Bart., M.A., F.L.S. 2 Stone-buildings, Lincoln's Inn, London, W.C.
1883. ‡Elwes, Captain 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.
1891. ‡Emerton, Wolseley. Banwell Castle, Somerset.
1891. ‡Emerton, Mrs. Wolseley. Banwell Castle, Somerset.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1858. ‡*Empson, Christopher. Bramhope Hall, Leeds.*
1890. ‡Emsley, Alderman W. Richmond House, Richmond-road, Headingley, Leeds.
1894. ‡Emtage, W. T. A. University College, Nottingham.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.

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Year of Election.

1884. ‡England, Luther M. Knowlton, Quebec, Canada.
1853. ‡English, E. Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1883. ‡Entwistle, James P. Beachfield, 2 Westclyffe-road, Southport.
1869. *Enys, John Davis. Enys, Penryn, Cornwall.
1894. §Erskine-Murray, James R. 40 Montgomerie-drive, Glasgow.
1864. *Eskrigge, R. A., F.G.S. 18 Hackins-hey, Liverpool.
1862. *Esson, Professor William, M.A., F.R.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. Vyrniew House, Talbot-road, Old Trafford, Manchester.
1887. *Estcourt, P. A., F.C.S., F.I.C. 20 Albert-square, Manchester.
1869. ‡Etheridge, R., F.R.S., F.R.S.E., F.G.S. 14 Carlyle-square, S.W.
1888. ‡Etheridge, Mrs. 14 Carlyle-square, S.W.
1883. §§Eunson, Henry J., F.G.S., Assoc.M.Inst.C.E. Vizianagram, Madras.
1891. ‡Evan-Thomas, C., J.P. The Gnoll, Neath, Glamorganshire.
1881. ‡Evans, Alfred, M.A., M.B. Pontypridd.
1889. *Evans, A. H. Care of R. H. Porter, 18 Prince's-street, W.
1887. *Evans, Mrs. Alfred W. A. Spring Bank, New Mills, near Stockport.
1870. *Evans, Arthur John, M.A., F.S.A. Youlbury, Abingdon.
1896. §Evans, Edward, jun. Spital Old Hall, Spital, Cheshire.
1865. *Evans, Rev. Charles, M.A. 41 Lancaster-gate, London, W.
1891. ‡Evans, Franklen. Llwynarthen, Castleton, Cardiff.
1889. ‡Evans, Henry Jones. Greenhill, Whitchurch, Cardiff.
1884. ‡Evans, Horace L. 6 Albert-buildings, Weston-super-Mare.
1883. *Evans, James C. Morannedd, Eastbourne-road West, Birkdale Park, Southport.
1883. *Evans, Mrs. James C. Morannedd, Eastbourne-road West, Birkdale Park, Southport.
1861. *Evans, Sir John, K.C.B., D.C.L., LL.D., D.Sc., Treas.R.S., F.S.A., F.L.S., F.G.S. (President Elect). Nash Mills, Hemel Hempstead.
1881. ‡Evans, Lewis. Llanfyrnach R.S.O., Pembrokeshire.
1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.
1865. *Evans, William. The Spring, Kenilworth.
1891. ‡Evans, William Llewellin. Guildhall-chambers, Cardiff.
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., F.R.S.E., Professor of Natural Philosophy in Queen's College, Belfast. Derryvolgie, Belfast.
1895. §§Everett, W. H., B.A. Derryvolgie, 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., F.R.S., Professor of Natural History in the University of Edinburgh.
1874. ‡Ewart, Sir W. Quartus, Bart. Glenmachan, Belfast.
1876. *Ewing, James Alfred, M.A., B.Sc., F.R.S., F.R.S.E., M.Inst.C.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, F.Z.S. Oakhurst, Easton, Pennsylvania, U.S.A.
1882. ‡Eyre, G. E. Briscoe. Warrens, near Lyndhurst, Hants.
Eyton, Charles. Hendred House, Abingdon.

Year of Election.

1890. ‡FABER, EDMUND BECKETT. Straylea, Harrogate.
1896. §Fairbrother, Thomas. Lethbridge-road, Southport.
1865. *FAIRLEY, THOMAS, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1886. ‡Fairley, William. Beau Desert, Rugeley, Staffordshire.
1896. §Falk, Herman John, M.A. Thorshill, West Kirby, Liverpool.
1883. ‡Fallon, Rev. W. S. 9 St. James's-square, Cheltenham.
1877. §FARADAY, F. J., F.L.S., F.S.S. College-chambers, 17 Brazenose-street, Manchester.
1891. ‡Fards, G. Penarth.
1892. *FARMER, J. BRETLAND, M.A., F.L.S., Professor of Botany, Royal College of Science, S.W., 4 Lichfield-road, Kew.
1886. ‡Farncombe, Joseph, J.P. Lewes.
1879. *Farnworth, Ernest. Rosslyn, Goldthorn Hill, Wolverhampton.
1883. ‡Farnworth, Walter. 86 Preston New-road, Blackburn.
1883. ‡Farnworth, William. 86 Preston New-road, Blackburn.
1885. ‡Farquhar, Admiral. Carlogie, Aberdeen.
1886. ‡Farquharson, Colonel J., R.E. Ordnance Survey Office, Southampton.
1859. ‡Farquharson, Robert F. O. Haughton, Aberdeen.
1885. ‡Farquharson, Mrs. R. F. O. Haughton, Aberdeen.
1866. *FARRAR, The Very Rev. FREDERIC WILLIAM, D.D., F.R.S. The Deanery, Canterbury.
1883. ‡Farrell, John Arthur. Moynalty, Kells, North Ireland.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869. *Faulding, Joseph. Boxley House, Tenterden, Kent.
1883. ‡Faulding, Mrs. Boxley House, Tenterden, Kent.
1887. §Faulkner, John. 13 Great Ducie-street, Strangeways, Manchester.
1890. *Fawcett, F. B. University College, Bristol.
1886. §§Felkin, Robert W., M.D., F.R.G.S. 8 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. Keswick, near Belfast.
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.
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.
1896. *Ferguson, John. Colombo, Ceylon.
1867. ‡Ferguson, Robert M., LL.D., Ph.D., F.R.S.E. 5 Learmouth-terrace, Edinburgh.
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, London. 34 Cavendish-square, London, W.
1892. ‡Ferrier, Robert M., B.Sc. College of Science, Newcastle-upon-Tyne.
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.
1882. ‡Filliter, Freeland. St. Martin's House, Wareham, Dorset.

Year of Election.

1883. *Finch, Gerard B., M.A. 1 St. Peter's-terrace, Cambridge.
Finch, John. Bridge Work, Chepstow.
1878. *Findlater, William. 22 Fitzwilliam-square, Dublin.
1892. ‡Findlay, J. R., B.A. 3 Rothesay-terrace, Edinburgh.
1884. ‡Finlay, Samuel. Montreal, Canada.
1887. ‡Finnemore, Rev. J., M.A., Ph.D., F.G.S. 12 College-road, Brighton.
1881. ‡Firth, Colonel Sir Charles. Heckmondwike.
Firth, Thomas. Northwich.
1895. §§Fish, Frederick J. Park-road, Ipswich.
1891. ‡Fisher, Major H. O. The Highlands, Llandough, near Cardiff.
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.
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. 25 Blenheim-gardens, Willesden Green, London, N.W.
1885. ‡Fison, E. Herbert. Stoke House, Ipswich.
1871. *FISON, FREDERICK W., M.A., M.P., F.C.S. Greenholme, Burley-in-Wharfedale, near Leeds.
1871. ‡FITCH, Sir J. G., M.A., LL.D. Athenæum Club, London, S.W.
1883. ‡Fitch, Rev. J. J. Ivyholme, Southport.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1878. §FITZGERALD, GEORGE FRANCIS, M.A., D.Sc., F.R.S., Professor of Natural and Experimental Philosophy in Trinity College, Dublin.
1885. *FitzGerald, Professor Maurice, B.A. 32 Eglantine-avenue, Belfast.
1894. §Fitzmaurice, M., M.Inst.C.E. Blackwall Tunnel Office, East Greenwich, London, S.E.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Bagot-street, Dublin.
1888. *FITZPATRICK, Rev. THOMAS C. Christ's College, Cambridge.
1865. ‡*Fleetwood, D. J. 45 George-street, St. Paul's, Birmingham.*
1881. ‡Fleming, Rev. Canon J., B.D. St. Michael's Vicarage, Ebury-square, London, S.W.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, near Glasgow.
1876. ‡Fleming, Sandford, C.M.G., F.G.S. Ottawa, Canada.
1867. §FLETCHER, ALFRED E., F.C.S. Delmore, Caterham, Surrey.
1870. ‡Fletcher, B. Edgington. Norwich.
1890. ‡Fletcher, B. Morley. 7 Victoria-street, London, S.W.
1892. ‡Fletcher, George, F.G.S. 60 Connaught-avenue, Plymouth.
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. 36 Woodville-road, Ealing, London, W.
1862. §FLOWER, Sir WILLIAM HENRY, K.C.B., LL.D., D.C.L., D.Sc., 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, Lady. 26 Stanhope-gardens, London, S.W.
1877. *Floyer, Ernest A., F.R.G.S., F.L.S. Downton, Salisbury.
1890. *Flux, A. W., M.A. Owens College, Manchester.
1887. ‡Foale, William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1883. ‡Foale, Mrs. William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1891. §Foldvary, William. Museum Ring, 10, Buda Pesth.
1879. ‡Foote, Charles Newth, M.D. 3 Albion-place, Sunderland.
1880. ‡Foote, R. Bruce, F.G.S. Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.

Year of Election.

1873. *Forbes, George, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 34 Great George-street, London, S.W.
1883. ‡Forbes, Henry O., LL.D., F.Z.S., Director of Museums for the Corporation of Liverpool. The Museum, Liverpool.
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. Odsey, Ashwell, Baldock, Herts.
1883. §Formby, R. Kirklake Bank, Formby, near Liverpool.
1894. §Forrest, Frederick. Castledown, Castle Hill, Hastings.
1887. ‡Forrest, Sir John, K.C.M.G., F.R.G.S., F.G.S. Perth, Western Australia.
1867. ‡Forster, Anthony. Finlay House, St. Leonards-on-Sea.
1883. ‡Forsyth, A. R., M.A., D.Sc., F.R.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. Trinity College, Cambridge.
1884. ‡Fort, George H. Lakefield, Ontario, Canada.
1877. ‡Fortescue, The Right Hon. the Earl. Castle Hill, North Devon.
1882. ‡Forward, Henry. 10 Marine-avenue, Southend.
1896. §Forwood, Sir William B., J.P. Ramleh, Blundellsands, Liverpool.
1875. ‡Foster, A. Le Neve. 51 Cadogan-square, London, S.W.
1865. ‡Foster, Sir B. Walter, M.D., M.P. 16 Temple-row, Birmingham.
1865. *Foster, Clement Le Neve, B.A., D.Sc., F.R.S., F.G.S., Professor of Mining in the Royal College of Science, London. Llandudno.
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.
1896. §Foster, Miss Harriet, Cambridge Training College, Wollaston-road, Cambridge.
1877. §Foster, Joseph B. 4 Cambridge-street, Plymouth.
1859. *Foster, Michael, M.A., M.D., LL.D., D.C.L., Sec.R.S., F.L.S., F.C.S., Professor of Physiology in the University of Cambridge. Great Shelford, Cambridge.
1863. ‡Foster, Robert. The Quarries, Grainger Park-road, Newcastle-upon-Tyne.
1896. §Fowkes, F. Hawkshead, Ambleside.
1866. ‡Fowler, George, M.Inst.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1888. §Fowler, Gilbert J. Dalton Hall, Manchester.
1892. §§Fowler, Miss Jessie A. 4 & 5 Imperial-buildings, Ludgate-circus, London, E.C.
1876. **Fowler, John.* 16 *Kerrsland-street, Hillhead, Glasgow.*
1882. ‡Fowler, Sir John, Bart., K.C.M.G., M.Inst.C.E., F.G.S. 2 Queen Square-place, Westminster, S.W.
1884. ‡Fox, Miss A. M. Penjerrick, Falmouth.
1883. *Fox, Charles. 104 Ritherdon-road, Upper Tooting, London, S.W.
1883. §Fox, Sir Charles Douglas, M.Inst.C.E. 28 Victoria-street, Westminster, S.W.
1896. §Fox, Henry J. Bank's Dale, Bromborough, near Liverpool.
1883. ‡Fox, Howard, F.G.S. Falmouth.
1847. *Fox, Joseph Hoyland. The Clive, Wellington, Somerset.
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.

Year of Election.

FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, E.C.; and Manor House, Richmond, Surrey.
1845. ‡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., F.R.S., Professor of Chemistry and Metallurgy in the Mason College, Birmingham.
1894. §Franklin, Mrs. E. L. 9 Pembridge-gardens, London, W.
1895. §Fraser, Alexander. 63 Church-street, Inverness.
1882. ‡Fraser, Alexander, M.B. Royal College of Surgeons, Dublin.
1885. ‡FRASER, ANGUS, M.A., M.D., F.C.S. 232 Union-street, Aberdeen.
1865. *FRASER, JOHN, M.A., M.D., F.G.S. Chapel Ash, Wolverhampton.
1871. ‡FRASER, THOMAS R., M.D., F.R.S., F.R.S.E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1859. *Frazer, Daniel. Rowmore House, Garelochhead, N.B.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1884. *Frazer, Persifor, M.A., D.Sc. (Univ. de France). Room 1042, Drexel Building, Philadelphia, U.S.A.
1884. *FREAM, W., LL.D., B.Sc., F.L.S., F.G.S., F.S.S. The Vinery, Downton, Salisbury.
1877. §Freeman, Francis Ford. Abbotsfield, Tavistock, South Devon.
1884. *FREMANTLE, The Hon. Sir C. W., K.C.B. 10 Sloane-gardens, London, S.W.
1869. ‡Frere, Rev. William Edward. The Rectory, Bitton, near Bristol.
1886. ‡Freshfield, Douglas W., F.R.G.S. 1 Airlie-gardens, Campden Hill, London, W.
1887. ‡Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1887. ‡Froehlich, The Chevalier. Grosvenor-terrace, Withington, Manchester.
1892. *Frost, Edmund. The Elms, Lasswade, Midlothian.
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. 53 Victoria-road, London, W.
1875. ‡Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
1875. *Fry, Joseph Storrs. 13 Upper Belgrave-road, Clifton, Bristol.
1884. §Fryer, Joseph, J.P. Smelt House, Howden-le-Wear, Co. Durham.
1895. §§Fullarton, Dr. J. H. Fishery Board for Scotland, George-street, Edinburgh.
1872. *Fuller, Rev. A. 7 Sydenham-hill, Sydenham, London, S.E.
1859. ‡FULLER, FREDERICK, M.A. 9 Palace-road, Surbiton.
1869. ‡FULLER, G., M.Inst.C.E. 71 Lexham-gardens, Kensington, W.
1884. §Fuller, William, M.B. Oswestry.
1891. ‡Fulton, Andrew. 23 Park-place, Cardiff.

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. Skendleby Hall, Spilsby.
1896. §Gair, H. W. 21 Water-street, Liverpool.
1876. ‡Gairdner, Charles. Broom, Newton Mearns, Renfrewshire.
1850. ‡GAIRDNER, W. T., M.D., LL.D., F.R.S., Professor of Medicine in the University of Glasgow. The University, 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.

Year of Election.

1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1889. ‡Galloway, Walter. Eighton Banks, Gateshead.
1875. ‡GALLOWAY, W. Cardiff.
1887. *Galloway, W. J., M.P. 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. 12 Chester-street, Grosvenor-place, London, S.W.
1860. *GALTON, FRANCIS, M.A., D.C.L., D.Sc., 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. New University Club, St. James's-street, London, S.W.
1870. §Gamble, Lieut.-Colonel D., C.B. St. Helens, Lancashire.
1889. §Gamble, David, jun. Ratonagh, Colwyn Bay.
1870. ‡Gamble, J. C. St. Helens, Lancashire.
1888. *Gamble, J. Sykes, M.A., F.L.S. Dehra Dún, North-West Provinces, India.
1877. ‡Gamble, William. St. Helens, Lancashire.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S. 8 Avenue de la Gare, Lausanne, Switzerland.
1889. ‡Gamgee, John. 6 Lingfield-road, Wimbledon, Surrey.
1887. ‡GARDINER, WALTER, M.A., F.R.S., F.L.S. 45 Hills-road, Cambridge.
1882. *Gardner, H. Dent, F.R.G.S. Fairmead, 46 The Goffs, Eastbourne.
1894. ‡Gardner, J. Addyman. 5 Bath-place, Oxford.
1896. §Gardner, James. The Grove, Grassendale, Liverpool.
1882. ‡GARDNER, JOHN STARKIE, F.G.S. 29 Albert Embankment, S.E.
1884. ‡Garman, Samuel. Cambridge, Massachusetts, U.S.A.
1887. *Garnett, Jeremiah. The Grange, near Bolton, Lancashire.
1882. ‡Garnett, William, D.C.L. London County Council, Spring-gardens, London, S.W.
1873. ‡Garnham, John. Hazelwood, Crescent-road, St. John's, Brockley, Kent, S.E.
1883. §GARSON, J. G., M.D. 64 Harley-street, London, W.
1894. §Garstang, Walter, M.A., F.Z.S. Lincoln College, Oxford.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1882. ‡Garton, William. Woolston, Southampton.
1892. §Garvie, James. Devanha House, Bowes-road, New Southgate, N.
1889. ‡Garwood, E. J., B.A., F.G.S. Trinity College, Cambridge.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Clayton Lodge, Aigburth, Liverpool.
1896. §GASKELL, WALTER HOLBROOK, M.A., M.D., LL.D., F.R.S. The Uplands, Great Shelford, near Cambridge.
1896. §Gatehouse, Charles. Westwood, Noctorum, Birkenhead.
1862. *Gatty, Charles Henry, M.A., LL.D., F.R.S.E., F.L.S., F.G.S. Felbridge Place, East Grinstead, Sussex.
1890. ‡Gaunt, Sir Edwin. Carlton Lodge, Leeds.
1875. ‡Gavey, J. Hollydale, Hampton Wick, Middlesex.
1892. ‡Geddes, George H. 8 Douglas-crescent, Edinburgh.
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1883. ‡Geddes, John. 33 Portland-street, Southport.
1885. ‡Geddes, Professor Patrick. Ramsay-garden, Edinburgh.
1887. ‡Gee, W. W. Haldane. Owens College, Manchester.
1867. ‡GEIKIE, Sir ARCHIBALD, LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom. 10 Chester-terrace, Regent's-park, London, N.W.

Year of Election.

1871. ‡GEIKIE, JAMES, LL.D., D.C.L., F.R.S., F.R.S.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. 20 St. John-street, Oxford.

1884. ‡Gibb, Charles. Abbotsford, Quebec, Canada.

1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.

1874. ‡Gibson, The Right Hon. Edward, Q.C. 23 Fitzwilliam-square, Dublin.

1892. §Gibson, Francis Maitland. Care of Professor Gibson, 20 George-square, Edinburgh.

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.

1896. §Gibson, Harvey, M.A., Professor of Botany, University College, Liverpool.

1884. ‡Gibson, Rev. James J. 183 Spadina-avenue, Toronto, Canada.

1889. *Gibson, T. G. Lesbury House, Lesbury, R.S.O., Northumberland.

1893. ‡Gibson, Walcot, F.G.S. 28 Jermyn-street, London, S.W.

1887. ‡GIFFEN, Sir ROBERT, K.C.B., LL.D., F.R.S., V.P.S.S. Board of Trade, London, S.W.

1888. *Gifford, H. J. Lyston Court, Tram Inn, Hereford.

1884. ‡Gilbert, E. E. 245 St. Antoine-street, Montreal, Canada.

1842. GILBERT, SIR JOSEPH HENRY, Ph.D., LL.D., F.R.S., F.C.S. Harpenden, near St. Albans.

1883. §§Gilbert, Lady. Harpenden, near St. Albans.

1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.

1884. *Gilbert, Philip H. 63 Tupper-street, Montreal, Canada.

1895. §§Gilchrist, J. D. F. Carvenon, Anstruther, Scotland.

1896. *Gilchrist, Percy C. Frognal Bank, Finchley-road, Hampstead, N.W.

Gilderdale, Rev. John, M.A. Walthamstow, Essex.

1878. ‡Giles, Oliver. Crescent Villas, Bromsgrove.

Giles, Rev. William. Netherleigh House, near Chester.

1871. *GILL, DAVID, C.B., LL.D., F.R.S., F.R.A.S. Royal Observatory, Cape Town.

1888. §Gill, John Frederick. Douglas, Isle of Man.

1888. ‡*Gilliland, E. T. 259 West Seventy-fourth-street, New York, U.S.A.*

1884. ‡Gillman, Henry. 130 Lafayette-avenue, Detroit, Michigan, U.S.A.

1896. §Gilmour, H. B. Underlea, Aigburth, Liverpool.

1892. *Gilmour, Matthew A. B. Saffronhall House, Windmill-road, Hamilton, N.B.

1867. ‡Gilroy, Robert. Craigie, by Dundee.

1893. *Gimingham, Edward. Stamford House, Northumberland Park, Tottenham, London.

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.

1886. *Gisborne, Hartley. Qu'Appelle Station P.O., 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.

Year of Election.

1849. *GLADSTONE, JOHN HALL, Ph.D., D.Sc., 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. The Shola, Heathfield-road, South Croydon.
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. 7 Harvey-road, Cambridge.
1881. *Gleadow, Frederic. 38 Ladbroke-grove, London, W.
1859. ‡Glennie, J. S. Stuart, M.A. Verandah Cottage, Haslemere, Surrey.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
1874. ‡Glover, George T. 30 Donegall-place, Belfast.
Glover, Thomas. 124 Manchester-road, Southport.
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. The Lea, Harborne, Birmingham.
1887. ‡Godlee, Francis. 8 Minshall-street, Manchester.
1878. *Godlee, J. Lister. Whip's Cross, Walthamstow.
1880. ‡GODMAN, F. DU CANE, F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, London, W.
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.
1881. ‡GOLDSCHMIDT, EDWARD, J.P. Nottingham.
1886. ‡GOLDSMID, Major-General Sir F. J., C.B., K.C.S.I., F.R.G.S. Godfrey House, Hollingbourne.
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.
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.
1884. *Goodridge, Richard E. W. 1030 The Rookery Building, Chicago, Illinois, U.S.A.
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.
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. 8 St. Mary-street, St. Andrews, N.B.
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. 67 Broad-street, Birmingham.
1896. §Gossage, F. H. Camphill, Woolton, Liverpool.

Year of Election.

1875. *GOTCH, FRANCIS, M.A., B.Sc., F.R.S., Professor of Physiology in the University of Oxford.
1873. ‡Gott, Charles, M.Inst.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1881. ‡Gough, Thomas, B.Sc., F.C.S. Elmfield College, York.
1894. ‡Gould, G. M. 119 South 17th-street, Philadelphia, U.S.A.
1888. ‡Gouraud, Colonel. Little Menlo, Norwood, Surrey.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. ‡Gow, Robert. Cairndowan, Dowanhill, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill, Glasgow.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1886. ‡Grabham, Michael C., M.D. Madeira.
1875. ‡GRAHAME, JAMES. 12 St. Vincent-street, Glasgow.
1892. §Grange, C. Ernest. 57 Berners-street, Ipswich.
1893. ‡Granger, F. S., M.A., D.Litt. 2 Cranmer-street, Nottingham.
1896. §Grant, Sir James, K.C.M.G. Canada.
1892. ‡Grant, W. B. 10 Ann-street, Edinburgh.
1864. ‡Grantham, Richard F., F.G.S. Northumberland-chambers, Northumberland-avenue, London, W.C.
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1890. ‡GRAY, Professor ANDREW, M.A., LL.D., F.R.S., F.R.S.E. University College, Bangor.
1864. *Gray, Rev. Canon 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.
1893. ‡Gray, J. C., General Secretary of the Co-operative Union, Limited, Long Millgate, Manchester.
1870. ‡Gray, J. Macfarlane. 4 Ladbroke-crescent, W.
1892. *Gray, James H., M.A., B.Sc. The University, Glasgow.
1892. §Gray, John, B.Sc. 351 Clarewood-terrace, Brixton, London, S.W.
1887. ‡Gray, Joseph W., F.G.S. Cleveland Villa, Shurdington Road, Cheltenham.
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.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1893. *Greaves, Mrs. Elizabeth. Station-street, Nottingham.
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 33 Marlborough-place, London, N.W.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1888. §GREEN, JOSEPH R., M.A., B.Sc., F.R.S., 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. Highfield, Silverdale, Carnforth.

Year of Election.

1882. ‡GREENHILL, A. G., M.A., F.R.S., Professor of Mathematics in the Royal Artillery College, Woolwich. 10 New Inn, 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.
1884. ‡Greenshields, Samuel. Montreal, Canada.
1887. ‡Greenwell, G. C., jun. Driffield, near Derby.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1890. ‡Greenwood, Arthur. Cavendish-road, Leeds.
1875. ‡Greenwood, F., M.B. Brampton, Chesterfield.
1877. ‡Greenwood, Holmes. 78 King-street, Accrington.
1887. ‡Greenwood, W. H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
1887. *Greg, Arthur. Eagley, near Bolton, Lancashire.
1861. *GREG, ROBERT PHILIPS, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1860. ‡GREGOR, Rev. WALTER, M.A. Lauder Villa, Bonnyrigg, Midlothian.
1868. ‡Gregory, Sir Charles Hutton, K.C.M.G., M.Inst.C.E. 2 Delahay-street, Westminster, S.W.
1894. ‡Gregory, J. Walter, D.Sc., F.G.S. British Museum, Cromwell-road, London, S.W.
1896. §Gregory, R. A. 11 Southey-road, Wimbledon, Surrey.
1883. ‡Gregson, G. E. Ribble View, Preston.
1881. ‡Gregson, William, F.G.S. Baldersby, S.O., Yorkshire.
1859. ‡GRIERSON, THOMAS BOYLE, M.D. Thornhill, Dumfriesshire.
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.
1836. Griffin, S. F. Albion Tin Works, York-road, London, N.
1894. *Griffith, C. L. T. College-road, Harrow, Middlesex.
1894. *Griffith, Miss F. H. College-road, Harrow, Middlesex.
1859. *GRIFFITH, G., M.A. (ASSISTANT GENERAL SECRETARY.) College-road, Harrow.
1870. ‡*Griffith, Rev. Henry. Brooklands, Isleworth, Middlesex.*
1884. ‡GRIFFITHS, E. H., M.A., F.R.S. 12 Park-side, Cambridge.
1884. ‡Griffiths, Mrs. 12 Park-side, Cambridge.
1891. ‡Griffiths, P. Rhys, B.Sc., M.B. 71 Newport-road, Cardiff.
1847. ‡Griffiths, Thomas. The Elms, Harborne-road, Edgbaston, Birmingham.
1870. ‡Grimsdale, T. F., M.D. Hoylake, Liverpool.
1888. *Grimshaw, James Walter. Australian Club, Sydney, New South Wales.
1884. ‡Grinnell, Frederick. Providence, Rhode Island, U.S.A.
1881. ‡Gripper, Edward. Mansfield-road, Nottingham.
1894. ‡Groom, P., M.A., F.L.S. 38 Regent-street, Oxford.
1894. ‡Groom, T. T. The Poplars, Hereford.
1896. §Grossmann, Dr. Karl. 70 Rodney-street, Liverpool.
1892. ‡Grove, Mrs. Lilly, F.R.G.S. Mason College, Birmingham.
1891. ‡Grover, Henry Llewellin. Clydach Court, Pontypridd.
1863. *GROVES, THOMAS B., F.C.S. Belmont, Seldown, Poole, Dorset.
1869. ‡GRUBB, Sir HOWARD, F.R.S., F.R.A.S. 51 Kenilworth-square, Rathgar, Dublin.
1886. ‡Grundy, John. 17 Private-road, Mapperley, Nottingham.
1891. ‡Grylls, W. London and Provincial Bank, Cardiff.
1887. ‡GUILLEMARD, F. H. H. Eltham, Kent.
Guinness, Henry. 17 College-green, Dublin.

Year of Election.

1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1891. ‡Gunn, John. Llandaff House, Llandaff.
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., Pres.L.S., F.Z.S. 23 Lichfield-road, Kew, Surrey.
1894. ‡Günther, R. T. Magdalen College, Oxford.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1896. *Gustav, Jarmay. Hartford Lodge, Hartford, Cheshire.
1876. ‡Guthrie, Francis. Cape Town, Cape of Good Hope.
1883. ‡Guthrie, Malcolm. Prince's-road, Liverpool.
1896. §Guthrie, Tom, B.Sc. Yorkshire College, Leeds.
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.
1884. ‡Hadden, Captain C. F., R.A. Woolwich.
1881. *HADDON, ALFRED CORT, M.A., F.Z.S. Inisfail, Hills-road, Cambridge.
1842. Hadfield, George. Victoria-park, Manchester.
1888. *Hadfield, R. A. The Grove, Endcliffe Vale-road, Sheffield.
1892. ‡Haigh, E., M.A. Longton, Staffordshire.
1870. ‡Haigh, George. 27 Highfield South, Rock Ferry, Cheshire.
1879. ‡HAKE, H. WILSON, Ph.D., F.C.S. Queenwood College, Hants.
1887. ‡*Hale, The Hon. E. J. 9 Mount-street, Manchester.*
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1883. **Hall, Miss Emily. Burlington House, Spring Grove, Isleworth.*
1881. ‡Hall, Frederick Thomas, F.R.A.S. 15 Gray's Inn-square, London, W.C.
1854. *HALL, HUGH FERGIE, F.G.S. Staverton House, Woodstock-road, Oxford.
1887. ‡Hall, John. Springbank, Leftwich, Northwich.
1885. §Hall, Samuel. 19 Aberdeen Park, Highbury, London, N.
1896. §Hall, Thomas B. Larchwood, Rockferry, Cheshire.
1884. ‡Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1866. *HALL, TOWNSHEND M., F.G.S. Orchard House, Pilton, Barnstaple.
1896. §Hall-Dare, Mrs. Caroline. 13 Great Cumberland-place, London, W.
1891. *Hallett, George. Cranford, Victoria-road, Penarth, Glamorganshire.
1891. §Hallett, J. H., M.Inst.C.E. Maindy Lodge, Cardiff.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1888. §HALLIBURTON, W. D., M.D., F.R.S., Professor of Physiology in King's College, London. 9 Ridgmount-gardens, Gower-street, London, W.C.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
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.
1881. *Hammond, Robert. Ormond House, Great Trinity-lane, London, E.C.
1892. ‡Hanbury, Thomas, F.L.S. La Mortola, Ventimiglia, Italy.
1878. ‡Hance, Edward M., LL.B. Municipal Buildings, 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.
1890. ‡Hankin, Ernest Hanbury. St. John's College, Cambridge.

Year of Election.

1882. ‡Hankinson, R. C. Bassett, Southampton.
1884.§§Hannaford, E. P. 2573 St. Catherine-street, Montreal, Canada.
1894. §Hannah, Robert, F.G.S. 82 Addison-road, London, W.
1886. §Hansford, Charles. 3 Alexandra-terrace, Dorchester.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., F.R.S., Pres.C.S. (GENERAL SECRETARY.) Cowley Grange, Oxford.
1890. *HARCOURT, L. F. VERNON, M.A., M.Inst.C.E. 6 Queen Anne's-gate, London, S.W.
1886. *Hardcastle, Basil W., F.S.S. 12 Gainsborough-gardens, Hampstead, London, N.W.
1892. *Harden, Arthur, Ph.D., M.Sc. Ashville, Upper Chorlton-road, Manchester.
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.
1894. ‡Hardman, S. C. 225 Lord-street, Southport.
1894. ‡Hare, A. T., M.A. Neston Lodge, East Twickenham, Middlesex.
1894. ‡Hare, Mrs. Neston Lodge, East Twickenham, Middlesex.
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, M.A., F.G.S. St. John's College, Cambridge.
1896. §Harker, Dr. John Allen. Springfield House, Stockport.
1887. ‡Harker, T. H. Brook House, Fallowfield, Manchester.
1878. *Harkness, H. W., M.D. California Academy of Sciences, San Francisco, California, U.S.A.
1871. ‡Harkness, William, F.C.S. Laboratory, Somerset House, London.
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. Rosslyn, Westbourne-road, Forest-hill, London, S.E.
1883. *Harley, Harold. 14 Chapel-street, Bedford-row, London, W.C.
1862. *HARLEY, Rev. ROBERT, M.A., F.R.S., F.R.A.S. Rosslyn, Westbourne-road, Forest-hill, London, S.E.
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., F.G.S., 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.
1842. *Harris, G. W., M.Inst.C.E. Moray-place, Dunedin, New Zealand.
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.
1860. ‡Harrison, Rev. Francis, M.A. North Wraxall, Chippenham.

Year of
Election.

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.
1892. ‡HARRISON, JOHN. Rockville, Napier-road, Edinburgh.
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.
1892. ‡Harrison, Rev. S. N. Ramsay, Isle of Man.
1895. §Harrison, Thomas. 48 High-street, Ipswich.
1886. ‡Harrison, W. Jerome, F.G.S. Board School, Icknield-street, Birmingham.
1876. *Hart, Thomas. Brooklands, Blackburn.
1875. ‡Hart, W. E. Kilderry, near Londonderry.
1893. *HARTLAND, E. SIDNEY, F.S.A. Highgarth, Gloucester.
Hartley, James. Sunderland.
1871. ‡HARTLEY, WALTER NOEL, F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the Royal College of Science, Dublin. 36 Waterloo-road, Dublin.
1896. §Hartley, W. P., J.P. Aintree, Liverpool.
1890. **Hartnell, Wilson.* 8 *Blenheim-terrace, Leeds.*
1886. *HARTOG, Professor M. M., D.Sc. Queen's College, Cork.
1887. §§Hartog, P. J., B.Sc. Owens College, Manchester.
1885. §§Harvie-Brown, J. A. Dunipace, Larbert, N.B.
1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
1884. ‡Haslam, Rev. George, M.A. Trinity College, Toronto, Canada.
1882. ‡Haslam, George James, M.D. Owens College, Manchester.
1893. §Haslam, Lewis. Ravenswood, near Bolton, Lancashire.
1875. *HASTINGS, G. W. 23 Kensington-square, London, W.
1889. ‡Hatch, F. H., Ph.D., F.G.S. 28 Jermyn-street, London, S.W.
1893. ‡Hatton, John L. S. People's Palace, Mile End-road, London, E.
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.
1896. §Hause, Edward M. 42 Bedford-street, Liverpool.
1887. *Hawkins, William. Earlston House, Broughton Park, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, S.W.
1864. *HAWKSHAW, JOHN CLARKE, M.A., M.Inst.C.E., F.G.S. 2 Down-street, W., and 33 Great George-street, London, S.W.
1884. *Haworth, Abraham. Hilston House, Altrincham.
1889. ‡Haworth, George C. Ordsal, Salford.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1887. ‡Haworth, S. E. Warsley-road, Swinton, Manchester.
1886. ‡Haworth, Rev. T. J. Albert Cottage, Saltley, Birmingham.
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.
1885. *Haycraft, John Berry, M.D., B.Sc., F.R.S.E., Professor of Physiology, University College, Cardiff.
1891. ‡Hayde, Rev. J. St. Peter's, Cardiff.
1894. ‡Hayes, Edward Harold. 5 Rawlinson-road, Oxford.
1896. §Hayes, F. C. The Rectory, Raheny, Dublin.
1896. §Hayes, William. Fernyhurst, Rathgar, Dublin.
1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1858. *HAYWARD, R. B., M.A., F.R.S. Ashcombe, Shanklin, Isle of Wight.
1896. *Haywood, A. G. Rearsby, Merrilocks-road, Blundellsands.

Year of Election.

1879. *Hazelhurst, George S. The Grange, Rock Ferry.
1851. §HEAD, JEREMIAH, M.Inst.C.E., F.C.S. 47 Victoria-street, Westminster, S.W.
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. Heyroun, Chaucer-road, Cambridge.
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.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1884. ‡Heath, Thomas, B.A. Royal Observatory, Edinburgh.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1865. ‡Heaton, Harry. Harborne House, Harborne, Birmingham.
1892. *HEATON, WILLIAM H., M.A., Professor of Physics in University College, Nottingham.
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. 7 Grosvenor-street, Coventry.
1833. ‡HEAVISIDE, Rev. Canon J. W. L., M.A. The Close, Norwich.
1888. *Heawood, Edward, M.A. 3 Underhill-road, Lordship-lane, London, S.E.
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., 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.
1887. *HEDGES, KILLINGWORTH, M.Inst.C.E. Wootton Lodge, 39 Streatham hill, London, S.W.
1881. *HELE-SHAW, H. S., M.Inst.C.E., Professor of Engineering in University College, Liverpool. 20 Waverley-road, Liverpool.
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.
1891. *HENDERSON, G. G., D.Sc., M.A., F.C.S., F.I.C., Professor of Chemistry in the Glasgow and West of Scotland Technical College. 204 George-street, Glasgow.
1892. ‡Henderson, John. 3 St. Catherine-place, Grange, Edinburgh.
1880. *Henderson, Captain W. H., R.N. 21 Albert Hall-mansions, London, S.W.
1896. §Henderson, W. Saville, B.Sc. Beech Hill, Fairfield, Liverpool.
1885. ‡Henderson, Sir William. Devanha House, Aberdeen.
1892. §Henigan, Richard. Alma-road, The Avenue, Southampton.
1856. ‡HENNESSY, HENRY G., F.R.S., M.R.I.A. Clarens, Montreux, Switzerland.
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. 34 Clarendon-road, Notting Hill, W.

Year of Election.

Henry, Franklin. Portland-street, Manchester.
Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
Henry, Mitchell. Stratheden House, Hyde Park, London, W.
1884. ‡*Henshaw, George H. 43 Victoria-street, Montreal, Canada.*
1892. ‡Hepburn, David, M.D., F.R.S.E. The University, Edinburgh.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Oakfield Cottage, 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.
1892. *Herbertson, Andrew J. University Hall, Edinburgh.
1887. *Herdman, William A., D.Sc., F.R.S., F.R.S.E., F.L.S., Professor of Natural History in University College, Liverpool.
1893. *Herdman, Mrs. 32 Bentley-road, Liverpool.
1891. ‡Hern, S. South Cliff, Marine Parade, Penarth.
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. Observatory House, Slough, Bucks.
1874. §Herschel, Colonel John, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.
1895. §Hesketh, James. Scarisbrick Avenue-buildings, 107 Lord-street, Southport.
1894. §§Hewetson, G. H. 39 Henley-road, Ipswich.
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.*
1894. ‡Hewins, W. A. S., M.A., F.S.S. 26 Cheyne-row, Chelsea, London, S.W.
1896. §Hewitt, David Basil. Oakleigh, Northwich, Cheshire.
1893. ‡Hewitt, Thomas P. Eccleston Park, Prescot, Lancashire.
1883. ‡Hewson, Thomas. Care of J. C. C. Payne, Esq., Botanic-avenue, The Plains, Belfast.
1882. ‡Heycock, Charles T., M.A., F.R.S. King's College, Cambridge.
1883. §Heyes, Rev. John Frederick, M.A., F.C.S., F.R.G.S. Crowell, Tetsworth, Oxford.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1879. ‡Heywood, A. Percival. Duffield Bank, Derby.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
1886. §Heywood, Henry, J.P., F.C.S. Witla Court, near Cardiff.
1833. *Heywood, James, F.R.S., F.G.S., F.S.A., F.R.G.S., F.S.S. 26 Kensington Palace-gardens, London, W.
1887. ‡Heywood, Robert. Mayfield, Victoria Park, Manchester.
Heywood, Thomas Percival. Claremont, Manchester.
1888. ‡Hichens, James Harvey, M.A., F.G.S. The College, Cheltenham.
1875. ‡Hicks, H., M.D., F.R.S., Pres.G.S. Hendon Grove, Hendon, N.W.
1877. §Hicks, Professor W. M., M.A., D.Sc., F.R.S., Principal of Firth College, Sheffield. Firth College, Sheffield.
1886. ‡Hicks, Mrs. W. M. Dunheved, Endcliffe-crescent, Sheffield.
1884. ‡Hickson, Joseph. 272 Mountain-street, Montreal, Canada.
1887. *Hickson, Sydney J., M.A., D.Sc., F.R.S., Professor of Zoology in Owens College, Manchester.
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.
1871. ‡Higgins, Clement, B.A., F.C.S. 5 Trebovir-road, Earl's Court, London, S.W.
1891. §Higgs, Henry, LL.B., F.S.S. 12 Lyndhurst-road, Hampstead, London, N.W.

Year of Election.

Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.
1894. §Hill, Rev. A. Du Boulay. The Vicarage, Downton, Wilts.
1885. *Hill, Alexander, M.A., M.D. Downing College, Cambridge.
1872. §§Hill, Charles, F.S.A. Rockhurst, West Hoathly, East Grinstead.
*Hill, Rev. Canon Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1881. *HILL, Rev. EDWIN, M.A., F.G.S. The Rectory, Cockfield, R.S.O., Suffolk.
1887. ‡Hill, G. H., F.G.S. Albert-chambers, Albert-square, Manchester.
1884. ‡Hill, Rev. James Edgar, M.A., B.D. 2488 St. Catherine-street, Montreal, Canada.
1886. ‡HILL, M. J. M., M.A., D.Sc., F.R.S., Professor of Pure Mathematics in University College, London.
1881. ‡*Hill, Pearson.* *50 Belsize Park, London, N.W.*
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. 95 Harborne-road, Edgbaston, Birmingham.
1886. §Hillier, Rev. E. J. Cardington Vicarage, Bedford.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
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.R.S., 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, Sir Benjamin, Bart. 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.
1884. ‡*Hoadrey, John Chipman.* *Boston, Massachusetts, U.S.A.*
Hoare, J. Gurney. Hampstead, London, N.W.
1881. §Hobbes, Robert George, M.R.I. Livingstone House, 374 Wandsworth-road, London, S.W.
1879. ‡Hobkirk, Charles P., F.L.S. Hill House, Park-road, Dewsbury.
1887. *Hobson, Bernard, B.Sc., F.G.S. Tapton Elms, Sheffield.
1883. ‡Hobson, Mrs. Carey. 5 Beaumont-crescent, West Kensington, London, W.
1883. ‡Hobson, Rev. E. W. 55 Albert-road, Southport.
1877. ‡Hockin, Edward. Poughill, Stratton, Cornwall.
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, M.B., B.Sc., Lecturer on Laryngology at Owens College, Manchester. 18 St. John-street, Manchester.
1896. §Hodgkinson, Arnold. 16 Albert-road, Southport.
1880. §§Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., F.G.S., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 8 Park-villas, Blackheath, London, S.E.

Year of
Election.

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.
1896. §Hodgson, Dr. Wm., J.P. Helensville, Crewe.
1894. §§Hogg, A. F. 73 Stanhope-road, Darlington.
1894. §Holah, Ernest. 5 Crown-court, Cheapside, London, E.C.
1854. *Holcroft, George. Tyddyngwladis, Ganllwyd, near Dolgelly.
1883. ‡Holden, Edward. Laurel Mount, Shipley, Yorkshire.
1873. *Holden, Sir Isaac, Bart. Oakworth House, 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.
1896. §Holder, Thomas. 2 Tithebarn-street, Liverpool.
1887. *Holdsworth, C. J. Hill Top, near Kendal, Westmoreland.
1891. ‡Holgate, Benjamin, F.G.S. Cardigan Villa, Grove-lane, Headingley, Leeds.
1879. ‡Holland, Calvert Bernard. Hazel Villa, Thicket-road, Anerley, S.E.
1896. §Holland, Mrs. Hooton.
*Holland, Philip H. 3 Heath-rise, Willow-road, Hampstead, N.W
1889. §§Holländer, Bernard. King's College, Strand, London. W.C.
1886. ‡Holliday, J. R. 101 Harborne-road, Birmingham.
1865. ‡Holliday, William. New-street, Birmingham.
1883. ‡Hollingsworth, Dr. T. S. Elford Lodge, Spring Grove, Isleworth.
1883. *Holmes, Mrs. Basil. 5 Freeland-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. St. Helen's, Dennington Park-road, West Hampstead, London, N.W.
1892. ‡Holmes, Matthew. Netherby, Lenzie, Scotland.
1882. *Holmes, Thomas Vincent, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1896. §Holt, Alfred. Crofton, Aigburth, Liverpool.
1896. §Holt, R. D. 1 India-buildings, Liverpool.
1896. §Holt, William Henry. 11 Ashville-road, Birkenhead.
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.
1892. §Hooker, Reginald H., M.A. 3 Gray's Inn-place, W.C.
1865. *Hooper, John P. Deepdene, Rutford-road, Streatham, London, S.W.
1877. *Hooper, Rev. Samuel F., M.A. Holy Trinity 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. Orchard Dene, Henley-on-Thames.*
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1884. *Hopkinson, Charles. The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Oakleigh, Timperley, Cheshire.
1870. *Hopkinson, John, M.A., D.Sc., F.R.S. Holmwood, Wimbledon, Surrey.
1871. *Hopkinson, John, F.L.S., F.G.S., F.R.Met.Soc. 34 Margaret-street, Cavendish-square, London, W.; and The Grange, St. Albans.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
1891. ‡Horder, T. Garrett. 10 Windsor-place, Cardiff.
Hornby, Hugh. Sandown, Liverpool.
1885. ‡Horne, John, F.R.S.E., F.G.S. Geological Survey Office, Sheriff Court-buildings, Edinburgh.

Year of Election.

1875. *Horniman, F. J., M.P., 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.
1892. ‡*Horsley, Reginald E., M.B. 46 Heriot-row, Edinburgh.*
1893. *Horsley, Victor A. H., B.Sc., F.R.S., F.R.C.S. 25 Cavendish-square, London, W.
1884. *Hotblack, G. S. 52 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.
1896. *Hough, S. S. St. John's College, Cambridge.
1886. ‡Houghton, F. T. S., M.A., F.G.S. 188 Hagley-road, Edgbaston, Birmingham.
1887. ‡Houldsworth, Sir W. H., Bart., M.P. Norbury Booths, Knutsford.
1896. §Hoult, J. South Castle-street, Liverpool.
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.
1893.§§Howard, F. T., M.A., F.G.S. University College, Cardiff.
1883. ‡Howard, James Fielden, M.D., M.R.C.S. Sandycroft, Shaw.
1886. *Howard, James L., D.Sc. 86 St. John's-road, Waterloo, near Liverpool.
1887. *Howard, S. S. 58 Albemarle-road, Beckenham, Kent.
1882. ‡Howard, William Frederick, Assoc.M.Inst.C.E. 13 Cavendish-street, Chesterfield, Derbyshire.
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. University of Durham College of Medicine, Newcastle-upon-Tyne.
1857. ‡Howell, Henry H., F.G.S., Director of the Geological Survey of Great Britain. Geological Survey Office, Edinburgh.
1868. ‡Howell, Rev. Canon Hinds. Drayton Rectory, near Norwich.
1891. §Howell, Rev. William Charles, M.A., Vicar of Holy Trinity, High Cross, Tottenham, Middlesex.
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, Sir H. H., K.C.I.E., M.P., D.C.L., F.R.S., 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. 2 Barton-crescent, Dawlish.
1894. §Hudson, John E. 125 Milk-street, Boston, Massachusetts, U.S.A.
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. 90 Upper Tulse Hill, Brixton, London, S.W.
1892. ‡*Hughes, Alfred W. Woodside, Musselburgh.*
1887. ‡Hughes, E. G. 4 Roman-place, Higher Broughton, Manchester.
1883. §Hughes, Miss E. P. Cambridge Teachers' College, Cambridge.

Year of Election.

1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1887. ‡Hughes, John Taylor. Thorleymoor, Ashley-road, Altrincham.
1896. §Hughes, John W. New Heys, Allerton, Liverpool.
1870. *Hughes, Lewis. Fenwick-chambers, Liverpool.
1891. §§Hughes, Thomas, F.C.S. 31 Loudoun-square, Cardiff.
1868. §§HUGHES, T. M'K., M.A., F.R.S., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.
1891. ‡Hughes, Rev. W. Hawker. Jesus College, Oxford.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.
1867. §HULL, EDWARD, M.A., LL.D., F.R.S., F.G.S. 20 Arundel-gardens, Notting Hill, London, W.
*Hulse, Sir Edward, Bart., D.C.L. Breamore House, Salisbury.
1887. *HUMMEL, Professor J. J. 152 Woodsley-road, Leeds.
1890. ‡Humphrey, Frank W. 63 Prince's-gate, London, S.W.
1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880. ‡Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1891. *Hunt, Cecil Arthur. Southwood, Torquay.
1886. ‡Hunt, Charles. The Gas Works, Windsor-street, Birmingham.
1891. ‡Hunt, D. de Vere, M.D. Westbourne-crescent, Sophia-gardens, Cardiff.
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. 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 Marquess of. Aboyne Castle, Aberdeenshire.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1883. *HURST, CHARLES HERBERT, Ph.D. Royal College of Science, Dublin.
1869. ‡Hurst, George. Bedford.
1882. ‡*Hurst, Walter, B.Sc. West Lodge, Todmorden.*
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1896. *Hurter, Dr. Ferdinand. Holly Lodge, Cressington, Liverpool.
1887. ‡Husband, W. E. 56 Bury New-road, Manchester.
1882. ‡Hussey, Major E. R., R.E. 24 Waterloo-place, Southampton.
1894. *Hutchinson, A. Pembroke College, Cambridge.
1876. ‡*Hutchinson, John. 22 Hamilton Park-terrace, Glasgow.*
1896. §Hutchinson, W. B. 144 Sussex-road, Southport.
Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, London, N.W.
1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.
1861. *HUTTON, T. MAXWELL. Summerhill, Dublin.
Hyde, Edward. Dukinfield, near Manchester.
1883. ‡Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.

Year of Election.

1882. *I'Anson, James, F.G.S. Fairfield House, Darlington.
1883. §Idris, T. H. W. 58 Lady Margaret-road, London, N.W.
Ihne, William, Ph.D. Heidelberg.
1884. *Iles, George. 5 Brunswick-street, Montreal, Canada.
1885. ‡im-Thurn, Everard F., C.M.G., M.A. British Guiana.
1888. *Ince, Surgeon-Lieut.-Col. John, M.D. Montague House, Swanley, Kent.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1893. ‡Ingle, Herbert. Pool, Leeds.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.
1891. ‡Ingram, Lieut.-Colonel C. W. Bradford-place, Penarth.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Senior Lecturer in the University of Dublin. 2 Wellington-road, Dublin.
1885. ‡Ingram, William, M.A. Gamrie, Banff.
1886. ‡Innes, John. The Limes, Alcester-road, Moseley, Birmingham.
1892. ‡Ireland, D. W. 10 South Gray-street, Edinburgh.
1892. ‡Irvine, James. Devonshire-road, Birkenhead.
1892. ‡Irvine, Robert, F.R.S.E. Royston, Granton, Edinburgh.
1882. §IRVING, Rev. A., B.A., D.Sc., F.G.S. Hockerill, Bishop Stortford, Herts.
1888. *Isaac, J. F. V., B.A. Royal York Hotel, Brighton.
1883. ‡Isherwood, James. 18 York-road, Birkdale, Southport.
1881. ‡Ishiguro, Isoji. Care of the Japanese Legation, 9 Cavendish-square, London, W.
1891. *ISMAY, THOMAS H. 10 Water-street, Liverpool.
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. 358 Collins-street, Melbourne, Australia.
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.
1887. *Jackson, George. 53 Elizabeth-street, Cheetham, Manchester.
1885. ‡Jackson, Henry. 19 Golden-square, Aberdeen.
1866. ‡Jackson, H. W., F.R.A.S. 67 Upgate, Louth, Lincolnshire.
1869. §Jackson, Moses, J.P. 139 Lower Addiscombe-road, Croydon.
1887. §Jacobson, Nathaniel. Olive Mount, Cheetham Hill-road, Manchester.
1874. *Jaffe, John. Villa Jaffe, Nice, France.
1865. *Jaffray, Sir John, Bart. Park-grove, Edgbaston, Birmingham.
1891. ‡James, Arthur P. Grove House, Park-grove, Cardiff.
1891. *James, Charles Henry. 8 Courtland-terrace, Merthyr Tydfil.
1891. *James, Charles Russell. 6 New-court, Lincoln's Inn, London, W.C.
1860. ‡James, Edward H. Woodside, Plymouth.
1886. ‡James, Frank. Portland House, Aldridge, near Walsall.
1891. ‡James, Ivor. University College, Cardiff.
1891. ‡James, John. 24 The Parade, Cardiff.
1891. ‡James, John Herbert. Howard House, Arundel-street, Strand, London, W.C.
1891. ‡James, J. R., L.R.C.P. 158 Cowbridge-road, Canton, Cardiff.

Year of Election.

1858. ‡James, William C. Woodside, Plymouth.
1896. *Jameson, H. Lyster. Killencoole, Castlebellingham, Ireland.
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. 37 Drumsheugh-gardens, Edinburgh.
1885. ‡Jamieson, Patrick. Peterhead, N.B.
1885. ‡Jamieson, Thomas. 173 Union-street, Aberdeen.
1859. *Jamieson, Thomas F., LL.D., F.G.S. Ellon, Aberdeenshire.
1889. *JAPP, F. R., M.A., LL.D., F.R.S., F.C.S., Professor of Chemistry in the University of Aberdeen.
1870. ‡Jarrold, John James. London-street, Norwich.
1891. ‡*Jasper, Henry. Holmedale, New Park-road, Clapham Park, London, S.W.*
1891. ‡Jefferies, Henry. Plas Newydd, Park-road, Penarth.
1855. *Jeffray, John. 9 Winton-drive, Kelvinside, Glasgow.
1867. ‡Jeffreys, Howel, M.A. 61 Bedford-gardens, Kensington, London, W.
1885. ‡*Jeffreys, Dr. Richard Parker. Eastwood House, Chesterfield.*
1887. §JEFFS, OSMUND W. 164 Falkner-street, Liverpool.
1864. ‡Jelly, Dr. W. Aveleanas, 11, Valencia, Spain.
1891. ‡Jenkins, Henry C., Assoc.M.Inst.C.E., F.C.S. Royal College of Science, South Kensington, London, S.W.
1873. §Jenkins, Major-General J. J. 16 St. James's-square, London, S.W.
1880. *JENKINS, Sir JOHN JONES, M.P. The Grange, Swansea.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1893. §Jennings, G. E. Ashleigh, Ashleigh-road, Leicester.
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.
1891. ‡John, E. Cowbridge, Cardiff.
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. 1 Victoria-road, Clapham Common, 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.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1881. ‡Johnson, Sir Samuel George. Municipal Offices, Nottingham.
1890. *JOHNSON, THOMAS, D.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, Sir H. H., K.C.B., F.R.G.S. Queen Anne's Mansions, S.W.

Year of Election.

1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, N.W.
1884. ‡Johnston, John L. 27 St. Peter-street, Montreal, Canada.
1883. ‡Johnston, Thomas. Broomsleigh, Seal, Sevenoaks.
1884. ‡Johnston, Walter R. Fort Qu'Appelle, N.W. Territory, Canada.
1884. *Johnston, W. H. County Offices, Preston, Lancashire.
1885. ‡Johnston-Lavis, H. J., M.D., F.G.S. Beaulieu, Alpes Maritimes, France.
1886. ‡Johnstone, G. H. Northampton-street, Birmingham.
1864. *Johnstone, James. Alva House, Alva, by Stirling, N.B.
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.
1896. §Joly, C. J., M.A. Trinity College, Dublin.
1888. ‡Joly, John, M.A., D.Sc., F.R.S. 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., H.M. Inspector of Schools. 7 Marine-terrace, Aberystwith.
1891. ‡Jones, D. Edgar, M.D. Spring Bank, Queen-street, Cardiff.
1896. §Jones, E. Taylor. University College, Bangor.
1890. §Jones, Rev. Edward, F.G.S. Fairfax-road, Prestwich, Lancashire.
1891. ‡Jones, Dr. Evan. Aberdare.
1887. ‡Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *Jones, Rev. G. Hartwell, M.A. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. Inchyra House, Waterloo, Liverpool.
1895. §§Jones, Harry. Engineer's Office, Great Eastern Railway, Ipswich.
1884. ‡Jones, Rev. Harry, M.A. 8 York-gate, Regent's Park, London, N.W.
1877. ‡Jones, Henry C., F.C.S. Royal College of Science, South Kensington, London, S.W.
1881. *Jones, J. Viriamu, M.A., B.Sc., F.R.S., 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. 17 Parson's Green, Fulham, London, S.W.
1896. §Jones, W. Hope Bank, Lancaster-road, Pendleton, Manchester.
1883. ‡Jones, William. Elsinore, Birkdale, Southport.
1891. ‡Jones, William Lester. 22 Newport-road, Cardiff.
1875. *Jose, J. E. 49 Whitechapel, Liverpool.
1884. ‡Joseph, J. H. 738 Dorchester-street, Montreal, Canada.
1891. ‡Jotham, F. H. Penarth.
1891. ‡Jotham, T. W. Penylan, Cardiff.
1879. ‡Jowitt, A. Scotia Works, Sheffield.
1890. ‡Jowitt, Benson R. Elmhurst, Newton-road, Leeds.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, 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.
1896. §Joyce, Joshua. 151 Walton-street, Oxford.
1891. ‡Joynes, John J. Great Western Colliery, near Coleford, Gloucestershire.
1848. *Jubb, Abraham. Halifax.
1870. ‡Judd, John Wesley, C.B., F.R.S., F.G.S., Professor of Geology in the Royal College of Science, London. 16 Cumberland-road, Kew.

Year of Election.

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, M.Inst.C.E., M.Inst.E.E. 3 Lindenallee, Westend, Berlin.
1887. ‡Kay, Miss. Hamerlaund, Broughton Park, Manchester.
1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, W.
1884. ‡Keefer, Samuel. Brockville, Ontario, Canada.
1875. ‡Keeling, George William. Tuthill, Lydney.
1886. ‡Keen, Arthur, J.P. Sandyford, Augustus-road, Birmingham.
1894. §§Keene, Captain C. T. P., F.L.S., F.Z.S., F.S.S. 11 Queen's-gate, London, S.W.
1894 §§Keightley, Rev. G. W. Great Stambridge Rectory, Rochford, Essex.
1892. ‡Keiller, Alexander, M.D., LL.D., F.R.S.E. 54 Northumberland-street, Edinburgh.
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, Assist.Sec.R.G.S., F.S.S. 1 Savile-row, London, W.
1847. *KELVIN, The Right Hon. Lord, M.A., LL.D., D.C.L., F.R.S., F.R.S.E., F.R.A.S. The University, Glasgow.
1877. *Kelvin, Lady. The University, Glasgow.
1887. ‡Kemp, Harry. 254 Stretford-road, Manchester.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.
1890. §Kempson, Augustus. Kildare, Arundel-road, Eastbourne.
1891. §KENDALL, PERCY F., F.G.S., Professor of Geology in Yorkshire College, Leeds.
1875. ‡KENNEDY, ALEXANDER B. W., F.R.S., M.Inst.C.E. 17 Victoria-street, S.W., and 1 Queen Anne-street, Cavendish-square, London, 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. 20 Mirkland-street, Glasgow.
1884. ‡Kennedy, John. 113 University-street, Montreal, Canada.
1884. ‡Kennedy, William. Hamilton, Ontario, Canada.
1886. ‡Kenrick, George Hamilton. Whetstone, Somerset-road, Edgbaston, Birmingham.
1893. §Kent, A. F. Stanley, F.G.S. St. Thomas's Hospital, London, S.E.
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1886. §KENWARD, JAMES, F.S.A. 43 Streatham High-road, London, S.W.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.
1881. ‡Kermode, Philip M. C. Ramsey, Isle of Man.
1892. §§Kerr, J. Graham. Christ's College, Cambridge.
1884. ‡Kerr, James, M.D. Winnipeg, Canada.
1887. ‡Kerr, James. Dunkenhalgh, Accrington.
1883. ‡KERR, REV. JOHN, LL.D., F.R.S. Free Church Training College, Glasgow.
1889. ‡Kerry, W. H. R. Wheatlands, Windermere.
1887. ‡Kershaw, James. Holly House, Bury New-road, Manchester.
1869. *Kesselmeyer, Charles A. Rose Villa, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Rose Villa, Vale-road, Bowdon, Cheshire.

Year of Election.

1883. *Keynes, J. N., M.A., D.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.
1896. *Killey, George Deane. Bentuther, 11 Victoria-road, Waterloo, Liverpool.
1890. ‡Kimmins, C. W., M.A., D.Sc. Downing College, Cambridge.
1878. ‡Kinahan, Sir Edward Hudson, Bart. 11 Merrion-square North, Dublin.
1860. ‡Kinahan, G. Henry, M.R.I.A., 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. Stonelands, East Grinstead.
1870. ‡King, John Thomson. 4 Clayton-square, Liverpool.
King, Joseph. Welford House, Greenhill, Hampstead, N.W.
1883. *King, Joseph, jun. Lower Birtley, Witley, Godalming.
1860. *King, Mervyn Kersteman. 3 Clifton-park, Clifton, Bristol.
1875. *King, Percy L. 2 Worcester-avenue, Clifton, Bristol.
1870. ‡King, William. 5 Beach Lawn, Waterloo, Liverpool.
1889. §King, Sir William. Stratford Lodge, Southsea.
1869. ‡Kingdon, K. Taddiford, Exeter.
1875. §Kingzett, Charles T., F.C.S. Elmstead Knoll, Chislehurst Kent.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1892. ‡Kinnear, The Hon. Lord, F.R.S.E. Blair Castle, Culross, N.B.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1890. *Kitson, Sir James, Bart., M.P. Gledhow Hall, Leeds.
1896. §Klein, L. de Beaumont. 6 Devonshire-road, Liverpool.
1886. ‡Klein, Rev. L. Martial. University College, Dublin.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1886. ‡Knight, J. M., F.G.S. Bushwood, Wanstead, Essex.
1888. ‡Knott, Professor Cargill G., D.Sc., F.R.S.E. 42 Upper Gray-street, Edinburgh.
1887. *Knott, Herbert. Aingarth, Stalybridge, Cheshire.
1887. *Knott, John F. Staveleigh, Stalybridge, Cheshire.
1887. ‡Knott, Mrs. Staveleigh, Stalybridge, Cheshire.
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. 27 Portland-terrace, Regent's Park, N.W.
1875. *Knubley, Rev. E. P., M.A. Staveley Rectory, Leeds.
1883. ‡Knubley, Mrs. Staveley Rectory, Leeds.
1892. ‡Kohn, Charles A., Ph.D. University College, Liverpool.
1890. *Krauss, John Samuel, B.A. Wilmslow, Cheshire.
1888. *Kunz, G. F. Care of Messrs. Tiffany & Co., 11 Union-square, New York City, U.S.A.
1881. ‡*Kurobe, Hiroo. Legation of Japan, 9 Cavendish-square, London, W.*
1870. ‡Kynaston, Josiah W., F.C.S. Kensington, Liverpool.

Year of Election.

1858. ‡Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1884. ‡Laflamme, Rev. Professor J. C. K. Laval University, Quebec, Canada.
1885. *Laing, J. Gerard. 111 Church-street, Chelsea, S.W.
1870. §Laird, John. Grosvenor-road, Claughton, Birkenhead.
1877. ‡Lake, W. C., M.D., F.R.G.S. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. City Hall, Cork Hill, Dublin.
1889. *Lamb, Edmund, M.A. Old Lodge, Salisbury.
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, S.E.
1896. §Lambert, Frederick Samuel. Balgowan, Newland, Lincoln.
1893. ‡Lambert, J. W., J.P. Lenton Firs, Nottingham.
1884. ‡Lamborn, Robert H. Montreal, Canada.
1893. §§Lamplugh, G. W., F.G.S. Geological Survey Office, Jermyn-street, London, S.W.
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, London, 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. 2 Bradmore-road, Oxford.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Morden College, Blackheath, London, S.E.
1884. §Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1885. ‡LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S., Professor of Geology and Physiography in the Mason Science College, Birmingham. 13 Duchess-road, Edgbaston, Birmingham.
1887. ‡Larmor, Alexander. Clare College, Cambridge.
1881. ‡LARMOR, JOSEPH, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1883. §Lascelles, B. P., M.A. The Moat, Harrow.
1896. *Last, William J. South Kensington Museum, London, S.W.
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. Catesby House, Manor-road, Barnet, Herts.
1891. ‡Laurie, A. P. 49 Beaumont-square, London, E.
1888. ‡Laurie, Colonel R. P., C.B. 79 Farringdon-street, London, E.C.
1892. §Laurie, Malcolm, B.A., B.Sc., F.L.S. King's College, Cambridge.
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.
1884. §Law, Robert, F.G.S. Fennyroyd Hall, Hipperholme, near Halifax, Yorkshire.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1881. ‡Lawrence, Rev. F., B.A. The Vicarage, Westow, York

Year of Election.

1889. §Laws, W. G., M.Inst.C.E. 5 Winchester-terrace, Newcastle-upon-Tyne.
1885. ‡Lawson, James. 8 Church-street, Huntly, N.B.
1853. ‡*Lawton, William. 5 Victoria-terrace, Derringham, Hull.*
1888. §Layard, Miss Nina F. 2 Park-place, Fonnereau-road, Ipswich.
1856. ‡Lea, Henry. 38 Bennett's-hill, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1875. ‡Leach, Colonel Sir G., K.C.B., R.E. 6 Wetherby-gardens, London, S.W.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. Pembury-road, Tunbridge Wells.
1894. *Leahy, A. H., M.A., Professor of Mathematics in Firth College, Sheffield.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1884. ‡Learmont, Joseph B. 120 Mackay-street, Montreal, Canada.
1847. **Leatham, Edward Aldam.* 46 *Eaton-square, London, S.W.*
1863. ‡Leavers, J. W. The Park, Nottingham.
1884. *Leavitt, Erasmus Darwin. 2 Central-square, 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.
1895. *Ledger, Rev. Edmund. Barham Rectory, Claydon, Ipswich.
1861. ‡Lee, Henry. Sedgeley Park, Manchester.
1896. §Lee, Rev. H. J. Barton. Ashburton, Devon.
1891. §§Lee, Mark. The Cedars, Llandaff-road, Cardiff.
1884. *Leech, Sir Bosdin T. Oak Mount, Timperley, Cheshire.
1896. *Leech, Lady. Oak Mount, Timperley, Cheshire.
1887. ‡Leech, D. J., M.D., Professor of Materia Medica in the Owens College, Manchester. Elm House, Whalley Range, Manchester.
1892. *LEES, CHARLES H., M.Sc. 6 Heald-road, Rusholme, Manchester.
1886. *Lees, Lawrence W. Claregate, Tettenhall, Wolverhampton.
1882. ‡Lees, R. W. Moira-place, Southampton.
1859. ‡Lees, William, M.A. 12 Morningside-place, Edinburgh.
1896. §Lees, William. 10 Norfolk-street, Manchester.
1883. *Leese, Miss H. K. 3 Lord-street West, Southport.
*Leese, Joseph. 3 Lord-street West, Southport.
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1881. ‡LE FEUVRE, J. E. Southampton.
1872. ‡LEFEVRE, The Right Hon. G. SHAW, F.R.G.S. 18 Bryanston-square, London, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1892. ‡Lehfeldt, Robert A. Firth College, Sheffield.
1868. ‡LEICESTER, The Right Hon. the Earl of, K.G. Holkham, Norfolk.
1856. ‡LEIGH, The Right Hon. Lord. Stoneleigh Abbey, Kenilworth.
1890. ‡Leigh, Marshall. 22 Goldsmid-road, Brighton.
1891. ‡Leigh, W. W. Treharris, R.S.O., Glamorganshire.
1867. ‡Leishman, James. Gateacre Hall, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1882. §Lemon, James, M.Inst.C.E., F.G.S. Lansdowne House, Southampton.
1867. ‡Leng, Sir John, M.P. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.
1887. *Leon, John T. 38 Portland-place, London, W.
1871. ‡LEONARD, HUGH, M.R.I.A. 24 Mount Merrion-avenue, Blackrock, Co. Dublin.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.

Year of Election.

1884. ‡Lesage, Louis. City Hall, Montreal, Canada.
1890. *Lester, Joseph Henry. 51 Arcade-chambers, St. Mary's Gate, Manchester.
1883. §Lester, Thomas. Fir Bank, Penrith.
1880. ‡LETCHER, R. J. Lansdowne-terrace, Walters-road, Swansea.
1894. ‡Leudesdorf, Charles. Pembroke College, Oxford.
1896. §Lever, Mr. Port Sunlight, Cheshire.
1887. *Levinstein, Ivan. Hawkesmoor, Fallowfield, Manchester.
1890. ‡Levy, J. H. Florence, 12 Abbeville-road South, Clapham Park, London, S.W.
1893. *Lewes, Vivian B., F.C.S., Professor of Chemistry in the Royal Naval College, Greenwich, S.E.
1879. ‡Lewin, Colonel, F.R.G.S. Garden Corner House, Chelsea Embankment, London, S.W.
1870. ‡LEWIS, ALFRED LIONEL. 54 Highbury-hill, London, N.
1891. ‡Lewis, D., J.P. 44 Park-place, Cardiff.
1891. §Lewis, D. Morgan, M.A. University College, Aberystwith.
1891. ‡Lewis, W. Lyncombe Villa, Cowbridge-road, Cardiff.
1891. ‡Lewis, W. 22 Duke-street, Cardiff.
1891. ‡Lewis, W. Henry. Bryn Rhos, Llanishen, Cardiff.
1884. *Lewis, Sir W. T., Bart. The Mardy, Aberdare.
1860. ‡LIDDELL, The Very Rev. H. G., D.D. Ascot, Berkshire.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1887. *Lightbown, Henry. Hayfield Mills, Pendleton, Manchester.
*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.
1883. ‡Lisle, H. Claud. Nantwich.
1895. §LISTER, Sir JOSEPH, Bart., D.C.L., Pres.R.S. (PRESIDENT.) 12 Park-crescent, Portland-place, W.
1882. *Lister, Rev. Henry, M.A. Hawridge Rectory, Berkhampstead.
1888. ‡Lister, J. J. Leytonstone, Essex, N.E.
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, M.A., F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry in the University of Sydney, N.S.W. Care of Messrs. Kegan Paul & Co., Charing Cross-road, W.C.
1864.§§Livesay, J. G. Cromartie House, Ventnor, Isle of Wight.
1880. ‡LLEWELYN, Sir JOHN T. D., Bart., M.P. 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, J. Henry. Ferndale, Carpenter-road, Edgbaston, Birmingham.
1891. *Lloyd, R. J., M.A., D.Litt. 4 Halkyn-avenue, Sefton Park, Liverpool.
1886. ‡Lloyd, Samuel. Farm, Sparkbrook, Birmingham.
1865. *Lloyd, Wilson, F.R.G.S. Myvod House, Wednesbury.
1854. *LOBLEY, JAMES LOGAN, F.G.S. City of London College, Moorgate-street, London, E.C.

Year of Election.

1892. §Loch, C. S., B.A. 15A Buckingham-street, London, W.C.
1867. *Locke, John. 163 Holland-road, Kensington, London, W.
1892. ‡Lockhart, Robert Arthur. 10 Polwarth-terrace, Edinburgh.
1863. ‡LOCKYER, J. NORMAN, C.B., 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. 2 Grove-park, Liverpool.
1894. *Lodge, Oliver W. F. 2 Grove-park, Liverpool.
1889. ‡Logan, William. Langley Park, Durham.
1896. §Lomas, J. 16 Mellor-road, Birkenhead.
1876. ‡Long, H. A. Charlotte-street, Glasgow.
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.D., F.C.S., F.S.S. Highlands, Putney Heath, 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. The Priory, Southport.
1861. *Lord, Edward. Adamroyd, Todmorden.
1894. ‡Lord, Edwin C. E., Ph.D. 247 Washington-street, Brooklyn, U.S.A.
1889. ‡Lord, Riley. 75 Pilgrim-street, Newcastle-upon-Tyne.
1883. *Louis, D. A., F.C.S. 77 Shirland-gardens, London, W.
1896. §Louis, Henry, Professor of Mining, Durham College of Science, Newcastle-on-Tyne.
1887. *LOVE, A. E. H., M.A., F.R.S. 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. 33 Clanricarde-gardens, London, W.
1883. ‡Love, James Allen. 8 Eastbourne-road West, Southport.
1875. *Lovett, W. Jesse, F.I.C. 29 Park-crescent, Monkgate, York.
1892. §Lovibond, J. W. Salisbury, Wiltshire.
1889. ‡Low, Charles W. 84 Westbourne-terrace, London, W.
1867. *Low, James F. Monifieth, by Dundee.
1885. §Lowdell, Sydney Poole. Baldwin's Hill, East Grinstead, Sussex.
1891. §Lowdon, John. St. Hilda's, Barry, Cardiff.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1892. ‡Lowe, D. T. Heriot's Hospital, Edinburgh.
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.
1886. *Lowe, John Landor, M.Inst.C.E. The Birches, Burton-road, Derby.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1894. ‡Lowenthal, Miss Nellie. 60 New North-road, Huddersfield.
1881. ‡Lubbock, Arthur Rolfe. High Elms, Farnborough, R.S.O., 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. High Elms, Farnborough, R.S.O., Kent.
1881. ‡Lubbock, John B. 14 Berkeley-street, London, W.
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.

Year of Election.

1889. ‡Luckley, George. The Grove, Jesmond, Newcastle-upon-Tyne.
1891. *Lucovich, Count A. The Rise, Llandaff.
1875. ‡Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1881. ‡Luden, C. M. 4 Bootham-terrace, York.
1866. *Lund, Charles. Ilkley, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 32 Newport-road, Cardiff.
1892. ‡Lunn, Robert. Geological Survey Office, Sheriff Court House, Edinburgh.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S., Professor of Coal Mining in Yorkshire College, Leeds. 6 De Grey-road, Leeds.
1874. *Lupton, Sydney, M.A. A. Audley-mansions, 44 Mount-street, London, W.
1864. *Lutley, John. Brockhampton Park, Worcester.
1871. ‡Lyell, Sir Leonard, Bart., M.P., F.G.S. 48 Eaton-place, London, S.W.
1884. ‡Lyman, A. Clarence. 84 Victoria-street, Montreal, Canada.
1884. ‡Lyman, H. H. 74 McTavish-street, Montreal, Canada.
1874. ‡Lynam, James. Ballinasloe, Ireland.
1885. §§Lyon, Alexander, jun. 52 Carden-place, Aberdeen.
1896. §Lyster, A. G. Dockyard, Coburg Dock, Liverpool.
1896. §Lyster, George F. Plas Isaf, Ruthin.
1862. *Lyte, F. Maxwell, F.C.S. 60 Finborough-road, London, S.W.

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, F.R.S.E., F.I.C., F.C.S. Surgeons' Hall, Edinburgh.
1868. ‡Macalister, Alexander, M.A., 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.
1896. §Macalister, N. A. S. 2 Gordon-street, London, W.C.
1896. §Macallum, Professor A. B., Ph.D. (Local Secretary.) The University, Toronto.
1879. §MacAndrew, James J., F.L.S. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, William. Westwood House, near Colchester.
1866. *M'Arthur, Alexander, F.R.G.S. 79 Holland Park, London, W.
1896. §McArthur, Charles. Villa Marina, New Brighton, Chester.
1884. ‡Macarthur, D. Winnipeg, Canada.
1834. Macaulay, James, A.M., M.D. 25 Carlton-vale, London, N.W.
1840. **MacBrayne, Robert. 65 West Regent-street, Glasgow.*
1896. §MacBride, E. W., M.A. St. John's College, Cambridge.
1884. ‡McCabe, T., Chief Examiner of Patents. Patent Office, Ottawa, Canada.
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.
1891. *McClean, Frank, M.A., LL.D., F.R.S., M.Inst.C.E. Rusthall House, Tunbridge Wells.
1876. *M'Clelland, A. S. 4 Crown-gardens, Dowanhill, Glasgow.

Year of Election.

1868. ‡M'Clintock, Admiral Sir Francis L., R.N., K.C.B., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1872. *McClure, J. H., F.R.G.S. 77 Mayfield-street, Hull.
1878. *M'Comas, Henry. Homestead, Dundrum, Co. Dublin.
1892. *McCowan, John, M.A., D.Sc. University College, Dundee.
1892. ‡McCrae, George. 3 Dick-place, Edinburgh.
1883. ‡McCrossan, James. 92 Huskisson-street, Liverpool.
1886. ‡McDonald, John Allen. Hillsboro' House, Derby.
1884. ‡MacDonald, Kenneth. Town Hall, Inverness.
1884. *McDonald, W. C. 891 Sherbrooke-street, Montreal, Canada.
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, M.Inst.C.E. (Local Secretary.) 32 Adelaide-street East, 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., Professor of Biology in the University of Pennsylvania, Lansdowne, Delaware Co., Pennsylvania, U.S.A.
1879. ‡Macfarlane, Walter, jun. 12 Lynedoch-crescent, Glasgow.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
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.
1885. ‡M'Gregor-Robertson, J., M.A., M.B. 26 Buchanan-street, Hillhead, Glasgow.
1867. *M'Intosh, W. C., M.D., LL.D., F.R.S., F.R.S.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.
1896. *McKechnie, Duncan. Eccleston Grange, Preston.
1873. ‡McKendrick, John G., M.D., LL.D., F.R.S., F.R.S.E., Professor of Physiology in the University of Glasgow. 2 Florentine-gardens, Glasgow.
1883. ‡McKendrick, Mrs. 2 Florentine Gardens, 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.
1872. *Mackey, J. A. 175 Grange-road, London, S.E.
1867. ‡Mackie, Samuel Joseph. 17 Howley-place, London, W.

Year of
Election.

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.
1889. ‡*McKinley, Rev. D. 33 Milton-street, West Hartlepool.*
1891. ‡Mackintosh, A. C. Temple Chambers, Cardiff.
1850. ‡Macknight, Alexander. 20 Albany-street, Edinburgh.
1872. *McLACHLAN, ROBERT, F.R.S., F.L.S. West View, Clarendon-road, Lewisham, S.E.
1896. §Maclagan, Miss Christian. Ravenscroft, Stirling.
1892. ‡MACLAGAN, Sir DOUGLAS, M.D., LL.D., F.R.S.E., Professor of Medical Jurisprudence in the University of Edinburgh. 28 Heriot-row, Edinburgh.
1892. ‡Maclagan, Philip K. D. 14 Belgrave-place, Edinburgh.
1892. ‡Maclagan, R. Craig, M.D., F.R.S.E. 5 Coates-crescent Edinburgh.
1873. ‡McLandsborough, John, F.R.A.S., F.G.S. Manningham, Bradford, Yorkshire.
1885. *M'LAREN, The Hon. Lord, F.R.S.E., F.R.A.S. 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.
1892. *Maclean, Magnus, M.A., F.R.S.E. The University, Glasgow.
1884. ‡McLennan, Frank. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, Hugh. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, John. Lancaster, Ontario, Canada.
1868. §McLEOD, HERBERT, F.R.S., F.C.S., Professor of Chemistry in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1892. ‡*Macleod, Reginald. Woodhall, Midlothian.*
1892. ‡Macleod, W. Bowman. 16 George-square, Edinburgh.
1861. *Maclure, John William, M.P., F.R.G.S., F.S.S. Whalley Range, Manchester.
1883. *McMAHON, Lieut.-General C. A., F.G.S. 20 Nevern-square, South Kensington, London, S.W.
1883. ‡MACMAHON, Major P. A., R.A., F.R.S., Professor of Electricity in the Artillery College, Woolwich. 40 Shaftesbury-avenue, London, W.C.
1878. *M'Master, George, M.A., J.P. Rathmines, Ireland.
1874. ‡MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1884. ‡McMurrick, J. Playfair. Cincinnati, Ohio, U.S.A.
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, A. W. Care of Messrs. Maconochie Bros., Lowestoft.
1883. ‡Macpherson, J. 44 Frederick-street, Edinburgh.
*MACRORY, EDMUND, M.A. 19 Pembridge-square, London, W.
1887. ‡Macy, Jesse. Grinnell, Iowa, U.S.A.
1883. ‡Madden, W. H. Marlborough College, Wilts.
1883. ‡Maggs, Thomas Charles, F.G.S. 56 Clarendon-villas, West Brighton.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Sir Philip, B.Sc. 16 Gloucester-terrace, Hyde Park, W.
1896. §Maguire, Thomas Philip. Eastfield, Lodge-lane, Liverpool.
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., F.G.S. Stirling, N.B.
1883. ‡Maitland, P. C. 136 Great Portland-street, London, W.
1881. ‡Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.

Year of Election.

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.
1896. *Manbré, Alexandre. 15 Alexandra-drive, Liverpool.
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.
1894. §Manning, Percy, M.A., F.S.A. Watford, Herts.
1878. §Manning, Robert. 4 Upper Ely-place, Dublin.
1864. ‡Mansel-Pleydell, J. C., F.G.S. Whatcombe, Blandford.
1888. ‡Mansergh, James, M.Inst.C.E., F.G.S. 5 Victoria-street, Westminster, S.W.
1891. ‡Manuel, James. 175 Newport-road, Cardiff.
1889. ‡Manville, E. 3 Prince's-mansions, Victoria-street, London, S.W.
1887. *March, Henry Colley, M.D., F.S.A. Portesham, Dorchester, Dorsetshire.
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. Spratton, Northampton.
1864. ‡Markham, Sir Clements R., K.C.B., F.R.S., F.L.S., Pres.R.G.S., F.S.A. 21 Eccleston-square, London, S.W.
1894.§§Markoff, Dr. Anatolius. 44 Museum-street, London, W.C.
1863. ‡Marley, John. Mining Office, Darlington.
1888. ‡Marling, W. J. Stanley Park, Stroud, Gloucestershire.
1888. ‡Marling, Lady. Stanley Park, Stroud, Gloucestershire.
1881. *Marr, J. E., M.A., F.R.S., Sec.G.S. St. John's College, Cambridge.
1887. ‡Marsden, Benjamin. Westleigh, Heaton Mersey, Manchester.
1884. *Marsden, Samuel. 1015 North Leffingwell-avenue, St. Louis, Missouri, U.S.A.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.
1883. *Marsh, Henry. Hurstwood, Roundhay, Leeds.
1887. ‡Marsh, J. E., M.A. The Museum, Oxford.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1889. *Marshall, Alfred, M.A., LL.D., Professor of Political Economy in the University of Cambridge. Balliol Croft, Madingley-road, Cambridge.
1889. ‡Marshall, Frank, B.A. 31 Grosvenor-place, Newcastle-upon-Tyne.
1892. §Marshall, Hugh, D.Sc., F.R.S.E. 131 Warrender Park-road, Edinburgh.
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.
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.
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.
1883. *Martin, John Biddulph, M.A., F.S.S. 17 Hyde Park gate, London, S.W.

Year of Election.

1884. §Martin, N. H., F.L.S. 8 Windsor-crescent, Newcastle-upon-Tyne.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Northdene, 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.
1883. ‡Marwick, Sir James, LL.D. Killermont, Maryhill, Glasgow.
1891. ‡Marychurch, J. G. 46 Park-street, Cardiff.
1878. ‡Masaki, Taiso. Japanese Consulate, 84 Bishopsgate-street Within, London, E.C.
1847. ‡MASKELYNE, NEVIL STORY, M.A., F.R.S., F.G.S. Basset Down House, Swindon.
1886. ‡Mason, Hon. J. E. Fiji.
1879. ‡Mason, James, M.D. Montgomery House, Sheffield.
1896. §Mason, Philip B., F.L.S., F.Z.S. Burton-on-Trent.
1893. *Mason, Thomas. 6 Pelham-road, Sherwood Rise, Nottingham.
1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
1885. ‡Masson, Orme, D.Sc. 58 Great King-street, Edinburgh.
1883. ‡Mather, Robert V. Birkdale Lodge, Birkdale, Southport.
1887. *Mather, William, M.Inst.C.E. Salford Iron Works, Manchester.
1890. ‡Mathers, J. S. 1 Hanover-square, Leeds.
1865. ‡Mathews, C. E. Waterloo-street, Birmingham.
1894. ‡Mathews, G. B., M.A. Bangor.
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. 21 Augustus-road, Edgbaston, Birmingham.
1881. ‡Mathwin, Henry, B.A. Bickerton House, Southport.
1883. ‡Mathwin, Mrs. 40 York-road, Birkdale, Southport.
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-upon-Tyne.
1893.§§Mavor, Professor James. University of Toronto, Canada.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall, Kenley, Surrey.
1894. §Maxim, Hiram S. 18 Queen's Gate-place, Kensington, S.W.
1876. ‡Maxton, John. 6 Belgrave-terrace, Glasgow.
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. 33 Castle-street, Dublin.
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.

Year of Election.

1883. §Mello, Mrs. J. M. Mapperley Vicarage, Derby.
1896. §Mellor, G. H. Weston. Blundell Sands, Liverpool.
1881. §Melrose, James. Clifton Croft, 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.
1896. §Menneer, R. R. Care of Messrs. Grindlay & Co., Parliament-street, London, S.W.
1862. ‡Mennell, Henry T. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1879. §Merivale, John Herman, M.A. Togston Hall, Acklington.
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.
1896. §Metzler, W. H., Professor of Mathematics in Syracuse University, Syracuse, New York, U.S.A.
1869. ‡Miall, Louis C., F.R.S., F.L.S., F.G.S., Professor of Biology in the 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.
1893. §Middleton, A. 25 Lister-gate, Nottingham.
1881. ‡Middleton, R. Morton, F.L.S., F.Z.S. 15 Grange-road, West Hartlepool.
1894. *Miers, H. A., M.A., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. Magdalen College, Oxford.
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., Librarian R.G.S. 109 West End-lane, Hampstead, London, N.W.
1889. *Millar, Robert Cockburn. 30 York-place, Edinburgh.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1892. *Millard, William Joseph Kelson, M.D., F.R.G.S. Holmleigh, Rockleaze, Stoke Bishop, Bristol.
1882. ‡*Miller, A. J. 15 East Park-terrace, Southampton.*
1875. ‡Miller, George. Brentry, near Bristol.
1895. §§Miller, Henry, M.Inst.C.E. Bosmere House, Norwich-road, Ipswich.
1892. ‡Miller, Hugh, F.R.S.E., F.G.S. 3 Douglas-crescent, Edinburgh.
1888. ‡Miller, J. Bruce. Rubislaw Den North, Aberdeen.
1885. ‡Miller, John. 9 Rubislaw-terrace, Aberdeen.
1886. ‡Miller, Rev. John, B.D. The College, Weymouth.
1861. *Miller, Robert. Totteridge House, Hertfordshire, N.
1884. ‡Miller, T. F., B.Ap.Sc. Napanee, Ontario, Canada.
1895. §Miller, Thomas, M.Inst.C.E. Thoroughfare, Ipswich.
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., M.Inst.C.E., F.G.S. Mansfield Woodhouse, Mansfield.
1834. Milne, Admiral Sir Alexander, Bart., G.C.B., F.R.S.E. Inveresk.
1885. ‡Milne, Alexander D. 40 Albyn-place, Aberdeen.
1882. *Milne, John, F.R.S., F.G.S. Shide Hill House, Shide, Isle of Wight.
1885. ‡Milne, J. D. 14 Rubislaw-terrace, Aberdeen.
1885. ‡Milne, William. 40 Albyn-place, Aberdeen.

Year of Election.

1887. ‡Milne-Redhead, R., F.L.S. Holden Clough, Clitheroe.
1882. ‡Milnes, Alfred, M.A., F.S.S. 22A Goldhurst-terrace, South Hampstead, London, N.W.
1880. ‡MINCHIN, G. M., M.A., F.R.S., Professor of Mathematics in the 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.
1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.
1885. ‡Mitchell, Rev. J. Mitford, B.A. 6 Queen's-terrace, Aberdeen.
1885. ‡Mitchell, P. Chalmers. Christ Church, Oxford.
1879. ‡MIVART, ST. GEORGE, Ph.D., M.D., F.R.S., F.L.S., F.Z.S. Hurstcote, Chilworth, Surrey.
1895. *Moat, William, M.A. Johnson, Eccleshall, Staffordshire.
1885. ‡Moffat, William. 7 Queen's-gardens, Aberdeen.
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, Ph.D., F.R.S., F.C.S. 20 Avenue-road, Regent's Park, London, N.W.
1891. *Mond, Robert Ludwig, B.A., F.R.S.E., F.G.S. 20 Avenue-road, Regent's Park, London, N.W.
1882. *Montagu, Sir Samuel, Bart., M.P. 12 Kensington Palace-gardens, London, W.
1892. ‡Montgomery, Very Rev. J. F. 17 Athole-crescent, Edinburgh.
1872. ‡Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1896. §Moore, A. W., M.A. Woodbourne House, Douglas, Isle of Man.
1884. ‡Moore, George Frederick. 49 Hardman-street, Liverpool.
1894. §Moore, H. E. 41 Bedford-row, London, W.C.
1891. ‡Moore, John. Lindenwood, Park-place, Cardiff.
1890. ‡Moore, Major, R.E. School of Military Engineering, Chatham.
*MOORE, JOHN CARRICK, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W.; and Corswall, Wigtonshire.
1857. *Moore, Rev. William Prior. Carrickmore, Galway, Ireland.
1896. §Mordry, W. M. Redholm, Loughborough.
1891. ‡Morel, P. Lavernock House, near Cardiff.
1881. ‡MORGAN, ALFRED. 50 West Bay-street, Jacksonville, Florida, U.S.A.
1895. §Morgan, C. Lloyd, F.G.S., Principal of University College, Bristol. 16 Canynge-road, Clifton, Bristol.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, S.W.
1891. ‡Morgan, F. Forest Lodge, Ruspidge, Gloucestershire.
1896. §Morgan, George. 61 Hope-street, Liverpool.
1887. ‡Morgan, John Gray. 38 Lloyd-street, Manchester.
1882. §Morgan, Thomas, J.P. Cross House, Southampton.
1889. §Morison, J. Rutherford, M.D. 14 Saville-row, Newcastle-upon-Tyne.
1892. ‡Morison, John, M.D., F.G.S. Victoria-street, St. Albans.
1867. ‡Morison, William R. Dundee.
1893. ‡Morland, John, J.P. Glastonbury.

Year of Election.

1895. §§Morley, Edward W., M.A., Ph.D., LL.D., Professor of Chemistry in the Western Reserve University, Cleveland, Ohio, U.S.A.
1891. ‡Morley, H. The Gas Works, Cardiff.
1883. *MORLEY, HENRY FORSTER, M.A., D.Sc., F.C.S. 47 Broadhurst-gardens, South Hampstead, London, N.W.
1889. ‡MORLEY, The Right Hon. JOHN, M.A., LL.D., M.P., F.R.S. 95 Elm Park-gardens, London, S.W.
1896. §Morrell, R. S. Caius College, Cambridge.
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.
1892. ‡Morris, Daniel, C.B., M.A., F.L.S. 11 Kew Gardens-road, Kew.
1883. ‡Morris, George Lockwood. Millbrook Iron Works, Swansea.
1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1883. ‡Morris, John. 4 The Elms, Liverpool.
1896. *Morris, J. T. 13 Somers-place, W.
1888. ‡Morris, J. W., F.L.S. The Woodlands, Bathwick Hill, Bath.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1874. ‡Morrison, G. J., M.Inst.C.E. Shanghai, China.
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. Hook House, Hook, near Winchfield, Hampshire.
1896. §Morton, William B. 9 Chilworth-buildings, Stranmillis-road, Belfast.
1883. ‡Moseley, Mrs. Firwood, Clevedon, Somerset.
1878. *Moss, JOHN FRANCIS, F.R.G.S. Beechwood, Brincliffe, Sheffield.
1876. §Moss, RICHARD JACKSON, F.I.C., M.R.I.A. Royal Dublin Society, and St. Aubyn's, Ballybrack, Co. Dublin.
1864. *Mosse, J. R. 5 Chiswick-place, Eastbourne.
1892. ‡Mossman, R. C., F.R.S.E. 10 Blacket-place, Edinburgh.
1873. ‡Mossman, William. Ovenden, Halifax.
1892. *Mostyn, S. G., B.A. Colet House, Talgarth-road, London, W.
1869. §MOTT, ALBERT J., F.G.S. Detmore, Charlton Kings, Cheltenham.
1866. §§MOTT, FREDERICK T., F.R.G.S. Crescent House, Leicester.
1862. *MOUAT, FREDERICK JOHN, M.D., Local Government Inspector. 12 Durham-villas, Campden Hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. Roseland, Meadfoot, Torquay.
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. The Wigwam, Ellenbrook, near Manchester.
1877. ‡MOUNT-EDGCUMBE, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
1887. ‡Moxon, Thomas B. County Bank, Manchester.
1888. ‡Moyle, R. E., B.A., F.C.S. The College, Cheltenham.
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.

Year of Election.

1894. ‡Mugliston, Rev. J., M.A. Newick House, Cheltenham.
1876. *Muir, Sir John, Bart. Demster House, Perthshire.
1874. ‡MUIR, M. M. PATTISON, M.A. Caius College, Cambridge
1876. ‡*Muir, Thomas, M.A., LL.D., F.R.S.E. Beechcroft, Bothwell, Glasgow.*
1872. ‡Muirhead, Alexander, D.Sc., F.C.S. 2 Prince's-street, Storey's-gate, Westminster, S.W.
1876. *Muirhead, Robert Franklin, M.A., B.Sc. 61 Warrender Park-road, Edinburgh.
1883. ‡MULHALL, MICHAEL G. Fancourt, Balbriggan, Co. Dublin.
1883. ‡Mulhall, Mrs. Marion. Fancourt, Balbriggan, Co. Dublin.
1891. ‡MÜLLER, The Right Hon. F. MAX, M.A., Professor of Comparative Philology in the University of Oxford. 7 Norham-gardens, Oxford.
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. 16 Elvaston-place, London, S.W.
1876. ‡Munro, Donald, F.C.S. The University, Glasgow.
1883. *MUNRO, ROBERT, M.A., M.D. 48 Manor-place, Edinburgh.
1864. *Murchison, K. R. Brockhurst, East Grinstead.
1855. ‡Murdoch, James Barclay. Capelrig, Mearns, Renfrewshire.
1890. ‡Murphy, A. J. Preston House, Leeds.
1889. ‡Murphy, James, M.A., M.D. Holly House, Sunderland.
1884. §Murphy, Patrick. Newry, Ireland.
1887. ‡Murray, A. Hazeldean, Kersal, Manchester.
1891. ‡Murray, G. R. M., F.R.S.E., F.L.S. British Museum (Natural History), South Kensington, London, S.W.
1859. ‡Murray, John, M.D. Forres, Scotland.
1884. ‡MURRAY, JOHN, LL.D., Ph.D., F.R.S., 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.
1892. ‡Murray, T. S. 1 Nelson-street, Dundee.
1863. ‡Murray, William, M.D. 9 Ellison-place, Newcastle-on-Tyne.
1883. ‡Murray, W. Vaughan, F.R.G.S. 2 Savile-row, London, W.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1891. ‡Muybridge, Eadweard. University of Pennsylvania, Philadelphia, U.S.A.
1890. *Myres, John L., M.A., F.S.A. Christ Church, Oxford.

1886. §NAGEL, D. H., M.A., F.C.S. Trinity College, Oxford.
1892. *Nairn, Michael B. Kirkcaldy, N.B.
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. 1 Beaufort-villas, Surbiton.
1887. ‡Nason, Professor Henry B., Ph.D., F.C.S. Troy, New York, U.S.A.
1896. §Neal, James E., U.S. Consul. 26 Chapel-street, Liverpool.
1887. §Neild, Charles. 19 Chapel Walks, Manchester.

Year of Election.

1883. *Neild, Theodore, B.A. Dalton Hall, Victoria Park, 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.
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.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
1889. *Newall, H. Frank. Madingley Rise, Cambridge.
1886. ‡Newbolt, F. G. Edenhurst, Addlestone, Surrey.
1842. *NEWMAN, Professor FRANCIS WILLIAM. 15 Arundel-crescent, Weston-super-Mare.
1889. §§Newstead, A. H. L., B.A. 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.
1892. ‡NEWTON, E. T., F.R.S., F.G.S. Geological Museum, Jermyn-street, London, S.W.
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.
1867. ‡NICHOLSON, HENRY ALLEYNE, M.D., D.Sc., F.G.S., Professor of Natural History in the University of Aberdeen.
1887. *Nicholson, John Carr. Moorfield House, 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.
1893. ‡Nickolls, John B., F.C.S. The Laboratory, Guernsey.
1887. ‡Nickson, William. Shelton, Sibson-road, Sale, Manchester.
1885. §Nicol, W. W. J., M.A., D.Sc., F.R.S.E. 15 Blacket-place, Edinburgh.
1896. §Nisbet, J. Tawse. 175 Lodge-lane, Liverpool.
1878. ‡NIVEN, CHARLES, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. 6 Chanonry, Aberdeen.
1877. ‡Niven, Professor 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, Sir ANDREW, K.C.B., F.R.S., F.R.A.S., F.C.S. Elswick Works, and Jesmond Dene House, Newcastle-upon-Tyne.
1879. ‡Noble, T. S., F.G.S. Lendal, York.
1886. ‡Nock, J. B. Mayfield, Penns, near Birmingham.
1887. ‡Nodal, John H. The Grange, Heaton Moor, near Stockport.
1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1863. §NORMAN, Rev. Canon ALFRED MERLE, M.A., D.C.L., F.R.S., F.L.S. Houghton-le-Spring, R.S.O., Co. Durham.
1888. ‡Norman, George. 12 Brock-street, Bath.

Year of Election.

1865. ‡NORRIS, RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1883. *Norris, William G. Coalbrookdale, R.S.O., Shropshire.
1881. ‡North, William, B.A., F.C.S. 84 Micklegate, York.
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.
1894. §NOTCUTT, S. A., LL.M., B.A., B.Sc. 9 Museum-street, Ipswich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1896. §Nugent, the Right Rev. Monsignor. 18 Adelaide-terrace, Waterloo, Liverpool.
1887. ‡Nursey, Perry Fairfax. 2 Trafalgar-buildings, Northumberland-avenue, London, W.C.

1882. §Obach, Eugene, Ph.D. 2 Victoria-road, Old Charlton, Kent.
O'Callaghan, George. Tallas, Co. Clare.
1878. ‡O'Conor Don, The. Clonalis, Castlerea, Ireland.
1883. ‡Odgers, William Blake, M.A., LL.D. 4 Elm-court, Temple, E.C.
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.
1894. §Ogden, James. Kilner Deyne, Rochdale.
1896. §Ogden, Thomas. 4 Prince's-avenue, Liverpool.
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., F.R.S.E. Heriot Watt College, Edinburgh.
1893. ‡Ogilvie, Miss Maria M., D.Sc. Gordon's College, Aberdeen.
1859. ‡Ogilvy, Rev. C. W. Norman. Baldan House, Dundee.
*Ogle, William, M.D., M.A. The Elms, Derby.
1884. ‡O'Halloran, J. S., C.M.G., F.R.G.S. Royal Colonial Institute, Northumberland-avenue, London, W.C.
1881. ‡Oldfield, Joseph. Lendal, York.
1887. ‡Oldham, Charles. Romiley, Cheshire.
1896. §Oldham, G. S. Town Hall, Birkenhead.
1892. §§Oldham, H. Yule, M.A., F.R.G.S., Lecturer in Geography in the University of Cambridge. King's College, Cambridge.
1853. ‡OLDHAM, JAMES, M.Inst.C.E. Cottingham, near Hull.
1885. ‡Oldham, John. River Plate Telegraph Company, Monte Video.
1893. ‡Oldham, R. D., F.G.S., Geological Survey of India. Care of Messrs. H. S. King & Co., Cornhill, London, E.C.
1892. ‡Oliphant, James. 50 Palmerston-place, Edinburgh.
1863. ‡OLIVER, DANIEL, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew, Surrey.
1887. ‡Oliver, F. W., D.Sc., Professor of Botany in University College, London. 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. 7 Ellison-place, Newcastle-upon-Tyne.

Year of Election.

1882. §Olsen, O. T., F.R.A.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
1860. *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. St. Michael's and All Angels, Portsea, Hants.
1872. ‡Onslow, D. Robert. New University Club, St. James's, 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. 2 Pembroke-vale, Clifton, Bristol.
1880. ‡O'Reilly, J. P., Professor of Mining and Mineralogy in the Royal College of Science, Dublin.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1883. ‡Orpen, Miss. 58 Stephen's-green, Dublin.
1884. *Orpen, Lieut.-Colonel R. T., R.E. Care of G. H. Orpen, Esq., Erpingham, Bedford Park, Chiswick, London.
1884. *Orpen, Rev. T. H., M.A. Binnbrooke, Cambridge.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1887. §§O'Shea, L. T., 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., Johns Hopkins University, Baltimore, U.S.A.
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. 14 Mill Hill-road, Derby.
1896. §Oulton, W. Hillside, Gateacre, Liverpool.
1882. ‡Owen, Rev. C. M., M.A. St. George's, Edgbaston, Birmingham.
1889. *Owen, Alderman H. C. Compton, Wolverhampton.
1896. §Owen, Peter. The Elms, Capenhurst, Chester.
1888. *Owen, Thomas, M.P. Henley-grove, Westbury-on-Trym, Bristol.
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.
1894. ‡Paget, Octavius. 158 Fenchurch-street, London, E.C.
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. Belton, Great Yarmouth.
1883. ‡Palgrave, Mrs. R. H. Inglis. Belton, Great Yarmouth.
1896. §Pallis, Alexander. Tatoi, Aigburth-drive, Liverpool.
1889. ‡PALMER, Sir CHARLES MARK, Bart., M.P. Grinkle Park, Yorkshire.
1873. ‡Palmer, George. The Acacias, Reading, Berks.
1878. *Palmer, Joseph Edward. Rose Lawn, Ballybrack, Co. Dublin.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
Palmes, Rev. William Lindsay, M.A. Naburn Hall, York.
1883. §Pant, F. J. Van der. Clifton Lodge, Kingston-on-Thames.
1886. ‡Panton, George A., F.R.S.E. 73 Westfield-road, Edgbaston, Birmingham.

Year of Election.

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. St. John's, Wakefield, Yorkshire.
1863. ‡Parker, Henry. Low Elswick, Newcastle-upon-Tyne.
1886. ‡Parker, Lawley. Chad Lodge, Edgbaston, Birmingham.
1891. ‡Parker, William Newton, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1879. ‡Parkin, William. The Mount, Sheffield.
1887. §Parkinson, James. Station-road, Turton, Bolton.
1859. ‡Parkinson, Robert, Ph.D. Yewbarrow House, Grange-over-Sands.
1862. *Parnell, John, M.A. Hadham House, Upper Clapton, London, N.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. Mountlands, Norfolk-road, Edgbaston, Birmingham.
1878. ‡Parsons, Hon. C. A. Elvaston Hall, Newcastle-upon-Tyne.
1883. ‡Part, Isabella. Rudleth, Watford, Herts.
1875. ‡Pass, Alfred C. Rushmere House, Durdham Down, Bristol.
1881. ‡Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.
1887. ‡Paterson, A. M., M.D., Professor of Anatomy in University College, Liverpool.
1896. §Paton, A. A. Greenbank-drive, Wavertree, Liverpool.
1884. *Paton, David. Johnstone, Scotland.
1883. *Paton, Henry, M.A. 15 Myrtle-terrace, Edinburgh.
1884. *Paton, Hugh. Care of the Sheddon Co., Montreal, Canada.
1871. *Patterson, A. Henry. 16 Ashburn-place, London, S.W.
1876. ‡Patterson, T. L. Maybank, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
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.
1879. *Patzer, F. R. Stoke-on-Trent.
1863. ‡PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1892. ‡Paul, J. Balfour. 30 Heriot-row, Edinburgh.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S. 35 Grosvenor-street, London, W.
1887. *Paxman, James. Stisted Hall, near Braintree, Essex.
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. 1 Botanic-avenue, The Plains, Belfast.
1881. ‡Payne, Mrs. 1 Botanic-avenue, The Plains, Belfast.
1866. ‡Payne, Joseph F., M.D. 78 Wimpole-street, London, W.
1888. *Paynter, J. B. Hendford Manor House, Yeovil.
1886. ‡Payton, Henry. Wellington-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., 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.

Year of Election

1888. §Pearce, Rev. R. J., D.C.L. Bedlington Vicarage, R.S.O., Northumberland.
1884. ‡Pearce, William. Winnipeg, Canada.
1886. ‡Pearsall, Howard D. 19 Willow-road, Hampstead, London, N.W.
1883. ‡Pearson, Arthur A. Colonial Office, London, S.W.
1891. ‡Pearson, B. Dowlais Hotel, Cardiff.
1893. *Pearson, Charles E. Chilwell House, Nottinghamshire.
1883. ‡Pearson, Miss Helen E. 69 Alexandra-road, Southport.
1892. ‡Pearson, J. M. John Dickie-street, Kilmarnock.
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. 57 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., M.P. 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.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
*Peckover, Alexander, LL.D., F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1885. ‡Peddie, William, D.Sc., F.R.S.E. 2 Cameron Park, Edinburgh.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1883. ‡PEEK, CUTHBERT E., M.A., F.S.A. 22 Belgrave-square, London, S.W.
1878. *Peek, William. The Manor House, Kemp Town, Brighton.
1881. ‡Peggs, J. Wallace. 21 Queen Anne's-gate, London, S.W.
1861. *Peile, George. Greenwood, Shotley Bridge, Co. Durham.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, London, W.C.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1887. §§PENDLEBURY WILLIAM H., M.A., F.C.S. 6 Gladstone-terrace, Priory Hill, Dover.
1894. §Pengelly, Miss. Lamorna, Torquay.
1894. §Pengelly, Miss Hester. Lamorna, Torquay.
1896. §Pennant, P. P. Nantlys, St. Asaph.
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. 16 Ellison-place, Newcastle-upon-Tyne.
1895. §Percival, John, M.A. The South-Eastern Agricultural College, Wye, Kent.
*Perigal, Frederick. Cambridge Cottage, Kingswood, Reigate.
1894. ‡Perkin, A. G., F.R.S.E., F.C.S., F.I.C. 8 Montpelier-terrace, Woodhouse Cliff, Leeds.
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 Organic Chemistry in Owens College, Manchester.
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.
1874. *PERRY, JOHN, M.E., D.Sc., F.R.S. 31 Brunswick-square, London, W.C.
1883. ‡Perry, Ottley L., F.R.G.S. Bolton-le-Moors, Lancashire.

Year of Election.

1883. ‡Perry, Russell R. 34 Duke-street, Brighton.
1883. ‡Petrie, Miss Isabella. Stone Hill, Rochdale.
1895. §PETRIE, W. M. FLINDERS, D.C.L., Professor of Egyptology in University College, London, W.C.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 13 Fourth Avenue, Brighton.
1882. ‡Pfoundes, Charles. Spring Gardens, London, S.W.
1886. ‡Phelps, Major-General 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.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, London, S.W.
1892. ‡Philip, R. W., M.D. 4 Melville-crescent, Edinburgh.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
1877. §Philips, T. Wishart. Elizabeth Lodge, George-lane, Woodford, 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.
1894. §Phillips, Staff-Commander E. C. D., R.N., F.R.G.S. 14 Hargreaves-buildings, Chapel-street, Liverpool.
1896. §Phillips, George, jun. 14 Holly-road, Fairfield, Liverpool.
1887. ‡Phillips, H. Harcourt, F.C.S. 183 Moss-lane East, Manchester.
1892. §Phillips, J. H. Poole, Dorset.
1880. ‡Phillips, John H., Hon. Sec. Philosophical and Archæological Society, Scarborough.
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.
1868. ‡PHIPSON, T. L., Ph.D., F.C.S. 4 The Cedars, Putney, Surrey, S.W.
1894. ‡PICKARD-CAMBRIDGE, Rev. O., M.A., F.R.S. Bloxworth Rectory, Wareham.
1884. *Pickard, Rev. H. Adair, M.A. 5 Canterbury-road, Oxford.
1883. *Pickard, Joseph William. Oatlands, Lancaster.
1885. *PICKERING, SPENCER U., M.A., F.R.S., F.C.S. 48 Bryanston-square, London, W.
1884. *Pickett, Thomas E., M.D. Maysville, Mason Co., Kentucky, U.S.A.
1896. §Picton, W. H. College-avenue, Crosby, Liverpool.
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.
1896. *Pilkington, A. C. The Hazels, Prescot, Lancashire.
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.

Year of Election.

1883. ‡Pitt, George Newton, M.A., M.D. 24 St. Thomas-street, London, S.E.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1883. ‡Pitt, Sydney. 16 St. Andrew's-street, Holborn-circus, London, E.C.
1893. *Pitt, Walter, M.Inst.C.E. South Stoke House, near Bath.
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.
1842. Playfair, The Right Hon. Lord, G.C.B., Ph.D., LL.D., F.R.S., F.R.S.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, S.W.
1893. ‡Plowright, Henry J., F.G.S. Brampton Foundries, Chesterfield.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
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.
1896. *Pollex, Albert. Dale-road, Cavendish Park, Rockferry.
*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1891. ‡Pomeroy, Captain Ralph. 201 Newport-road, Cardiff.
1892. §Popplewell, W. C., M.Sc. Yorkshire College, Leeds.
1868. ‡Portal, Wyndham S. Malshanger, Basingstoke.
1883. *Porter, Rev. C. T., LL.D. All Saints' Vicarage, Southport.
1883. ‡Postgate, Professor J. P., M.A. Trinity College, Cambridge.
1863. ‡Potter, D. M. Cramlington, near Newcastle-upon-Tyne.
1887. ‡Potter, Edmund P. Hollinhurst, Bolton.
1883. ‡Potter, M. C., M.A., F.L.S., Professor of Botany in the College of Science, Newcastle-upon-Tyne. 14 Portland-terrace, Newcastle-upon-Tyne.
1886. *Poulton, Edward B., M.A., F.R.S., F.L.S., F.G.S., F.Z.S., Professor of Zoology in the University of Oxford. Wykeham House, Banbury Road, Oxford.
1873. *Powell, Sir Francis S., Bart., 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.
1894. *Powell, Richard Douglas, M.D. 62 Wimpole-street, London, W.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1887. §Pownall, George H. Manchester and Salford Bank, St. Ann-street, Manchester.
1867. ‡Powrie, James. Reswallie, Forfar.
1883. ‡Poynting, J. H., D.Sc., F.R.S., Professor of Physics in the Mason College, Birmingham.
1884. ‡Prance, Courtenay C. Hatherley Court, Cheltenham.
1884. *Prankerd, A. A., D.C.L. 27 Norham-road, Oxford.
1891. ‡Pratt, Bickerton. Brynderwen, Maindee, Newport, Monmouthshire.

Year of Election.

1869. *PREECE, WILLIAM HENRY, C.B., F.R.S., M.Inst.C.E. Gothic Lodge, Wimbledon Common, Surrey.
1888. *Preece, W. Llewellyn. Telegraph Department, Midland Railway, Derby.
1884. *Premio-Real, His Excellency the Count of. Quebec, Canada.
1894. §Prentice, Manning, F.C.S. Woodfield, Stowmarket.
1892. §Prentice, Thomas. Willow Park, Greenock.
1889. §Preston, Alfred Eley, M.Inst.C.E., F.G.S. 14 The Exchange, Bradford, Yorkshire.
1894. ‡Preston, Arthur E. Piccadilly, Abingdon, Berkshire.
1893. *Preston, Martin Inett. 9 St. James's-terrace, Nottingham.
1893. §PRESTON, Professor THOMAS. Bardowie, Orwell Park, Dublin.
1884. *Prevost, Major L. de T. 2nd Battalion Argyll and Sutherland Highlanders.
1856. *PRICE, Rev. BARTHOLOMEW, M.A., D.D., F.R.S., F.R.A.S., Master of Pembroke College, 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.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1891. ‡Price, William. 40 Park-place, Cardiff.
1892. ‡Prince, Professor Edward E. Canada.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. St. Giles, Norwich.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 26 Wimpole-street, London, W.
1888. ‡Probyn, Leslie C. Onslow-square, London, S.W.
1881. §§Procter, John William. Ashcroft, York.
1863. ‡Proctor, R. S. Grey-street, Newcastle-upon-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1885. ‡Profeit, Dr. Balmoral, N.B.
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.
1872. *Pryor, M. Robert. Weston, Stevenage, Herts.
1871. *Puckle, Thomas John. 42 Cadogan-place, London, S.W.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Sir Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Ochil, Perth.
1891. ‡Pullen, W. W. F. University College, Cardiff.
1842. *Pumphrey, Charles. Southfield, King's Norton, near Birmingham.
1887. §PUMPHREY, WILLIAM. 2 Oakland-road, Redland, Bristol.
1885. §PURDIE, THOMAS, B.Sc., Ph.D., F.R.S., Professor of Chemistry in the University of St. Andrews. 14 South-street, 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 Stratford-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.

Year of Election.

1868. ‡Pye-Smith, P. H., M.D., F.R.S. 48 Brook-street, W.; and Guy's Hospital, London, S.E.
1879. ‡Pye-Smith, R. J. 350 Glossop-road, Sheffield.

1896. §Quaill, Edward. 3 Palm-grove, Claughton.
1893. ‡Quick, James. University College, Bristol.
1894. ‡Quick, Professor Walter J. University of Missouri, Columbia, U.S.A.

1870. ‡Rabbits, W. T. 6 Cadogan-gardens, London, S.W.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
1896. §Radcliffe, Herbert. Balderstone Hall, Rochdale.
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. Mayfield, Woolston, Southampton.
1888. ‡Radway, C. W. 9 Bath-street, Bath.
1887. *Ragdale, John Rowland. The Beeches, Whitefield, Manchester.
1864. ‡Rainey, James T. 3 Kent-gardens, Ealing, London, W.
Rake, Joseph. Charlotte-street, Bristol.
1896. *Ramage, Hugh. 10 Bridle-road, Crewe.
1894. *Rambaut, Arthur A., M.A., D.Sc., F.R.A.S., M.R.I.A., Andrews' Professor of Astronomy in the University of Dublin, and Astronomer Royal for Ireland. Dunsink Observatory, Co. Dublin.
1885. ‡Ramsay, Major. Straloch, N.B.
1863. ‡Ramsay, Alexander, F.G.S. 2 Cowper-road, Acton, Middlesex, W.
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.
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.
1835. *Rance, Henry. 6 Ormond-terrace, Regent's Park, London, N.W.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, West Kensington, London, W.
1868. *Ransom, Edwin, F.R.G.S. 24 Ashburnham-road, Bedford.
1893. ‡Ransom, W. B., M.D. The Pavement, Nottingham.
1863. ‡Ransom, William Henry, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡Ransome, Arthur, M.A., M.D., F.R.S. Sunninghurst, Deane Park, Bournemouth.
Ransome, Thomas. Hest Bank, near Lancaster.
1889. §Rapkin, J. B. Sidcup, Kent.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.
1864. ‡Rate, Rev. John, M.A. Fairfield, East Twickenham.
1892. §Rathbone, Miss May. Backwood, Neston, Cheshire.
1870. §Rathbone, R. R. Glan y Menai, Anglesey.
1895. ‡Rathbone, W., LL.D. Green Bank, Liverpool.
1874. ‡Ravenstein, E. G., F.R.G.S., F.S.S. Albion House, 91 Upper Tulse-hill, London, S.W.
1889. ‡Rawlings, Edward. Richmond House, Wimbledon Common, Surrey.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.

Year of Election.

1866. *RAWLINSON, Rev. Canon GEORGE, M.A. The Oaks, Precincts, Canterbury.
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.
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.
1895.§§Raynbird, Hugh, jun. Garrison Gateway Cottage, Old Basing, Basingstoke.
1883. *Rayne, Charles A., M.D., M.R.C.S. Queen-street, Lancaster.
1896. §Read, Charles H., F.S.A. British Museum, London, W.C.
*Read, W. H. Rudston, M.A. 12 Blake-street, York.
1870. ‡READE, THOMAS MELLARD, F.G.S. Blundellsands, Liverpool.
1884. §Readman, J. B., D.Sc., F.R.S.E. 4 Lindsay-place, Edinburgh.
1852. *REDFERN, Professor PETER, M.D. 4 Lower-crescent, Belfast.
1892. ‡Redgrave, Gilbert R., Assoc.M.Inst.C.E. The Elms, Westgate-road, Beckenham, Kent.
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.*
1890. *Redwood, Boverton, F.R.S.E., F.C.S. 4 Bishopsgate-street Within, London, E.C.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1891. ‡Reece, Lewis Thomas. Somerset House, Roath, Cardiff.
1861. ‡REED, Sir EDWARD JAMES, K.C.B., F.R.S. 75 Harrington-gardens, London, S.W.
1889. ‡Reed, Rev. George. Bellingham Vicarage, Bardon Mill, Carlisle.
1891. *Reed, Thomas A. Bute Docks, Cardiff.
1894. *Rees, Edmund S. G. 15 Merridale-lane, Wolverhampton.
1891. §Rees, I. Treharne, M Inst.C.E. Highfield, Penarth.
1891. ‡Rees, Samuel. West Wharf, Cardiff.
1891. ‡Rees, William. 25 Park-place, Cardiff.
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.L.S., F.G.S. 28 Jermyn-street, London, S.W.
1892. ‡Reid, E. Waymouth, B.A., Professor of Physiology in University College, Dundee.
1889. ‡Reid, G., Belgian Consul. Leazes House, Newcastle-upon-Tyne.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1892.§§Reid, Thomas. University College, Dundee.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1893.§§Reinach, Baron Albert von. Frankfort s. M., Prussia.
1875. §REINOLD, A. W., M.A., F.R.S., Professor of Physics in the Royal Naval College, Greenwich, S.E.
1863. ‡RENALS, E. 'Nottingham Express' Office, Nottingham.
1894. §RENDALL, G. H., M.A., Principal of University College, Liverpool.
1891. §Rendell, Rev. J. R. Whinside, Whalley-road, Accrington.
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. 2 Waterloo Road, Birkdale, Southport.

Year of
Election.

1871. ‡REYNOLDS, JAMES EMERSON, M.D., D.Sc., 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, and Cliff Lodge, Hyde Park, Leeds.
1896. §Reynolds, Richard S. 73 Smithdown-lane, Liverpool.
1896. §Rhodes, Albert. Fieldhurst, Liversidge, Yorkshire.
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. Potternewton House, Chapel Allerton, 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. Rua Muro, 14, Modena, Italy.
1891. ‡Richards, D. 1 St. Andrew's-crescent, Cardiff.
1891. ‡Richards, H. M. 1 St. Andrew's-crescent, Cardiff.
1889. ‡Richards, Professor T. W., Ph.D. Cambridge, Massachusetts, U.S.A.
1888. *RICHARDSON, ARTHUR, M.D. University College, Bristol.
1863. ‡RICHARDSON, Sir BENJAMIN WARD, M.A., M.D., LL.D., F.R.S. 25 Manchester-square, London, W.
1869. *Richardson, Charles. 6 The Avenue, Bedford Park, Chiswick, London.
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.
1896. §Richardson, Nelson M. Montevideo, Chickerell, near Weymouth.
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.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1891. ‡Riches, Carlton H. 21 Dumfries-place, Cardiff.
1891. §Riches, T. Hurry. 8 Park-grove, Cardiff.
1886. §Richmond, Robert. Leighton Buzzard.
1868. ‡RICKETTS, CHARLES, M.D., F.G.S. 19 Hamilton-square, Birkenhead.
*RIDDELL, Major-General CHARLES J. BUCHANAN, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1883. *RIDEAL, SAMUEL, D.Sc., F.C.S. 28 Victoria-mansions, London, S.W.
1894. §RIDLEY, E. P. 6 Paget-road, Ipswich.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1889. ‡Ridley, Thomas D. Coatham, Redcar.
1884. ‡Ridout, Thomas. Ottawa, Canada.
1881. *Rigg, Arthur. 5 Harewood-square, London, N.W.
1883. *RIGG, EDWARD, M.A. Royal Mint, London, E.
1883. ‡*Rigg, F. F., M.A. 32 Queen's-road, Southport.*
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.
1873. ‡Ripley, Sir Edward, Bart. Acacia, Apperley, near Leeds.

Year of Election.

*RIPON, The Most Hon. the Marquess 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.
1892. ‡Ritchie, R. Peel, M.D., F.R.S.E. 1 Melville-crescent, Edinburgh.
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.*
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. 30 St. George's-square, Regent's Park, London, N.W.
1859. ‡Roberts, George Christopher. Hull.
1870. *ROBERTS, ISAAC, D.Sc., F.R.S., F.R.A.S., F.G.S. Starfield, Crowborough, Sussex.
1894. *Roberts, Miss Janora. 5 York-road, Birkdale, Southport.
1891. ‡*Roberts, Rev. John Crossby, F.R.G.S. 41 Derby-road, East Park, Northampton.*
1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. 17 Charterhouse-square, London, E.C.
1879. ‡Roberts, Samuel. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1896. §Roberts, Thomas J. 31 North-road, Cowley Hill, St. Helens.
1883. ‡ROBERTS, Sir WILLIAM, M.D., F.R.S. 8 Manchester-square, 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.
1884. ‡Robertson, E. Stanley, M.A. 43 Waterloo-road, Dublin.
1883. ‡Robertson, George H. Plas Newydd, Llangollen.
1883. ‡Robertson, Mrs. George H. Plas Newydd, Llangollen.
1892. ‡Robertson, W. W. 3 Parliament-square, Edinburgh.
1888. *Robins, Edward Cookworthy, F.S.A. 8 Marlborough-road, St. John's Wood, London, N.W.
1886. *Robinson, C. R. 27 Elvetham-road, Birmingham.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1887. §Robinson, Henry, M.Inst.C.E. 13 Victoria-street, London, S.W.
1888. ‡Robinson, John. 8 Vicarage-terrace, Kendal.
1863. ‡Robinson, J. H. 6 Montallo-terrace, Barnard Castle.
1878. ‡Robinson, John L. 198 Great Brunswick-street, Dublin.
1895. *Robinson, Joseph Johnson. 8 Trafalgar-road, Birkdale, Southport.
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.
1891. ‡Robinson, William, Assoc.M.Inst.C.E., Professor of Engineering in University College, Nottingham.
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.
1872. *Robson, William. 5 Gillsland-road, Merchiston, Edinburgh.
1890. ‡Rochester, The Right Rev. the Lord Bishop of, Kennington-park, S.E.
1896. §Rock, W. H. 75 Botanic-road, Liverpool.
1896. §Rodger, Alexander M. The Museum, Tay Street, Perth.

Year of Election.

1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1894. *Rodger, J. W. 80 Anerley-park, London, S.E.
1885. *Rodriguez, Epifanio. 12 John-street, Adelphi, London, W.C.
1866. ‡Roe, Sir Thomas. Grove-villas, Litchurch.
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.
1884. *Rogers, Walter M. Lamowa, Falmouth.
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.
1892. *Romanes, John. 3 Oswald-road, Edinburgh.
1891. ‡Rönnfeldt, W. 43 Park-place, Cardiff.
1894. *Rooper, T. Godolphin. The Elms, High Harrogate.
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. Town Clerk, Lancaster.
1855. *ROSCOE, Sir HENRY ENFIELD, B.A., Ph.D., LL.D., D.C.L., F.R.S. 10 Bramham-gardens, London, S.W.
1883. *Rose, J. Holland, M.A. 11 Endlesham-road, Balham, London, S.W.
1892. ‡Rose, Hugh. Kilravock Lodge, Blackford-avenue, Edinburgh.
1894. *Rose, T. K., D.Sc. 9 Royal Mint, London, E.
1885. ‡Ross, Alexander. Riverfield, Inverness.
1874. ‡Ross, Alexander Milton, M.A., M.D., F.G.S. Toronto, Canada.
1887. ‡Ross, Edward. Marple, Cheshire.
1880. ‡Ross, Captain G. E. A., F.G.S. 8 Collingham-gardens, Cromwell-road, London, S.W.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
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.
1891. §Roth, H. Ling. 32 Prescott-street, Halifax, Yorkshire.
1893. ‡Rothera, G. B. Sherwood Rise, Nottingham.
1865. *Rothera, George Bell, F.L.S. Orston House, Sherwood Rise, Nottingham.
1876. ‡Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1884. *Rouse, M. L. 54 Westbourne-villas, West Brighton.
1861. ‡ROUTH, EDWARD J., M.A., D.Sc., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1861. ‡Rowan, David. Elliot-street, Glasgow.
1883. ‡Rowan, Frederick John. 134 St. Vincent-street, Glasgow.
1887. ‡*Rowe, Rev. Alfred W., M.A. 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.
1881. *ROWNTREE, JOHN S. Mount Villas, York.
1881. *Rowntree, Joseph. 38 St. Mary's, York.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1883. ‡ROY, CHARLES S., M.D., F.R.S., Trinity College, Cambridge.
1885. ‡Roy, John. 33 Belvidere-street, Aberdeen.
1888. ‡Roy, Parbati Churn, B.A. Calcutta, Bengal, India.

Year of Election.

1875. *Rücker, A. W., M.A., D.Sc., F.R.S., Professor of Physics in the Royal College of Science, London. (General Treasurer.) 19 Gledhow-gardens, South Kensington, London, S.W.
1892. §Rücker, Mrs. Levetleigh, Dane-road, St. Leonard's-on-Sea.
1869. §Rudler, F. W., F.G.S. The Museum, Jermyn-street, London, S.W.
1882. ‡Rumball, Thomas, M.Inst.C.E. 8 Union-court Chambers, Old Broad-street, London, E.C.
1896. §Rundell, T. W. 25 Castle-street, Liverpool.
1887. §Ruscoe, John, F.R.G.S., F.G.S. Ferndale, Gee Cross, near Manchester.
1847. ‡Ruskin, John, M.A., D.C.L., F.G.S. Brantwood, Coniston, Ambleside.
1889. ‡Russell, The Right Hon. Earl. Amberley Cottage, Maidenhead.
1875. *Russell, The Hon. F. A. R. Dunrozel, Haslemere.
1884. ‡Russell, George. 13 Church-road, Upper Norwood, London, S.E.
1890. ‡Russell, J. A., M.B. Woodville, Canaan-lane, Edinburgh.
1883. *Russell, J. W. 16 Bardwell-road, Oxford.
Russell, John. 39 Mountjoy-square, Dublin.
1852. *Russell, Norman Scott. Arts Club, Hanover-square, London, W.
1876. ‡Russell, Robert, F.G.S. 1 Sea View, St. Bees, Carnforth.
1886. ‡Russell, Thomas H. 3 Newhall-street, Birmingham.
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. Monk's Manor, Lincoln.
1891. §Rutherford, George. Garth House, Taff's Well, Cardiff.
1871. §Rutherford, William, M.D., F.R.S., F.R.S.E., Professor of Physiology in the University of Edinburgh.
1887. ‡Rutherford, William. 7 Vine-grove, Chapman-street, Hulme, Manchester.
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.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1861. *Rylands, Thomas Glazebrook, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. 186 Aldersgate-street, London, E.C.
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. 225 Castle-road, Cardiff.
1893. ‡Salisbury, The Most Hon. the Marquis of, K.G., D.C.L., F.R.S. 20 Arlington Street, London, S.W.
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. Kingswood-road, Upper Norwood, S.E.
1873. *Salomons, Sir David, Bart., F.G.S. Broomhill, Tunbridge Wells.
1872. ‡Salvin, Osbert, M.A., F.R.S., F.L.S. Hawksfold, Haslemere.
1887. ‡Samson, C. L. Carmona, Kersal, Manchester.

Year of Election.

1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1894. §SAMUELSON, The Right Hon. Sir BERNHARD, Bart., F.R.S., M.Inst.C.E. 56 Prince's-gate, London, S.W.
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.
1883. ‡Sanderson, Deputy Surgeon-General Alfred. East India United Service Club, St. James's-square, London, S.W.
1872. §SANDERSON, J. S. BURDON, M.A., M.D., D.Sc., LL.D., D.C.L., F.R.S., F.R.S.E., Regius Professor of Medicine in the University of Oxford. 64 Banbury-road, Oxford.
1883. ‡Sanderson, Mrs. Burdon. 64 Banbury-road, Oxford.
1893. ‡Sanderson, F. W., M.A. The School, Oundle.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1896. §Saner, John Arthur, Assoc.M.Inst.C.E. Highfield, Northwich.
1896. §Saner, Mrs. Highfield, Northwich.
1892. §Sang, William D. 28 Whyte's Causeway, Kirkcaldy, Fife.
1886. §Sankey, Percy E. Down Lodge, Fairlight, Hastings.
1896. *Sargant, Miss Ethel. Quarry Hill, Reigate.
1896. §Sargant, W. L. Quarry Hill, Reigate.
1886. ‡Sauborn, John Wentworth. Albion, New York, U.S.A.
1886. ‡Saundby, Robert, M.D. 83A Edmund-street, Birmingham.
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.
1891. ‡Saunders, W. H. R. Llanishen, Cardiff.
1884. ‡Saunderson, C. E. 26 St. Famille-street, Montreal, Canada.
1887. §Savage, Rev. E. B., M.A., F.S.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. 55 Buckingham-place, Brighton.
1887. §SAYCE, Rev. A. H., M.A., D.D., Professor of Assyriology in the University of Oxford. Queen's College, Oxford.
1884. ‡Sayre, Robert H. Bethlehem, Pennsylvania, U.S.A.
1883. *Scarborough, George. Whinney Field, Halifax, Yorkshire.
1884. ‡Scarth, William Bain. Winnipeg, Manitoba, Canada.
1879. *SCHÄFER, E. A., F.R.S., M.R.C.S., Professor of Physiology in University College, London. (GENERAL SECRETARY.) Croxley Green, Rickmansworth.
1888. *SCHARFF, ROBERT F., Ph.D., B.Sc., Keeper of the Natural History Department, Museum of Science and Art, Dublin.
1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1892. ‡Schloss, David F. 1 Knaresborough-place, London, S.W.
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. Eden-terrace, Harriet-street, Stretford, Manchester.
SCHUNCK, EDWARD, Ph.D., F.R.S., F.C.S. Oaklands, Kersal Moor, Manchester.

Year of Election

1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S., Professor of Physics in the Owens College, 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, W. LUTLEY, M.A., F.Z.S. South African Museum, Cape Town.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1881. *Scott, Alexander, M.A., D.Sc. University Chemical Laboratory, Cambridge.
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 Angas, D.Sc. Lancashire College, Whalley Range, Manchester.
1889. *SCOTT, D. H., M.A., Ph.D., F.R.S., F.L.S. The Old Palace, Richmond, Surrey.
1885. ‡Scott, George Jamieson. Bayview House, Aberdeen.
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.
1884. *Scott, Sydney C. 28 The Avenue, Gipsy Hill, S.E.
1869. ‡Scott, William Bower. Chudleigh, Devon.
1895. §Scott-Elliott, G. F., M.A., B.Sc., F.L.S. Newton, Dumfries.
1881. *Scrivener, A. P. Haglis House, Wendover.
1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1895. §Scull, Miss E. M. L. 2 Langland-gardens, Finchley-road, London, N.W.
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.
1861. *SEELEY, HARRY GOVIER, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geology in King's College, London. 25 Palace Gardens-terrace, Kensington, London, W.
1895. ‡SEFTON, The Right Hon. the Earl of. Abbeystead, Lancaster.
1891. ‡Selby, Arthur L., M.A., Assistant Professor of Physics in University College, Cardiff.
1893. ‡SELBY-BIGGE, L. A., M.A. University College, Oxford.
1855. ‡Seligman, H. L. 27 St. Vincent-place, Glasgow.
1879. ‡Selim, Adolphus. 21 Mincing-lane, London, E.C.
1885. ‡Semple, Dr. A. United Service Club, Edinburgh.
1887. §Semple, James C., F.R.G.S., M.R.I.A. 2 Marine-terrace, Kingstown, Co. Dublin.
1892. ‡*Semple, William. Gordon's College, Aberdeen.*
1888. *SENIER, ALFRED, M.D., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.
1858. *Senior, George. Ashgate-road, Chesterfield.
1888. *Sennett, Alfred R., A.M.Inst.C.E. Crystal Palace, London, S.E.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1892.§§Seton, Miss Jane. 37 Candlemaker-row, Edinburgh.
1895. §Seton-Karr, H. W. Atherton Grange, Wimbledon, Surrey.
1892. §Seward, A. C., M.A., F.G.S. 33 Chesterton-road, Cambridge.
1891. ‡Seward, Edwin. 55 Newport-road, Cardiff.
1868. ‡Sewell, Philip E. Catton, Norwich.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.

Year of Election.

1888. ‡Shackles, Charles F. Hornsea, near Hull.
1883. ‡Shadwell, John Lancelot. 30 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.A., M.B., F.R.S., F.L.S. Museum of Zoology, Cambridge.
1896. §Sharp, Mrs. E. 65 Sankey-street, Warrington.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1886. ‡Sharp, T. B. French Walls, Birmingham.
1883. ‡Sharples, Charles H., F.C.S. 7 Fishergate, Preston.
1870. ‡Shaw, Duncan. Cordova, Spain.
1896. §Shaw, Frank. Ellerslie, Aigburth-drive, Liverpool.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1887. *Shaw, James B. 7 The Beeches, Didsbury, Manchester.
1870. ‡Shaw, John. 21 St. James's-road, Liverpool.
1891. ‡Shaw, Joseph. 1 Temple-gardens, London, E.C.
1889. *Shaw, Mrs. M. S., B.Sc. Halberton, near Tiverton, Devon.
1887. §Shaw, Saville, F.C.S. College of Science, Newcastle-upon-Tyne.
1883. *SHAW, W. N., M.A., F.R.S. Emmanuel House, Cambridge.
1883. ‡Shaw, Mrs. W. N. Emmanuel House, Cambridge.
1891. ‡Sheen, Dr. Alfred. 23 Newport-road, Cardiff.
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.
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. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Rev. Edgar. Bentham Rectory, *viâ* Lancaster.
1896. §SHERRINGTON, C. S., M.D., F.R.S., Professor of Physiology in University College, Liverpool. 16 Grove-road, Liverpool.
1888. *Shickle, Rev. C. W., M.A. Langridge Rectory, Bath.
1886. ‡Shield, Arthur H. 35A Great George-street, London, S.W.
1892. ‡Shields, John, D.Sc., Ph.D. Dolphingston, Tranent, Scotland.
1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, 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, J. N., M.Inst.C.E., F.G.S. 47 Victoria-street, S.W.
1888. ‡Shoppee, C. H. 22 John-street, Bedford-row, London, W.C.
1875. ‡SHORE, THOMAS W., F.G.S. Hartley Institution, Southampton.
1882. ‡SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital, E.C.
1889. ‡Sibley, Walter K., B.A., M.B. 7 Upper Brook-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.

Year of Election.

1877. *Sidebotham, Joseph Watson, M.P. 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. Upper Queen-street, Belfast.
1876. ‡Simon, Frederick. 24 Sutherland-gardens, London, W.
1887. *Simon, Henry. Lawnhurst, 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.
1893. ‡Simpson, A. H., F.R.Met.Soc. Attenborough, Nottinghamshire.
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.
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., 9 Barton-street, West Kensington, London, W.
1894. §Simpson, Thomas. Fennymere, Castle Bar, Ealing, London, W.
1883. ‡Simpson, Walter M. 7 York-road, Birkdale, Southport.
1896. *Simpson, W., F.G.S. The Gables, Halifax.
1887. ‡Sinclair, Dr. 268 Oxford-street, Manchester.
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1870. *Sinclair, W. P. Rivelyn, Prince's Park, Liverpool.
1864. *Sircar, The Hon. Mahendra Lal, M.D., C.I.E. 51 Sankaritola, Calcutta.
1892. ‡Sisley, Richard, M.D. 11 York-street, Portman-square, London, W.
1879. ‡Skertchly, Sydney B. J. 3 Loughborough-terrace, Carshalton, Surrey.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1885. ‡Skinner, Provost. Inverurie, N.B.
1892. ‡Skinner, William. 35 George-square, Edinburgh.
1888. §Skrine, H. D., J.P., D.L. Claverton Manor, Bath.
1870. §Sladen, Walter Percy, F.G.S., F.L.S. 13 Hyde Park-gate, London, S.W.
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.
1891. §Slocombe, James. Redland House, Fitzalan, Cardiff.
1884. ‡Slooten, William Venn. Nova Scotia, Canada.
1849. ‡Sloper, George Elgar. Devizes.
1887. §Small, Evan W., M.A., B.Sc., F.G.S. County Council Offices, Newport, Monmouthshire.
1887. §Small, William. Lincoln-circus, The Park, Nottingham.
1885. §Smart, James. Valley Works, Brechin, N.B.
1889. *Smart, William, LL.D. Nunholme, Dowanhill, Glasgow.
1876. ‡Smellie, Thomas D. 213 St. Vincent-street, Glasgow.

Year of Election.

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.
1892. ‡SMITH, ADAM GILLIES, F.R.S.E. 35 Drumsheugh-gardens, Edinburgh.
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. The University, Chicago, Illinois, U.S.A.
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, Professor C. Michie, B.Sc., F.R.S.E., F.R.A.S. The Observatory, Madras.
1865. ‡SMITH, DAVID, F.R.A.S. 40 Bennett's-hill, Birmingham.
1886. ‡Smith, Edwin. 33 Wheeley's-road, Edgbaston, Birmingham.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1886. ‡Smith, E. Fisher, J.P. The Priory, Dudley.
1886. ‡Smith, E. O. Council House, Birmingham.
1892. ‡Smith, E. Wythe. 66 College-street, Chelsea, London, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1887. §SMITH, Rev. F. J., M.A., F.R.S. Trinity College, Oxford.
1892. ‡*Smith, Rev. Frederick. 16 Grafton-street, Glasgow.*
1885. ‡Smith, Rev. G. A., M.A. 21 Sardinia-terrace, Glasgow.
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, E.
1888. ‡Smith, H. W. Owens College, Manchester.
1885. ‡Smith, Rev. James, B.D. Manse of Newhills, N.B.
1876. *Smith, J. Guthrie. 5 Kirklee-gardens, Kelvinside, Glasgow.
Smith, John Peter George. Sweyney Cliff, Coalport, Iron Bridge, Shropshire.
1883. ‡Smith, M. Holroyd. Royal Insurance Buildings, Crossley-street, Halifax.
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.
1894. §Smith, T. Walrond. 32 Victoria Street, Westminster, S.W.
1884. ‡Smith, Vernon. 127 Metcalfe-street, Ottawa, Canada.
1892. ‡Smith, Walter A. 120 Princes-street, Edinburgh.
1885. *Smith, Watson. University College, London, W.C.
1896. *Smith, Rev. W. Hodson. 29 Hope-street, Liverpool.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.

Year of
Election.

1875. *Smith, William. Sundon House, Clifton Downs, 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.
1892. §Smithson, G. E. T. Tyneside Geographical Society, Barras Bridge, Newcastle-upon-Tyne.
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. Firwood, Chalford, Stroud.
1857. *SMYTH, JOHN, 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. Brightside, Salusbury-road, Brondesbury, London, N.W.
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.
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, and Lisnabin, Dartry Park-road, Rathgar, Dublin.
1892. *Somervail, Alexander. Torquay.
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, Ranmoor, Sheffield.
1892. ‡Sorley, James, F.R.S.E. 18 Magdala-crescent, Edinburgh.
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. 44 Brown-street, 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.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1889. ‡*Spence, Faraday. 67 Grey-street, Hexham.*
1887. ‡Spencer, F. M. Fernhill, Knutsford.
1884. §Spencer, John, M.Inst.M.E. Globe Tube Works, Wednesbury.
1889. *Spencer, John. Newburn, Newcastle-upon-Tyne.
1891. *Spencer, Richard Evans. 6 Working-street, Cardiff.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, London, N.
1894. ‡Spiers, A. H. Newton College, South Devon.
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., LL.D., 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.

Year of Election.

1888. ‡Spreat, John Henry. Care of Messrs. Vines & Froom, 75 Aldersgate-street, London, E.C.
1884. *Spruce, Samuel, F.G.S. Beech House, Tamworth.
1888. *Stacy, J. Sargeant. 7 and 8 Paternoster-row, London, E.C.
1884. ‡Stancoffe, Frederick. Dorchester-street, Montreal, Canada.
1892. ‡Stanfield, Richard, Assoc.M.Inst.C.E., F.R.S.E., Professor of Engineering in the Heriot Watt College, Edinburgh. 49 Mayfield-road, Edinburgh.
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.
1894. *Stansfield, Alfred. Royal Mint, London, E.
1893. ‡Staples, Sir Nathaniel, Bart. Lisson, Cookstown, Ireland.
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. 3 Victoria-road, Old Charlton, Kent.
Staveley, T. K. Ripon, Yorkshire.
1894. ‡Stavert, Rev. W. J., M.A., F.C.S. Burnsall Rectory, Skipton-in-Craven, Yorkshire.
1873. *Stead, Charles. Red Barns, Freshfield, Liverpool.
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.
1892. *STEBBING, Rev. THOMAS R. R., M.A., F.R.S. Ephraim Lodge, The Common, Tunbridge Wells.
1896 *Stebbing, W. P. D. 169 Gloucester-terrace, London, W.
1891. ‡Steeds, A. P. 15 St. Helen's-road, Swansea.
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, Lewis County, 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, LL.B. Le Mayals, near Swansea.
1886. ‡Stevens, Marshall. Highfield House, Urmston, near Manchester.
1892. ‡Stevenson, D. A., B.Sc., F.R.S.E., M.Inst.C.E. 84 George-street, Edinburgh.
1863. *STEVENSON, JAMES C. Westoe, South Shields.
1889. ‡*Stevenson, T. Shannon. Westoe, South Shields.*
1890. *Steward, Rev. Charles J., F.R.M.S. Somerleyton Rectory, Lowestoft.
1885. *Stewart, Rev. Alexander, M.D., LL.D. Heathcot, Aberdeen.
1887. **Stewart, A. H. St. Thomas's Hospital, London, S.E.*
1892. ‡Stewart, C. Hunter. 3 Carlton-terrace, Edinburgh.
1864. ‡STEWART, CHARLES, M.A., F.L.S. St. Thomas's Hospital, London, S.E.
1885. ‡Stewart, David. Banchory House, Aberdeen.
1886. *Stewart, Duncan. Bandora, Bridge of Allan, N.B.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Dunmurry, Sneyd Park, near Clifton, Gloucestershire.
1892. ‡Stewart, Samuel. Knocknairn, Bagston, Greenock.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.

Year of Election.

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. N., M.A., Professor of Physics in the Royal Indian Engineering College. Cooper's Hill, Staines.
1845. *STOKES, Sir GEORGE GABRIEL, Bart., 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. 19 Lever-street, Piccadilly, Manchester.
1862. ‡STONE, EDWARD JAMES, M.A., Ph.D., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1886. ‡Stone, Sir J. Benjamin, M.P. The Grange, Erdington, Birmingham.
1886. ‡Stone, J. H. Grosvenor-road, Handsworth, Birmingham.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, London, E.C.
1888. ‡STONE, JOHN. 15 Royal-crescent, Bath.
1876. ‡Stone, Octavius C., F.R.G.S. 49 Bolsover-street, Regent's Park, London, N.W.
1883. ‡Stone, Thomas William. 189 Goldhawk-road, Shepherd's Bush, London, 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.
1895. *Stoney, Miss Edith A. 8 Upper Hornsey Rise, London, N.
1895. *Stoney, F. G. M., M.Inst.C.E. Tumbricane, Ipswich.
1878. *Stoney, G. Gerald. 90 Meldon-terrace, Newcastle-upon-Tyne.
1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. 8 Upper Hornsey Rise, London, N.
1876. §Stopes, Henry, F.G.S. Mansion House, Swanscombe, Greenhithe, Kent.
1883. ‡Stopes, Mrs. Mansion House, Swanscombe, Greenhithe, Kent.
1887. ‡*Storer, Edwin. Woodlands, Crumpsall, Manchester.*
1887. *Storey, H. L. Yealand Conyers, Carnforth.
1873. §Storr, William. The 'Times' Office, Printing-house-square, London, E.C.
1884. §Storrs, George H. Gorse Hall, Stalybridge.
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., LL.D., F.R.S., F.R.G.S., F.L.S., F.G.S. 69 Lancaster-gate, Hyde Park, 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. §Streatfeild, H. S., F.G.S. The Limes, Leigham Court-road, Streatham, S.W.
1879. ‡Strickland, Sir Charles W., K.C.B. Hildenley-road, Malton.
1884. ‡Stringham, Irving. The University, Berkeley, California, U.S.A.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1887. *Stroud, Professor H., M.A., D.Sc. College of Science, Newcastle-upon-Tyne.

Year of Election.

1887. *STROUD, WILLIAM, D.Sc., Professor of Physics in the Yorkshire College, Leeds.
1876. *STRUTHERS, JOHN, M.D., LL.D., Emeritus Professor of Anatomy in the University of Aberdeen. 24 Buckingham-terrace, Edinburgh.
1878. ‡Strype, W. G. Wicklow.
1876. *Stuart, Charles Maddock. St. Dunstan's College, Catford, S.E.
1872. *Stuart, Rev. Edward A., M.A. St. Matthew, Bayswater, 5 Prince's-square, London, W.
1892. ‡Stuart, Morton Gray, M.A. Ettrickbank, Selkirk.
1884. ‡Stuart, Dr. W. Theophilus. 183 Spadina-avenue, Toronto, Canada.
1893. ‡Stubbs, Arthur G. Sherwood Rise, Nottingham.
1896. §Stubbs, Miss. Torrisholme, Aigburth-drive, Sefton Park, Liverpool.
1888. *Stubbs, Rev. E. Thackeray, M.A. Grove Lea, Lansdowne-grove, Bath.
1885. §§Stump, Edward C. 16 Herbert-street, Moss Side, Manchester.
1879. *Styring, Robert. 64 Crescent-road, Sheffield.
1891. *Sudborough, J. J., Ph.D., B.Sc. University College, Nottingham.
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, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. Thurso House, Newcastle-upon-Tyne.
1886. ‡Sutherland, Hugh. Winnipeg, Manitoba, Canada.
1892. ‡Sutherland, James B. 10 Windsor-street, Edinburgh.
1884 ‡Sutherland, J. C. Richmond, Quebec, Canada.
1863. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1889. ‡Sutton, William. Esbank, Jesmond, Newcastle-upon-Tyne.
1891. ‡Swainson, George, F.L.S. North Drive, St. Anne's-on-Sea, Lancashire.
1881. ‡Swales, William. Ashville, Holgate Hill, York.
1881. §SWAN, JOSEPH WILSON, M.A., F.R.S. 58 Holland Park, London, W.
1879. ‡Swanwick, Frederick. Whittington, Chesterfield.
1883. ‡Sweeting, Rev. T. E. 50 Roe-lane, Southport.
1887. §SWINBURNE, JAMES. 4 Hatherley-road, Kew Gardens, London.
1870. *Swinburne, Sir John, Bart. Capheaton Hall, Newcastle-upon-Tyne.
1887. *Swindells, Rupert, F.R.G.S. Wilton Villa, The Firs, Bowdon, Cheshire.
1890. §SWINHOE, Colonel C. Avenue House, Oxford.
1891. ‡Swinnerton, R. W., Assoc.M.Inst.C.E. Bolarum, Dekkan, India.
1889. §Sworn, Sidney A., B.A., F.C.S. The Municipal Technical School, Gravesend.
1873. ‡Sykes, Benjamin Clifford, M.D. St. John's House, Cleckheaton.
1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. Glencoe, Elmbourne-road, Tooting Common, London, S.W.
1895. §Sykes, E. R. 3 Gray's Inn-place, London, W.C.
1890. ‡*Sykes, Joseph.* 113 *Beeston-hill, Leeds.*
1896. §Sykes, Mark L. 19 Manor-street, Ardwick Green, Manchester.
1887. *Sykes, T. H. Cringle House, Cheadle, Cheshire.
SYLVESTER, JAMES JOSEPH, M.A., D.C.L., LL.D., F.R.S., Savilian Professor of Geometry, Oxford. Athenæum Club, S.W.
1893. ‡Symes, Rev. J. E., M.A. 70 Redcliffe-crescent, Nottingham.
1870. ‡SYMES, RICHARD GLASCOTT, M.A., F.G.S., Geological Survey of Scotland. Sheriff Court-buildings, Edinburgh.
1885. ‡Symington, Johnson, M.D. Queen's College, Belfast.
1881. *Symington, Thomas. Wardie House, Edinburgh.

Year of Election.

1859. §SYMONS, G. J., F.R.S., Sec.R.Met.Soc. 62 Camden-square, London, N.W.
1855. *SYMONS, WILLIAM, F.C.S. Dragon House, Bilbrook, near Taunton.
1886. §Symons, W. H., M.D. (Brux.), M.R.C.P., F.I.C. Guildhall, Bath.
1872. ‡*Synge, Major-General Millington, R.E., F.R.G.S. United Service Club, Pall Mall, London, S.W.*

1896. §Tabor, J. M. 20 Petherton-road, Canonbury, N.
1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, Forfarshire.
1877. *TAIT, LAWSON, F.R.C.S. 7 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.S.S. 37 Charlotte-street, Portland-place, London, W.
1894. ‡Takakusu, Jyun, B.A. 17 Worcester-terrace, Oxford.
1893. ‡Talbot, Herbert, M.I.E.E. 19 Addison-villas, Addison-street, Nottingham.
1891. ‡Tamblyn, James. Glan Llynvi, Maesteg, Bridgend.
1891. ‡Tanner, Colonel H. C. B., F.R.G.S. Fièsole, Bathwick Hill, Bath.
1890. ‡TANNER, H. W. LLOYD, M.A., Professor of Mathematics and Astronomy in University College, Cardiff.
1892. *Tansley, Arthur G. 167 Adelaide-road, London, N.W.
1883. *Tapscott, R. Lethbridge, Assoc.M.Inst.C.E., F.G.S., F.R.A.S. Woodlands Park, Altrincham, Cheshire.
1878. ‡TARPEY, HUGH. Dublin.
1861. *Tarratt, Henry W. St. Augustine, Southbourne, Christchurch, Hants.
1857. *Tate, Alexander. Rantalard, Whitehouse, Belfast.
1893. ‡Tate, George, Ph.D., F.C.S. College of Chemistry, Duke-street, Liverpool.
1890. ‡Tate, Thomas, F.G.S. 5 Eldon-mount, Woodhouse-lane, Leeds.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1884. *Taylor, Rev. Charles, D.D. St. John's Lodge, Cambridge.
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, S.W.
1884. *Taylor, H. M., M.A. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. Oxford-street, Nottingham.
1887. ‡TAYLOR, Rev. Canon ISAAC, D.D. Settrington Rectory, York.
1861. *Taylor, John, M.Inst.C.E., F.G.S. The Old Palace, Richmond, Surrey.
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
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.
1895. §§Taylor, W. A., M.A., F.R.S.E. Royal Scottish Geographical Society, Edinburgh.
1893. ‡Taylor, W. F. Bhootan, Whitehorse Road, Croydon, Surrey.

Year of Election.

1894. *Taylor, W. W. 10 King-street, Oxford.
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, S.W.
1879. ‡Temple, Lieutenant G. T., R.N., F.R.G.S. The Nash, near Worcester.
1880. ‡TEMPLE, The Right Hon. Sir RICHARD, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., F.R.G.S. Athenæum Club, London, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-upon-Tyne.
1889. ‡Tennant, James. Saltwell, Gateshead.
1894. §Terras, J. A., B.Sc. Royal Botanic Gardens, Edinburgh.
1882. §Terrill, William. 42 St. George's-terrace, Swansea.
1881. ‡Terry, Sir Joseph. Hawthorn Villa, York.
1896. *Terry, Rev. T. R. The Rectory, East Ilsley, Berkshire.
1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
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., C.I.E., M.A., B.Sc., Ph.D., LL.D., F.R.S., F.L.S. Royal Gardens, Kew.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1891. ‡Thomas, Alfred, M.P. Pen-y-lan, Cardiff.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1891. ‡Thomas, A. Garrod, M.D., J.P. Clytha Park, Newport, Monmouthshire.
1891. *Thomas, Miss Clara. Llwynmadoc, Garth, R.S.O.
1891. ‡Thomas, Edward. 282 Bute-street, Cardiff.
1891. §Thomas, E. Franklin. Dan-y-Bryn, Radyr, near Cardiff.
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.
1891. ‡*Thomas, John Tubb, L.R.C.P. Eastfields, Newport, Monmouthshire.*
1880. *Thomas, Joseph William, F.C.S. Drumpellier House, Brunswick-road, Gloucester.
1883. ‡Thomas, Thomas H. 45 The Walk, Cardiff.
1883. ‡Thomas, William. Lan, Swansea.
1886. ‡Thomas, William. 109 Tettenhall-road, Wolverhampton.
1886. ‡Thomason, Yeoville. 9 Observatory-gardens, Kensington, London, W.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1891. *Thompson, Beeby, F.C.S., F.G.S. 55 Victoria-road, Northampton.
1883. ‡Thompson, Miss C. E. Heald Bank, Bowdon, Manchester.
1891. ‡Thompson, Charles F. Penhill Close, near Cardiff.
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 Zoology in University College, Dundee. University College, Dundee.
1896. *Thompson, Edward P. Whitchurch, Salop.
1883. *Thompson, Francis. Lynton, Haling Park-road, Croydon.
1891. ‡Thompson, G. Carslake. Park-road, Penarth.

Year of Election.

1893. *Thompson, Harry J., M.Inst.C.E., Madras. Care of Messrs. Grindlay & Co., Parliament-street, London, S.W.

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. 86 Lower Addiscombe-road, Croydon.

Thompson, Henry Stafford. Fairfield, near York.

1891. ‡Thompson, Herbert M. Whitley Batch, Llandaff.

1891. ‡Thompson, H. Wolcott. 9 Park-place, Cardiff.

1883. *THOMPSON, ISAAC COOKE, F.L.S., F.R.M.S. 53 Croxteth-road, Liverpool.

1891. ‡Thompson, J. Tatham. 23 Charles-street, Cardiff.

1861. *THOMPSON, JOSEPH. Riversdale, Wilmslow, Manchester.

1876. *Thompson, Richard. Dringcote, The Mount, York.

1883. ‡Thompson, Richard. Bramley Mead, Whalley, Lancashire.

1876. ‡THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.S., F.R.A.S., Principal and Professor of Physics in the City and Guilds of London Technical College, Finsbury, E.C.

1883. *Thompson, T. H. Redlynet House, Green Walk, Bowdon, Cheshire.

1896. *Thompson, W. H., M.D., Professor of Physiology in Queen's College, Belfast.

1896. §Thompson, W. P. 6 Lord-street, Liverpool.

1867. ‡Thoms, William. Magdalen-yard-road, Dundee.

1894. ‡Thomson, Arthur, M.A., M.D., Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.

1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.

1868. §THOMSON, JAMES, F.G.S. 6 Stewart-street, Shawlands, Glasgow.

1876. ‡Thomson, James R. Mount Blow, Dalmuir, Glasgow.

1891. ‡Thomson, John. 70A Grosvenor-street, London, W.

1896. §Thomson, John. 3 Derwent-square, Stonycroft, Liverpool.

1890. §Thomson, J. Arthur, M.A., F.R.S.E., Lecturer on Zoology at the School of Medicine, Edinburgh. 11 Ramsay-garden, Edinburgh.

1883. ‡THOMSON, J. J., M.A., D.Sc., F.R.S., Professor of Experimental Physics in the University of Cambridge. 6 Scrope-terrace, Cambridge.

1871. *THOMSON, JOHN MILLAR, F.C.S., Professor of Chemistry in King's College, London. 85 Addison-road, London, W.

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.

1886. ‡Thornley, J. E. Lyndon, Bickenhill, near Birmingham.

1887. ‡Thornton, John. 3 Park-street, Bolton.

1867. ‡Thornton, Sir 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. Undercliffe, Holmfirth.

1864. *THORP, WILLIAM, B.Sc., F.C.S. 24 Crouch Hall-road, Crouch End, London, N.

1871. ‡THORPE, T. E., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S., Principal of the Government Laboratories, Somerset House, London, W.C.

1883. §Threlfall, Henry Singleton. 12 London-street, Southport.

1896. §Thrift, William Edward. Trinity College, Dublin.

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.

Year of Election.

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. Geological Survey Office, 28 Jermyn-street, S.W.

1874. ‡Tilden, William A., D.Sc., F.R.S., F.C.S., Professor of Chemistry in the Royal College of Science, South Kensington, London. 9 Ladbroke-gardens, London, W.

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.

1896. §Timmis, Thomas Sutton. Cleveley, Allerton.

1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, London, S.E.

1891. §§Todd, Richard Rees. Portuguese Consulate, Cardiff.

1889. §Toll, John M. Carlton House, Kirkby, near Liverpool.

1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.

1896. §Toms, Frederick. 1 Ambleside-avenue, Streatham, London, S.W.

1888. ‡Tomkins, Rev. Henry George. Park Lodge, Weston-super-Mare.

1864. *Tomlinson, Charles, F.R.S., F.C.S. 7 North-road, Highgate, N.

1887. ‡Tonge, Rev. Canon. Chorlton-cum-Hardy, Manchester.

1887. ‡Tonge, James, F.G.S. 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.

1886. ‡Topley, Mrs. W. 13 Havelock-road, Croydon.

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. St. Mary's, Stoke Bishop, Bristol.

1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.

1877. ‡Tozer, Henry. Ashburton.

1876. *Trail, J. W. H., M.A., M.D., F.R.S., F.L.S., Regius Professor of Botany in the University of Aberdeen.

1883. ‡Traill, A., M.D., LL.D. Ballylough, Bushmills, Ireland.

1870. ‡Traill, William A. Giant's Causeway Electric Tramway, Portrush, Ireland.

1868. ‡Traquair, Ramsay H., M.D., LL.D., F.R.S., F.G.S., Keeper of the Natural History Collections, Museum of Science and Art, Edinburgh.

1891. ‡Trayes, Valentine. Maindell Hall, Newport, Monmouthshire.

1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.

1868. ‡Trehane, John. Exe View Lawn, Exeter.

1891. ‡Treharne, J. Ll. 92 Newport-road, Cardiff.

Trench, F. A. Newlands House, Clondalkin, Ireland.

1887. *Trench-Gascoigne, Mrs. F. R. Parlington, Aberford, Leeds.

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.

Year of Election.

1871. ‡TRIMEN, ROLAND, F.R.S., F.L.S., F.Z.S. 9 Osborne-mansions, Northumberland-street, London, W.

1860. §TRISTRAM, Rev. HENRY BAKER, D.D., LL.D., F.R.S., Canon of Durham. The College, Durham.

1884. *Trotter, Alexander Pelham, Government Electrician and Inspector. The Treasury, Cape Town.

1885. §TROTTER, COUTTS, F.G.S., F.R.G.S. 17 Charlotte-square, Edinburgh.

1891. ‡Trounce, W. J. 67 Newport-road, Cardiff.

1887. *Trouton Frederick T., M.A., D.Sc. Trinity College, Dublin.

1896. §Truell, Henry Pomeroy, M.B., F.R.C.S. Clonmannon, Ashfield, Co. Wicklow.

1885. *Tubby, A. H., F.R.C.S. 25 Weymouth-street, Portland-place, London, W.

1847. *Tuckett, Francis Fox. Frenchay, Bristol.

1888. ‡Tuckett, William Fothergill, M.D. 18 Daniel-street, Bath.

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. 9 Victoria-chambers, London, S.W.

1892. ‡Turnbull, Alexander R. Ormiston House, Hawick.

1855. ‡Turnbull, John. 37 West George-street, Glasgow.

1896. §Turner, Alfred. Elmswood Hall, Aigburth, Liverpool.

1893. §Turner, Dawson, M.B. 37 George-square, Edinburgh.

1882. ‡Turner, G. S. Pitcombe, Winchester-road, Southampton.

1883. ‡Turner, Mrs. G. S. Pitcombe, Winchester-road, Southampton.

1894. *TURNER, H. H., M.A., B.Sc., Sec. R.A.S., Professor of Astronomy in the University of Oxford. The Observatory, Oxford.

1886. *TURNER, THOMAS, A.R.S.M., F.C.S., F.I.C. Ravenhurst, Rowley Park, Stafford.

1863. *TURNER, Sir WILLIAM, M.B., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.

1893. ‡TURNEY, Sir JOHN, J.P. Alexandra Park, Nottingham.

1890. *Turpin, G. S., M.A., D.Sc. School House, Swansea.

1883. ‡*Turrell, Miss S. S. High School, Redland-grove, Bristol.*

1884. *Tutin, Thomas. The Orchard, Chellaston, Derby.

1886. *Twigg, G. H. 56 Claremont-road, Handsworth, Birmingham.

1888. §Tyack, Llewellyn Newton. University College, Bristol.

1882. §§Tyer, Edward. Horneck, 16 Fitzjohn's-avenue, Hampstead, N.W.

1865. §TYLOR, EDWARD BURNETT, D.C.L., LL.D., F.R.S., Professor of Anthropology, and Keeper of the Museum, Oxford University.

1883. ‡Tyrer, Thomas, F.C.S. Stirling Chemical Works, Abbey-lane, Stratford, London, E.

1861. *Tysoe, John. 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. Eastcliffe Lodge, Southport.

1883. ‡Unwin, William Andrews. The Briars, Freshfield, Liverpool.

1876. *UNWIN, W. C., F.R.S., M.Inst.C.E., Professor of Engineering at the Central Institution of the City and Guilds of London Institute. 7 Palace-gate Mansions, Kensington, London, W.

1887. ‡Upton, Francis R. Orange, New Jersey, U.S.A.

Year of Election.

1872. ‡Upward, Alfred. 150 Holland-road, London, 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. 38 Charles-street, Cardiff.
1896. *Vacher, Francis. 7 Shrewsbury-road, Birkenhead.
1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1888. ‡Vallentin, Rupert. 18 Kimberley-road, Falmouth.
1884. ‡Van Horne, Sir W. C., K.C.M.G. Dorchester-street West, Montreal, Canada.
1883. *Vansittart, The Hon. Mrs. A. A. Haywood House, Oaklands-road, Bromley, Kent.
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. 5 Gayton-road, Hampstead, London, N.W.
1870. ‡Varley, Mrs. S. A. 5 Gayton-road, Hampstead, London, N.W.
1869. ‡Varwell, P. Alphington-street, Exeter.
1884. ‡Vasey, Charles. 112 Cambridge-gardens, London, W.
1887. *VAUGHAN, His Eminence Cardinal. Carlisle-place, Westminster, S.W.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. ‡Vaughan, William. 42 Sussex-road, Southport.
1895. §Vaughan, D. T. Gwynne. Howry Hall, Llandrindod, Radnorshire.
1881. §VELEY, V. H., M.A., F.R.S., F.C.S. 22 Norham-road, Oxford.
1873. *VERNEY, Sir EDMUND H., Bart., F.R.G.S. Claydon House, Winslow, Bucks.
1883. *Verney, Lady. Claydon House, Winslow, Bucks.
1883. ‡VERNON, H. H., M.D. York-road, Birkdale, Southport.
1896. *Vernon, Thomas T. 24 Waterloo-road, Waterloo, Liverpool.
1896. *Vernon, William. Tean Hurst, Tean, Stoke-upon-Trent.
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.
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.
1891. ‡Vivian, Stephen. Llantrisant.

1886. *Wackrill, Samuel Thomas, J.P. Leamington.
1860. ‡Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1890. ‡Wadsworth, G. H. 3 Southfield-square, Bradford, Yorkshire.
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.
1890. §WAGER, HAROLD W. T. Yorkshire College, Leeds.
1896. §Wailes, Ellen. Woodmead, Groombridge, Sussex.
1891. ‡Wailes, T. W. 23 Richmond-road, Cardiff.
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.
1870. ‡WAKE, CHARLES STANILAND. Welton, near Brough, East Yorkshire.
1892. ‡Walcot, John. 50 Northumberland-street, Edinburgh.

Year of Election.

1884. ‡Waldstein, C., M.A., Ph.D. Slade Professor of Fine Art in the University of Cambridge.
1891. ‡Wales, H. T. Pontypridd.
1891. ‡Walford, Edward, M.D. Thanet House, Cathedral-road, Cardiff.
1894. ‡WALFORD, EDWIN A., F.G.S. West Bar, Banbury.
1882. *Walkden, Samuel. Downside, Whitchurch, Tavistock.
1893. §Walker, Alfred O., F.L.S. Nant-y-Glyn, Colwyn Bay.
1890. ‡Walker, A. Tannett. Hunslet, Leeds.
1896. §§WALKER, B. E. (LOCAL SECRETARY). Toronto.
1885. ‡Walker, Mr. Baillie. 52 Victoria-street, Aberdeen.
1896. §Walker, Major H. W. Gateacre, Liverpool.
1885. ‡Walker, C. C., F.R.A.S. Lilleshall Old Hall, Newport, Shropshire.
1883. §Walker, Mrs. Emma. 13 Lendal, York.
1883. ‡Walker, E. R. Pagefield Ironworks, Wigan.
1891. ‡Walker, Frederick W. Hunslet, Leeds.
1883. ‡Walker, George. 11 Hamilton-square, Birkenhead, Liverpool.
1894. *WALKER, G. T., M.A. Trinity College, Cambridge.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1896. §Walker, Horace. Belvideré-road, Prince's Park, Liverpool.
1890. ‡Walker, Dr. James. 8 Windsor-terrace, Dundee.
1894. *Walker, James, M.A. 30 Norham-gardens, Oxford.
1866. *WALKER, J. FRANCIS, M.A., F.G.S., F.L.S. 45 Bootham, York.
1855. ‡WALKER, J. J., M.A., F.R S. 12 Denning-road, Hampstead, N.W.
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, F.G.S. 13 Lendal, York.
1895. §WALKER, W. G., A.M.Inst.C.E. 47 Victoria-street, London, S.W.
1896. §Walker, W. J. D. Lawrencetown, Co. Down, Ireland.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1863. ‡WALLACE, ALFRED RUSSEL, D.C.L., F.R.S., F.L.S., F.R.G.S. Corfe View, Parkstone, Dorset.
1892. ‡Wallace, Robert W. 14 Frederick street, Edinburgh.
1887. *WALLER, AUGUSTUS D., M.D., F.R.S. Weston Lodge, 16 Grove End-road, London, N.W.
1889. *Wallis, Arnold J., M.A. 5 Belvoir-terrace, Cambridge.
1895. §§WALLIS, E. WHITE, F.S.S. Sanitary Institute, Parkes Museum, Margaret-street, London, W.
1883. ‡Wallis, Rev. Frederick. Caius College, Cambridge.
1884. ‡Wallis, Herbert. Redpath-street, Montreal, Canada.
1886. ‡Wallis, Whitworth, F.S.A. Chevening, Montague-road, Edgbaston.
1883. ‡Walmesley, Oswald. Shevington Hall, near Wigan.
1894. *Walmisley, A. T., M.Inst.C.E. 9 Victoria-street, London, S.W.
1887. ‡Walmsley, J. Monton Lodge, Eccles, Manchester.
1891. §Walmsley, R. M., D.Sc. Northampton Institute, Clerkenwell, E.C.
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.
1895. §WALSINGHAM, The Right Hon. Lord, LL.D., F.R.S. Merton Hall, Thetford.
1881. ‡Walton, Thomas, M.A. Oliver's Mount School. Scarborough.
1863. ‡ *Wanklyn, James Alfred. 7 Westminster-chambers, London, S.W.*

Year of Election.

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. Wyncroft, Adelaide Park, Belfast.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1879. ‡Ward, H. Marshall, D.Sc., F.R.S., F.L.S., Professor of Botany, University of Cambridge. New Museums, Cambridge.
1890. ‡Ward, Alderman John. Moor Allerton House, Leeds.
1874. §Ward, John, J.P., 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, F.G.S. Leek Brook, Leek, Staffordshire.
1884. ‡Wardwell, George J. 31 Grove-street, Rutland, Vermont, U.S.A.
1887. *Waring, Richard S. Pittsburg, Pennsylvania, U.S.A.
1878. §Warington, Robert, F.R.S., F.C.S., Professor of Rural Economy in the University of Oxford. High Bank, Harpenden, St. Albans, Herts.
1882. ‡Warner, F. I., 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.
1896. §Warr, A. F. 4 Livingstone-drive North, Liverpool.
1896. §Warrand, Major-General, R.E. Westhorpe, Southwell, Middlesex.
1893. ‡Warwick, W. D. Balderton House, Newark-on-Trent.
1875. *Waterhouse, Lieut.-Colonel J. 15 West Chislehurst Park, Eltham, Kent.
1870. ‡Waters, A. T. H., M.D. 60 Bedford-street, Liverpool.
1892. ‡Waterston, James H. 37 Lutton-place, Edinburgh.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. The Grammar School, Hinckley, Leicestershire.
1887. ‡Watkin, F. W. 46 Auriol-road, West Kensington, London, W.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1886. *Watson, C. J. 34 Smallbrook-street, Birmingham.
1883. ‡Watson, C. Knight, M.A. 49 Bedford-square, London, W.C.
1892. §Watson, G. Athenæum-buildings, Park-lane, Leeds.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1882. ‡Watson, Rev. H. W., D.Sc., F.R.S. Berkeswell Rectory, Coventry.
1884. ‡Watson, John. Queen's University, Kingston, Ontario, Canada.
1889. ‡Watson, John, F.I.C. 5 Loraine-terrace, Low Fell, Gateshead.
1863. ‡Watson, Joseph. Bensham-grove, Gateshead.
1863. ‡Watson, R. Spence, LL.D., F.R.G.S. Bensham-grove, Gateshead.
1867. ‡Watson, Thomas Donald. 16 St. Mary's-road, Bayswater, W.
1892. §Watson, William, M.D. Slateford, Midlothian.
1879. *Watson, William Henry, F.C.S., F.G.S. Braystones, Cumberland.
1894. *Watson, W., B.Sc. 7 Upper Cheyne-row, London, S.W.
1882. ‡Watt, Alexander. 19 Brompton-avenue, Sefton Park, Liverpool.
1884. ‡Watt, D. A. P. 284 Upper Stanley-street, Montreal, Canada.

Year of Election.

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. Canon Robert R. Stourpaine Vicarage, Blandford.
1870. §Watts, William, F.G.S. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1896. §Watts, W. H. Elm Hall, Wavertree, Liverpool.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.
1883. *WATTS, W. W., M.A., F.G.S. Geological Survey Office, Jermyn-street, London, S.W.; and Corndon, Worcester-road, Sutton, Surrey.
1891. ‡Waugh, James. Higher Grade School, 110 Newport-road, Cardiff.
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., M.Inst.C.E. 17 Egerton-gardens, London, S.W.
1891. §Webber, Thomas. Kensington Villa, 6 Salisbury-road, Cardiff.
1859. ‡Webster, John. Edgehill, Aberdeen.
1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.
1882. *Webster, Sir Richard Everard, LL.D., 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. 48 Westendstrasse, Karlsruhe.
1889. ‡Weeks, John G. Bedlington.
1890. *Weiss, F. Ernest, B.Sc., F.L.S., Professor of Botany in Owens College, Manchester.
1886. ‡Weiss, Henry. Westbourne-road, Birmingham.
1865. ‡Welch, Christopher, M.A. United University Club, Pall Mall East, London, S.W.
1894. §Weld, Miss. Conal More, Norham Gardens, Oxford.
1876. *WELDON, W. F. R., M.A., F.R.S., F.L.S., Professor of Comparative Anatomy and Zoology in University College, London. 30A Wimpole-street, London, W.
1880. *Weldon, Mrs. 30A Wimpole-street, London, W.
1881. §Wellcome, Henry S. Snow Hill Buildings, London, E.C.
1879. §WELLS, CHARLES A., A.I.E.E. 219 High-street, Lewes.
1881. §Wells, Rev. Edward, B.A. West Dean Rectory, Salisbury.
1894.§§Wells, J. G. Selwood House, Shobnall-street, Burton-on-Trent.
1883. ‡Welsh, Miss. Girton College, Cambridge.
1887. **Welton, T. A. 38 St. John's-road, Brixton, London, S.W.*
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
1881. *Wenlock, The Right Hon. Lord. Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Hensingham, Whitehaven, Cumberland.
1886. *Wertheimer, Julius, B.A., B.Sc., F.C.S., Professor of Chemistry in the Merchant Venturers' Technical College, Bristol.
1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, London, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1853. ‡West, Leonard. Summergangs Cottage, Hull.

Year of Election.

1853. ‡*West, Stephen. Hessle Grange, near Hull.*
1882. *Westlake, Ernest, F.G.S. Vale of Health, Hampstead, London, N.W.
1882. ‡Westlake, Richard. Portswood, Southampton.
1882. ‡WETHERED, EDWARD B., F.G.S. 4 St. Margaret's-terrace, Cheltenham.
1885. *WHARTON, Admiral W. J. L., C.B., R.N., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty. 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., M.D. 251 West 52nd-street, New York City, U.S.A.
1883. *Wheeler, George Brash. Elm Lodge, Wickham-road, Beckenham, Kent.
1878. *Wheeler, W. H., M.Inst.C.E. Wyncote, Boston, Lincolnshire.
1888. §Whelen, John Leman. Bank House, 16 Old Broad-street, London, E.C.
1883. ‡Whelpton, Miss K. Newnham College, Cambridge.
1893. *WHETHAM, W. C. D., M.A. Trinity 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.
1874. ‡Whitaker, Henry, M.D. Fortwilliam Terrace, Belfast.
1883. *Whitaker, T. Savile Heath, Halifax.
1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. Freda, Campden-road, Croydon.
1884. ‡Whitcher, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
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. 47 Clanricarde-gardens, London, W.
1883. ‡White, Charles. 23 Alexandra-road, Southport.
1882. ‡White, Rev. George Cecil, M.A. Nutshalling Rectory, Southampton.
1885. *White, J. Martin, M.P. 5 King-street, 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-street, Nottingham.
1895. §§White, Philip J., M.B., Professor of Zoology in University College, Bangor, North Wales.
1884. ‡White, R. 'Gazette' Office, Montreal, Canada.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 66 Cambridge-gardens, Notting Hill, London, W
1883. *White, Mrs. 66 Cambridge-gardens, Notting Hill, London, W.
1886. *White, William. The Ruskin Museum, Sheffield.
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. 20 Beeches-road, West Bromwich.
1881. ‡Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1852. ‡Whitla, Valentine. Beneden, Belfast.

Year of
Election.

1891. §Whitmell, Charles T., M.A., B.Sc., F.G.S. 47 Park-place, Cardiff.
1896. §Whitney, Colonel C. A. The Grange, Fulwood Park, Liverpool.
1857. *WHITTY, Rev. JOHN IRWINE, M.A., D.C.L., LL.D. 33 Peak Hill-gardens, Sydenham, London, S.E.
1887. ‡Whitwell, William. Overdene, Saltburn-by-the-Sea.
1874. *Whitwill, Mark. Linthorpe, Tyndall's Park, Bristol.
1883. ‡Whitworth, James. 88 Portland-street, Southport.
1870. ‡Whitworth, Rev. W. Allen, M.A. 7 Margaret-street, London, W.
1892. §Whyte, Peter, M.Inst.C.E. 3 Clifton-terrace, Edinburgh.
1888. ‡Wickham, Rev. F. D. C. Horsington Rectory, Bath.
1865. ‡Wiggin, Sir H., Bart. Metchley Grange, Harborne, Birmingham.
1886. ‡Wiggin, Henry A. The Lea, Harborne, Birmingham.
1896. §Wigglesworth, J. County Asylum, Rainhill, Liverpool.
1883. ‡Wigglesworth, Mrs. Ingleside, West-street, Scarborough.
1881. *Wigglesworth, Robert. Beckwith Knowle, near Harrogate.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1889. *Wilberforce, L. R., M.A. Trinity College, Cambridge.
1887. ‡Wild, George. Bardsley Colliery, Ashton-under-Lyne.
1887. *WILDE, HENRY, F.R.S. The Hurst, Alderley Edge, Manchester.
1896. §Wildermann, Meyer. 22 Park-crescent, Oxford.
1887. ‡Wilkinson, C. H. Slaithwaite, near Huddersfield.
1892. ‡Wilkinson, Rev. J. Frome. Barley Rectory, Royston, Herts.
1886. *Wilkinson, J. H. Hamstead Hill, Handsworth, Birmingham.
1879. ‡Wilkinson, Joseph. York.
1887. *Wilkinson, Thomas Read. Vale Bank, Knutsford, Cheshire.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1890. ‡Willans, J. W. Kirkstall, Leeds.
1896.§§WILLASON, J S. (LOCAL SECRETARY). Toronto.
1872. ‡WILLETT, HENRY, F.G.S. Arnold House, Brighton.
1891. ‡Williams, Arthur J., M.P. Coedymwstwr, near Bridgend.
1861. *Williams, Charles Theodore, M.A., M.B. 2 Upper Brook-street, Grosvenor-square, London, W.
1887. ‡Williams, Sir 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. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1883. ‡Williams, Rev. H. Alban, M.A. Christ Church, Oxford.
1857. ‡Williams, Rev. James. Llanfairynghornwy, Holyhead.
1888. ‡Williams, James. Bladud Villa, Entryhill, Bath.
1891. §Williams, J. A. B., M.Inst.C.E. Midwood, Christchurch-road, Bournemouth.
1887. ‡Williams, J. Francis, Ph.D. Salem, New York, U.S.A.
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. 26 Elizabeth-street, Liverpool.
1891. ‡Williams, Morgan. 5 Park-place, Cardiff.
1886. ‡Williams, Richard, J.P. Brunswick House, Wednesbury.
1883. ‡Williams, R. Price. 28 Compayne-gardens, West Hampstead, London, N.W.
1883. ‡Williams, T. H. 21 Strand-street, Liverpool.
1888. ‡*Williams, W. Cloud House, Stapleford, Nottinghamshire.*
1877. *WILLIAMS, W. CARLETON, F.C.S. Firth College, Sheffield.
1883. ‡Williamson, Miss. Sunnybank, Ripon, Yorkshire.

Year of Election.

1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.D., LL.D., D.C.L., F.R.S., F.C.S., Corresponding Member of the French Academy. High Pitfold, Haslemere.
1857. ‡WILLIAMSON, BENJAMIN, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
1895. §WILLINK, W. 14 Castle-street, Liverpool.
1895. §§Willis, John C., M.A., Senior Assistant in Botany in Glasgow University. 8*i* Lawrence-place, Dowanhill, Glasgow.
1882. ‡Willmore, Charles. Queenwood College, near Stockbridge, Hants.
1859. *Wills, The Hon. Sir Alfred. Chelsea Lodge, Tite-street, London, S.W.
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. Free Church Manse, North Queensferry.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1894. *Wilson, Charles J., F.I.C., F.C.S. 19 Little Queen-street, Westminster, S.W.
1874. ‡WILSON, Major-General Sir C. W., R.E., K.C.B., K.C.M.G., D.C.L., F.R.S., F.R.G.S. The Athenæum Club, London, S.W.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1890. ‡Wilson, Edmund. Denison Hall, Leeds.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 9 Dent's-road, Wandsworth Common, S.W.
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.
1895. §§Wilson, Gregg. The University, Edinburgh.
1883. *Wilson, Henry, M.A. Farnborough Lodge, R.S.O., Kent.
1879. ‡Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1885. ‡Wilson, J. Dove, LL.D. 17 Rubislaw-terrace, Aberdeen.
1890. ‡Wilson, J. Mitchell, M.D. 51 Hall Gate, Doncaster.
1896. §Wilson, John H., D.Sc., F.R.S.E., Professor of Botany, Yorkshire College, Leeds.
1865. ‡WILSON, Ven. JAMES M., M.A., F.G.S. The Vicarage, Rochdale.
1884. ‡Wilson, James S. Grant. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1894. ‡Wilson, Rev. R. J., M.A., Warden of Keble College, Oxford. Oxford.
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.
1892. §Wilson, T. Stacey, M.D. Wyddrington, Edgbaston, Birmingham.
1861. ‡Wilson, Thos. Bright. 4 Hope View, Fallowfield, Manchester.
1887. §Wilson, W., jun. Hillock, Terpersie, by Alford, Aberdeenshire.
1871. *Wilson, William E. Daramona House, Streete, Rathowen, Ireland.
1861. *WILTSHIRE, Rev. THOMAS, M.A., F.G.S., F.L.S., F.R.A.S., 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., D.Sc., Professor of Anatomy in Mason College, Birmingham.

Year of
Election.

1887. ‡Windsor, William Tessimond. Sandiway, Ashton-on-Mersey.
1893. *Winter, G. K., M.Inst.C.E., F.R.A.S. Arkonam, Madras, India.
1863. *Winwood, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1894. ‡Witley, Arthur. 17 Acton-lane, Harlesden, London, N.W.
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. Bedford College, Baker-street, 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. Wharfedale College, Boston Spa, Yorkshire.
1883. *Wood, J. H. Hazelwood, 14 Lethbridge-road, Southport.
1893. ‡Wood, Joseph T. 29 Muster's-road, West Bridgeford, Nottinghamshire.
1883. ‡Wood, Mrs. Mary. Care of E. P. Sherwood, Esq., Holmes Villa, Rotherham.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1890. *Wood, Robert H., M.Inst.C.E. 15 Bainbrigge-road, Headingley, Leeds.
1871. ‡Wood, Provost T. Baileyfield, Portobello, Edinburgh.
1872. ‡Wood, William Robert. Carlisle House, Brighton.
1845. *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 Milk-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.
1896. §Woodhead, G. Sims, M.D. 1 Nightingale-lane, Balham, London, S.W.
1888. *Woodiwiss, Mrs. Alfred. Weston Manor, Birkdale, Lancashire.
1872. ‡Woodman, James. 26 Albany-villas, Hove, Sussex.
*Woods, Edward, M.Inst.C.E. 8 Victoria-street, Westminster, London, S.W.
1883. ‡Woods, Dr. G. A., F.R.S.E., F.R.M.S. 16 Adelaide-street, Leamington.
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.L.S., F.G.S., Assistant Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, London, S.W.
1869. *Woodward, C. J., B.Sc., F.G.S. 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.

Year of Election.

1870. ‡WOODWARD, HORACE B., F.R.S., F.G.S. Geological Museum, Jermyn-street, London, S.W.

1894. *Woodward, John Harold. 6 Brighton-terrace, Merridale-road, Wolverhampton.

1884. *Woolcock, Henry. Rickerby House, St. Bees.

1890. §Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.S.S., M.R.I.A., F.R.S.A. (Ireland). 14 Waterloo-road, Dublin.

1877. ‡Woollcombe, Surgeon-Major Robert W. 14 Acre-place, Stoke, Devonport.

1883. *Woolley, George Stephen. Victoria Bridge, 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. Old Swinford, Stourbridge.

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.

1896. §Wrench, Edward M., F.R.C.S. Park Lodge, Baston, Liverpool.

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.

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.

1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.

1884. ‡WRIGHT, Professor R. RAMSAY, M.A., B.Sc. (LOCAL TREASURER). University College, Toronto, Canada.

1831. WRIGHT, T. G., M.D. 91 Northgate, Wakefield.

1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.

1871. ‡WRIGHTSON, THOMAS, M.P., 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.*

1892. ‡*Wyld, Norman. University Hall, Edinburgh.*

1883. §Wyllie, Andrew. 1 Leicester-street, Southport.

1885. ‡Wyness, James D., M.D. 349 Union-street, 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.

1894. *Yarrow, A. F. Poplar, London, E.

1883. §Yates, James. Public Library, Leeds.

1896. §Yates, Rev. S. A. Thompson. 43 Phillimore-gardens, London, S.W.

1867. ‡Yeaman, James. Dundee.

1887. ‡Yeats, Dr. Chepstow.

1884. ‡Yee, Fung. Care of R. E. C. Fittock, Esq., Shanghai, China.

Year of Election.

1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1891. ‡Yorath, Alderman T. V. Cardiff.
1884. ‡York, Frederick. 87 Lancaster-road, Notting Hill, London, W.
1891. §Young, Alfred C., F.C.S. 64 Tyrwhitt-road, St. John's, London, S.E.
1886. *Young, A. H., M.B., F.R.C.S., Professor of Anatomy in Owens College, Manchester.
1894. *Young, George, Ph.D. Firth College, Sheffield.
1884. ‡Young, Sir Frederick, K.C.M.G. 5 Queensberry-place, London, S.W.
1884. ‡Young, Professor George Paxton. 121 Bloor-street, Toronto, Canada.
1896. §Young, J. Denholm. 88 Canning-street, Liverpool.
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., F.R.S., Professor of Chemistry in University College, Bristol. 10 Windsor-terrace, Clifton, 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.

1886. ‡Zair, George. Arden Grange, Solihull, Birmingham.
1886. ‡Zair, John. Merle Lodge, Moseley, Birmingham.

CORRESPONDING MEMBERS.

Year of Election.

1887. Professor Cleveland Abbe. Weather Bureau, Department of Agriculture, Washington, United States.
1892. Professor Svante Arrhenius. The University, Stockholm. (Bergsgatan 18).
1881. Professor G. F. Barker. University of Pennsylvania, Philadelphia, United States. (3909, Locust-street).
1894. Professor F. Beilstein. Technological Institute, St. Petersburg.
1894. Professor E. van Beneden. The University, Liége, Belgium.
1887. Professor A. Bernthsen, Ph.D. Mannheim, L 11, 3, Germany.
1892. Professor M. Bertrand. L'École des Mines, Paris.
1894. Deputy Surgeon-General J. S. Billings. Washington, United States.
1893. Professor Christian Bohr. 62 Bredgade, Copenhagen, Denmark.
1880. Professor Ludwig Boltzmann. Fürkenstrasse 3, Vienna, IX.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, United States.
1884. Professor H. P. Bowditch, M.D. Harvard Medical School, Boston, Massachusetts, United States.
1890. Professor Brentano. 1 Maximilian-platz, München.
1893. Professor W. C. Brögger. Universitets Mineralogske Institute, Christiania.
1887. Professor J. W. Brühl. Heidelberg.
1884. Professor George J. Brush. Yale College, New Haven, Conn., United States.
1894. Professor D. H. Campbell. Stanford University, Palo Alto, California, United States.
1887. Professor G. Capellini. Royal University of Bologna. (65 Via Zamboni).
1887. Professor J. B. Carnoy. Rue du Canal 22, Louvain.
1887. Hofrath Dr. H. Caro. Mannheim.
1894. Emile Cartailhac. Toulouse, France.
1861. Professor Dr. J. Victor Carus. Leipzig.
1894. Dr. A. Chauveau. The Sorbonne, Paris.
1887. F. W. Clarke. United States Geological Survey, Washington, United States.
1855. Professor Dr. Ferdinand Cohn. The University, Breslau, Prussia.
1873. Professor Guido Cora. 74 Corso Vittorio Emanuele, Turin.
1880. Professor Cornu. Rue de Grenelle 9, Paris.
1870. J. M. Crafts, M.D. L'École des Mines, Paris.
1876. Professor Luigi Cremona. The University, Rome. (5 Piazza S. Pietro in Vincoli).
1889. W. H. Dall. United States Geological Survey, Washington, United States.
1862. *Wilhelm Delffs, Heidelberg.*

Year of Election.

1864. M. Des Cloizeaux. Rue de Monsieur 13, Paris.
1872. Professor G. Dewalque. Liége, Belgium.
1870. Dr. Anton Dohrn, D.C.L. Naples.
1890. Professor V. Dwelshauvers-Dery. Liége, Belgium.
1876. Professor Alberto Eccher. Florence.
1894. Professor Dr. W. Einthoven. Leiden, Holland.
1892. Professor F. Elfving. Helsingfors, Finland.
1894. Professor T. W. W. Engelmann. Utrecht.
1892. Professor Léo Errera. 1 Place Stephanie, Brussels.
1874. Dr. W. Feddersen. 9 Carolinenstrasse, Leipzig.
1886. Dr. Otto Finsch. Bremen.
1887. Professor Dr. R. Fittig. Strassburg.
1894. Professor Wilhelm Foerster, D.C.L. Encke Platz 3A, Berlin, S.W.
1872. W. de Fonvielle. 50 Rue des Abbesses, Paris.
1894. Professor Léon Fredericq. Rue de Pitteurs 18, Liége, Belgium.
1894. Professor C. Friedel. 9 Rue Michelet, Paris.
1887. Professor Dr. Anton Fritsch. 66 Wentzelsgalatz, Prague.
1892. Professor Dr. Gustav Fritsch. Roon Strasse 10, Berlin.
1881. Professor C. M. Gariel. 6 Rue Edouard Detaille, Paris.
1866. Dr. Gaudry. 57 Rue Cuvier, 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. Newport, Rhode Island, United States.
1889. G. K. Gilbert. United States Geological Survey, Washington, United States.
1892. Daniel C. Gilman. President of the Johns Hopkins University, Baltimore, United States.
1870. William Gilpin. Denver, Colorado, United States.
1889. Professor Gustave Gilson. Louvain.
1889. A. Gobert. 222 Chaussée de Charleroi, Brussels.
1876. Dr. Benjamin A. Gould. Cambridge, Massachusetts, United States.
1884. General A. W. Greely, LL.D. War Department, Washington, U.S.A.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1876. Professor Ernst Haeckel. Jena.
1889. Horatio Hale. Clinton, Ontario, Canada.
1881. Dr. Edwin H. Hall. 37 Gorham-street, Cambridge, U.S.A.
1872. Professor James Hall. Albany, State of New York.
1895. Professor Dr. Emil Chr. Hansen. Carlsberg Laboratorium, Copenhagen, Denmark.
1889. Dr. Max von Hantken. Budapesth.
1887. Fr. von Hefner-Alteneck. Berlin.
1893. Professor Paul Heger. Rue de Drapiers 35, Brussels.
1894. Professor Ludimar Hermann. The University, Königsberg, Prussia.
1893. Professor Richard Hertwig. Zoolog. Museum, Munich.
1893. Professor Hildebrand. Stockholm.
1887. Professor W. His. Königstrasse 22, Leipzig.
1881. Professor A. A. W. Hubrecht, LL.D., C.M.Z.S. Utrecht.
1887. Dr. Oliver W. Huntington. Newport, Rhode Island, United States.
1884. Professor C. Loring Jackson. 12 Wave-street, Cambridge, Massachusetts, United States.
1867. Dr. J. 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. 32 East Preston-street, Baltimore, U.S.A.

Year of Election.

1887. Professor C. Julin. Liége.
1876. Dr. Giuseppe Jung. 7 Via Principe Umberto, Milan.
1887. *M. Akin Károly. 92 Rue Richelieu, Paris.*
1884. Professor Dairoku Kikuchi, M.A. Imperial University, Tōkyō, Japan.
1873. Professor Dr. Felix Klein. Wilhelm Weber Strasse 3, Göttingen.
1894. Professor L. Kny. Kaiser-Allee 92, Wilmersdorf, Berlin.
1896. Dr. Kohlrausch. Physikalisch-technische Reichsanstalt, Charlottenburg, Berlin.
1856. Professor A. von Kölliker. Würzburg, Bavaria.
1894. Professor J. Kollmann. Basle, Switzerland.
1887. Professor Dr. Arthur König. Physiological Institute, The University, Berlin, N.W.
1894. Maxime Kovalevsky. Beaulieu-sur-Mer, Alpes-Maritimes.
1887. Professor Krause. 31 Brueckenallee, Berlin, N.W.
1877. Dr. Hugo Kronecker, Professor of Physiology. The University, Bern, Switzerland.
1887. *Lieutenant R. Kund. German African Society, Berlin.*
1887. Professor A. Ladenburg. Kaiser Wilhelm Str. 108, Breslau.
1887. Professor J. W. Langley. 847½ Fairmount-street, Cleveland, Ohio, United States.
1882. Dr. S. P. Langley, D.C.L., Secretary of the Smithsonian Institution. Washington, United States.
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. Wasagasse 9, Vienna, IX.
1883. Dr. F. Lindemann. 42 Georgenstrasse, Munich.
1877. Dr. M. Lindemann, Hon. Sec. of the Bremen Geographical Society. Bremen.
1887. Professor Dr. Georg Lunge. The University, Zurich.
1871. Professor Jacob Lüroth. The University, Freiburg, Germany.
1871. Professor Dr. Lütken. Nörregade 10, Copenhagen, Denmark.
1894. Dr. Otto Maas. Wurzerstrasse 16, Munich.
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.
1887. Dr. C. A. Martius. Berlin.
1890. Professor E. Mascart, Membre de l'Institut. 176 Rue de l'Université, Paris.
1894. Professor A. M. Mayer. Stevens Institute of Technology, Hoboken, New Jersey, United States.
1887. Professor D. I. Mendeléeff, D.C.L. St. Petersburg.
1887. Professor N. Menschutkin. St. Petersburg.
1884. Professor Albert A. Michelson. The University, Chicago, U.S.A.
1848. Professor J. Milne-Edwards. 57 Rue Cuvier, Paris.
1887. Dr. Charles Sedgwick Minot. Boston, Massachusetts, United States.
1894. Professor G. Mittag-Leffler. Djuvsholm, Stockholm.
1893. Professor H. Moissan. The Sorbonne, Paris (7 Rue Vauquelin).
1877. Professor V. L. Moissenet. 4 Boulevard Gambetta, Chaumont, Hte. Marne.
1894. Dr. Edmund von Mojsisovics. Strohgasse 26, Vienna, III.
1864. Dr. Arnold Moritz. The University, Dorpat, Russia.
1887. E. S. Morse. Peabody Academy of Science, Salem, Mass., U.S.A.
1889. Dr. F. Nansen. Christiania.
1894. Professor R. Nasini. Istituto Chimico dell' Università, Padua, Italy.
1864. Dr. G. Neumayer. Deutsche Seewarte, Hamburg.

Year of Election.

1884. Professor Simon Newcomb. 1620 P.-street, Washington, United States.
1887. Professor Emilio Noelting. Mühlhausen, Elsass, Germany.
1894. Professor H. F. Osborn. Columbia College, New York, U.S.A.
1894. Baron Osten-Sacken. Heidelberg.
1890. Professor W. Ostwald. Brüderstrasse 34, 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, Italy.
1895. Professor F. Paschen. 6, Theodorstrasse, Hannover.
1887. Dr. Pauli. Höchst-on-Main, Germany.
1890. Professor Otto Pettersson. Hogskolas Laboratorium, Stockholm.
1894. Professor W. Pfeffer, D.C.L. The University, Leipzig.
1870. Professor Felix Plateau. 152 Chaussée de Courtrai, Gand.
1884. Major J. W. Powell, Director of the Geological Survey of the United States. Washington, United States.
1887. Professor W. Preyer. Villa Panorama, Wiesbaden.
1886. Professor Putnam, Secretary of the American Association for the Advancement of Science. Harvard University, Cambridge, Massachusetts, United States.
1887. Professor Georg Quincke. Heidelberg.
1868. L. Radlkofer, Professor of Botany in the University of Munich (Sonnen-Strasse 7).
1895. Professor Ira Remsen. Johns Hopkins University, Baltimore, U.S.A.
1886. Rev. A. Renard. Rue du Roger, Gand, Belgium.
1873. Professor Baron von Richthofen. Kurfürstenstrasse 117, Berlin.
1896. Dr. van Rijckevorsel. Rotterdam.
1892. Professor Rosenthal, M.D. Erlangen, Bavaria.
1890. A. Lawrence Rotch. Blue Hill Observatory, Readville, Massachusetts, United States.
1881. Professor Henry A. Rowland. Baltimore, United States.
1895. Professsr Karl Runge, Körnerstrasse 19A, Hannover.
1894. Professor P. H. Schoute. The University, Groningen, Holland.
1883. Dr. Ernst Schröder. Gottesanerstrasse 9, Karlsruhe, Baden.
1874. Dr. G. Schweinfurth. Potsdamerstrasse 75A, Berlin.
1846. Baron de Selys-Longchamps. Liége, Belgium.
1873. Dr. A. Shafarik. Weinberge 422, Prague.
1876. Professor R. D. Silva. L'École Centrale, Paris.
1892. Dr. Maurits Snellen, Chief Director of the Royal Meteorological Institute of the Netherlands. Utrecht.
1887. Professor Count Solms. Bot. Garten, Strassburg.
1887. Ernest Solvay. 25 Rue du Prince Albert, Brussels.
1888. Dr. Alfred Springer. Box 621, Cincinnati, Ohio, United States.
1866. Professor Dr. Steenstrup. Linnesgade 6/2 K., Copenhagen.
1889. Professor G. Stefanescu. Bucharest, Roumania.
1881. Dr. Cyparissos Stephanos. The University, Athens.
1894. Professor E. Strasburger. The University, Bonn.
1881. Professor Dr. Rudolf Sturm. The University, Breslau.
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.

Year of Election.

Arminius Vámbéry, Professor of Oriental Languages in the University of Pesth, Hungary.
1890. Professor J. H. van't Hoff. Amsterdam.
1889. Wladimir Vernadsky. Mineralogical Museum, Moscow.
1886. Professor Jules Vuylsteke. 80 Rue de Lille, Menin, Belgium.
1894. General F. A. Walker. Massachusetts Institute of Technology, Boston, United States.
1887. Professor H. F. Weber. Zurich.
1887. Professor Dr. Leonhard Weber. Kiel.
1887. Professor August Weismann. Freiburg-im-Breisgau, Baden.
1887. Dr. H. C. White. Athens, Georgia, United States.
1881. Professor H. M. Whitney. Beloit College, Wisconsin, United States.
1887. Professor E. Wiedemann. Erlangen. [C/o T. A. Barth, Johannisgasse, Leipzig.]
1874. Professor G. Wiedemann. Thalstrasse 35, Leipzig.
1887. Professor R. Wiedersheim. Hansastrasse 3, Freiburg-im-Breisgau, Baden.
1887. Professor J. Wislicenus. Liebigstrasse 18, Leipzig.
1887. Dr. Otto N. Witt. 33 Lindenallée, Westend-Charlottenburg, Berlin.
1876. Professor Adolph Wüllner. Aureliusstrasse 9, Aachen.
1887. Professor C. A. Young. Princeton College, New Jersey, U.S.A.
1896. Professor E. Zacharias. Hamburg.
1887. Professor F. Zirkel. The University, Leipzig.

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Cambridge Philosophical Society.
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Cornwall, Royal Geological Society of.
Dublin, Geological Survey of Ireland.
——, Royal College of Surgeons in Ireland.
——, Royal Geological Society of Ireland.
——, Royal Irish Academy.
——, Royal Society of.
Dundee, University College.
Edinburgh, Royal Society of.
——, Royal Medical Society of.
——, Scottish Society of Arts.
Exeter, Albert Memorial Museum.
Glasgow Philosophical Society.
——, Institution of Engineers and Shipbuilders in Scotland.
Leeds, Mechanics' Institute.
——, Philosophical and Literary Society of.
Liverpool, Free Public Library and Museum.
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London, Admiralty, Library of the.
——, Anthropological Institute.
——, Arts, Society of.
——, Chemical Society.
——, Civil Engineers, Institution of.
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——, Geological Society.
——, Geology, Museum of Practical, 28 Jermyn Street.
——, Greenwich, Royal Observatory.
——, Kew Observatory.
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——, London Institution.
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——, Meteorological Office.
——, Royal Asiatic Society.
——, Royal Astronomical Society.
——, Royal College of Physicians.
——, Royal College of Surgeons.
——, Royal Engineers' Institute, Chatham.
——, Royal Geographical Society.
——, Royal Institution.
——, Royal Meteorological Society.
——, Royal Society.
——, Royal Statistical Society.
——, Sanitary Institute.
——, United Service Institution.
——, University College.
——, War Office, Library of the.
——, Zoological Society.
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——, Mechanics' Institute.
Newcastle-upon-Tyne, Literary and Philosophical Society.
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Nottingham, The Free Library.
Oxford, Ashmolean Society.
——, Radcliffe Observatory.
Plymouth Institution.
Salford, Royal Museum and Library.
Sheffield, Firth College.
Southampton, Hartley Institution.
Stonyhurst College Observatory.
Swansea, Royal Institution of South Wales
The Corresponding Societies (see p. 31 of Report).
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Geneva............Natural History Society.
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Grätz ....Naturwissenschaftlicher Verein.
Halle ....Leopoldinisch-Carolinische Akademie.
Harlem ....Société Hollandaise des Sciences.
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—— ....University Library.
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Nicolaieff.........University Library.
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—— ....Geological Society.
—— ....Royal Academy of Sciences.
—— ....School of Mines.
Pultova ....Imperial Observatory.
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—— ....Collegio Romano.
—— ....Italian Geographical Society.
—— ....Italian Society of Sciences.
St. Petersburg . University Library.
—— ...Imperial Observatory.
Stockholm ......Royal Academy.
Turin ....Royal Academy of Sciences.
Utrecht ....University Library.
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—— ....Central Anstalt für Meteorologie und Erdmagnetismus.
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Calcutta ....Presidency College.
—— ....Hooghly College.
—— ....Medical College.
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Madras............The Observatory.
—— ....University Library.

AFRICA.

Cape of Good Hope . . . The Royal Observatory.

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Ottawa ....Geological Survey of Canada.
Philadelphia...American Medical Association.
—— ...American Philosophical Society.
—— ...Franklin Institute.
Toronto ......The Observatory.
Washington ...The Naval Observatory.
—— ...Smithsonian Institution.
—— ...United States Geological Survey of the Territories.

AUSTRALIA.

Adelaide . . . . The Colonial Government.
Brisbane . . . . Queensland Museum.
Sydney . . . . Public Works Department.
Victoria . . . . The Colonial Government.

NEW ZEALAND.

Canterbury Museum.

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