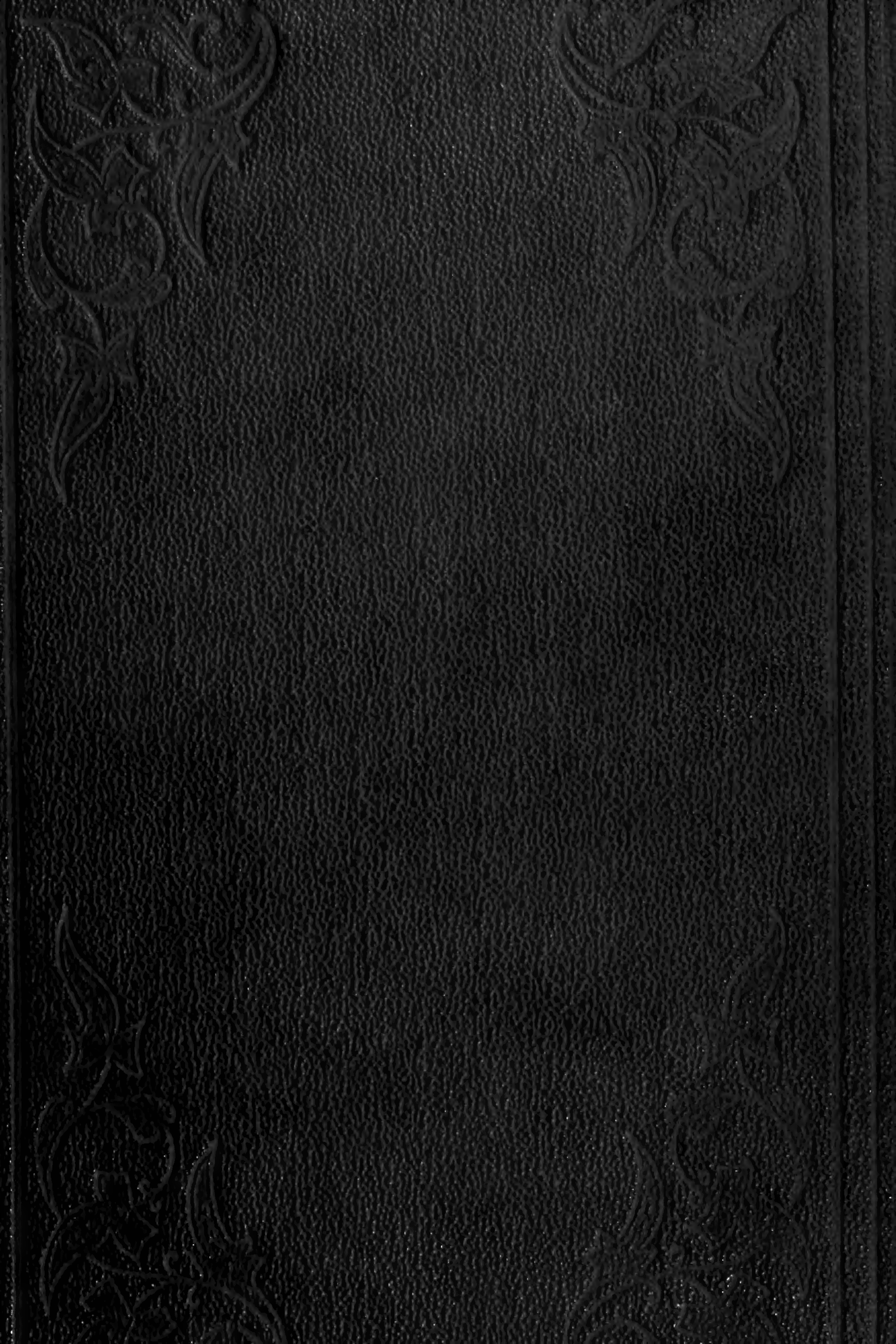

REPORT

OF THE

SIXTY-NINTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

HELD AT

DOVER IN SEPTEMBER 1899.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1900.

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REPORTS ON THE STATE OF SCIENCE.

[*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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Plan of Dover Harbour.

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.

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[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 exercise the functions of Sectional Committees 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

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

[2] Revised, Montreal, 1884.

[3] Passed, Edinburgh, 1871, revised, Dover, 1899.

[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

thereon, and on the order in which it is desirable that they should be read. 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 2 P.M., to appoint members of the Sectional Committee.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section, who will be appointed by the General Committee at 4 P.M., 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 appoint 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 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

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they are to be read, are now as far as possible determined by Organising Committees for the several Sections *before the beginning of the Meeting*. It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the 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, revised, Dover, 1899.

[3] Edinburgh, 1871, revised, Dover, 1899.

[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. xxxi), 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*

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[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.

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[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 G. Carey Foster, 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.

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

The *ex officio* members of the Committee of Recommendations are the President and Vice-Presidents of the Meeting, the General and Assistant-General Secretaries, the General Treasurer, the Trustees, and the Presidents of the Association in former years.

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.[1]

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.[2]

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[1] Passed by the General Committee at Birmingham, 1865.

[2] 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

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[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

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[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, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.

The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare. Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, 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 Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S. F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.

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. Campbel, 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.
IR 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.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
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.
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.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
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. B. Price, D.D., F.R.S., 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.Sc. 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, Esq.
SIR JOHN EVANS, K.C.B., D.C.L., LL.D., Sc.D., Treas R.S., F.S.A., For.Sec.G.S. TORONTO, August 18, 1897.	His Excellency the Right Hon. the Earl of Aberdeen, G.C.M.G., Governor-General of the Dominion of Canada The Right Hon. Lord Rayleigh, M.A., D.C.L., F.R.S. The Right Hon. Lord Kelvin, G.C.V.O., D.C.L., LL.D., F.R.S., F.R.S.E. The Hon. Sir Wilfrid Laurier, G.C.M.G., Prime Minister of the Dominion of Canada His Honour the Lieutenant-Governor of the Province of Ontario The Hon. the Premier of the Province of Ontario The Hon. the Minister of Education for the Province of Ontario The Hon. Sir Charles Tupper, Bart., G.C.M.G., C.B., LL.D. The Hon. Sir Donald A. Smith, G.C.M.G., LL.D., High Commissioner for Canada Sir William Dawson, C.M.G., F.R.S. The Mayor of Toronto Professor J. Loudon, M.A., LL.D., President of the University of Toronto	Professor A. B. Macallum, M.B., Ph.D. B. E. Walker, Esq., F.G.S. J. S. Willison, Esq.
SIR WILLIAM CROOKES, F.R.S., V.P.C.S. BRISTOL, September 7, 1898.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Rev. the Lord Bishop of Bristol, D.D. The Right Hon. Sir Edward Fry, D.C.L., F.R.S., F.S.A. Sir F. J. Bramwell, Bart., D.C.L., LL.D., F.R.S. The Right Worshipful the Mayor of Bristol The Principal of University College, Bristol The Master of The Society of Merchant Venturers of Bristol John Beddoe, Esq., M.D., LL.D., F.R.S. Professor T. G. Bonney, D.Sc., LL.D., F.R.S., F.S.A., F.G.S.	Arthur Lee, Esq., J.P. Bertram Rogers, Esq., M.D.
PROFESSOR SIR MICHAEL FOSTER, K.C.B., M.D., D.C.L., LL.D., Sec. R.S. DOVER, September 13, 1899.	His Grace the Lord Archbishop of Canterbury, D.D. The Most Hon. the Marquis of Salisbury, K.G., M.A., D.C.L., F.R.S. The Mayor of Dover The Major-General Commanding the South-Eastern District The Right Hon. A. Akers-Douglas, M.P. The Very Rev. F. W. Farrar, D.D., F.R.S., Dean of Canterbury Sir J. Norman Lockyer, K.C.B., F.R.S. Professor G. H. Darwin, M.A., LL.D., F.R.S., Pres. R.A.S.	E. Wollaston Knocker, Esq., C.B. W. H. Pendlebury, Esq., M.A.

TRUSTEES AND GENERAL OFFICERS, 1831—1900.

TRUSTEES.

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1858–82	General E. Sabine, F.R.S.
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1883	Lord Rayleigh, F.R.S.
1883–98	Sir Lyon (now Lord) Playfair, F.R.S.
1898	Prof. A. W. Rücker, F.R.S.

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1898	Prof. G. C. Foster, F.R.S.

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1835–36	Rev. W. Vernon Harcourt, F.R.S., and F. Baily, Esq., F.R.S.
1836–37	Rev. W. Vernon Harcourt, F.R.S., and R. I. Murchison, Esq., F.R.S.
1837–39	R. I. Murchison, Esq., F.R.S., and Rev. G. Peacock, F.R.S.
1839–45	Sir R. I. Murchison, F.R.S., and Major E. Sabine, F.R.S.
1845–50	Lieut.-Colonel E. Sabine, F.R.S.
1850–52	General E. Sabine, F.R.S., and J. F. Royle, Esq., F.R.S.
1852–53	J. F. Royle, Esq., F.R.S.
1853–59	General E. Sabine, F.R.S.
1859–61	Prof. R. Walker, F.R.S.
1861–62	W. Hopkins, Esq., F.R.S.
1862–63	W. Hopkins, Esq., F.R.S., and Prof. J. Phillips, F.R.S.
1863–65	W. Hopkins, Esq., F.R.S., and F. Galton, Esq., F.R.S.
1865–66	F. Galton, Esq., F.R.S.
1866–68	F. Galton, Esq., F.R.S., and Dr. T. A. Hirst, F.R.S.
1868–71	Dr. T. A. Hirst, F.R.S., and Dr. T. Thomson, F.R.S.
1871–72	Dr. T. Thomson, F.R.S., and Capt. Douglas Galton, F.R.S.
1872–76	Capt. Douglas Galton, F.R.S., and Dr. Michael Foster, F.R.S.
1876–81	Capt. Douglas Galton, F.R.S., and Dr. P. L. Sclater, F.R.S.
1881–82	Capt. Douglas Galton, F.R.S., and Prof. F. M. Balfour, F.R.S.
1882–83	Capt. Douglas Galton, F.R.S.
1883–95	Sir Douglas Galton, F.R.S., and A. G. Vernon Harcourt, Esq., F.R.S.
1895–97	A. G. Vernon Harcourt, Esq., F.R.S., and Prof. E. A. Schäfer, F.R.S.
1897	Prof. E. A. Schäfer, F.R.S., and Sir W. C. Roberts-Austen, K.C.B., F.R.S.

ASSISTANT GENERAL SECRETARIES.

1831	John Phillips, Esq., *Secretary.*
1832	Prof. J. D. Forbes, *Acting Secretary.*
1832–62	Prof. John Phillips, F.R.S.
1862–78	G. Griffith, Esq., M.A.
1878–80	J. E. H. Gordon, Esq., B.A., *Assistant Secretary.*
1881	G. Griffith, Esq., M.A., *Acting Secretary.*
1881–85	Prof. T. G. Bonney, F.R.S., *Secretary.*
1885–90	A. T. Atchison, Esq., M.A., *Secretary.*
1890	G. Griffith, Esq., M.A. *Acting Secretary.*
1890	G. Griffith, Esq., M.A.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries

MATHEMATICAL AND PHYSICAL SCIENCES.

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

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

SECTION A.—MATHEMATICS AND PHYSICS.

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

Date and Place	Presidents	Secretaries
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.
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.

Date and Place	Presidents	Secretaries
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.
1897. Toronto	Prof. A. R. Forsyth, M.A., F.R.S.	Prof. W. H. Heaton, J. C. Glashan, J. L. Howard, Prof. J. C. McLennan.
1898. Bristol	Prof W. E. Ayrton, F.R.S.	Prof. A. P. Chattock, J. L. Howard, C. H. Lees, Prof. W. Watson, E. T. Whittaker.
1899. Dover	Prof. J. H. Poynting, F.R.S.	J. L. Howard, C. H. Lees, Prof. W. Watson, E. T. Whittaker.

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.
1846. Southampton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.

Date and Place	Presidents	Secretaries
1847. Oxford	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S.	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford	Prof. B. C. Brodie, F.R.S.	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. 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.
1879. Sheffield	Prof. Dewar, M.A., F.R.S.	H. S. Bell, W. Chandler Roberts, J. M. Thomson.

Date and Place	Presidents	Secretaries
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. 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
1897. Toronto ...	Prof. W. Ramsay, F.R.S.......	Prof. W. H. Ellis, A. Harden, C. A. Kohn, Prof. R. F. Ruttan.
1898. Bristol	Prof. F. R. Japp, F.R.S.	C. A. Kohn, F. W. Stoddart, T. K. Rose.
1899. Dover	Horace T. Brown, F.R.S.......	A. D. Hall, C. A. Kohn, T. K. Rose, Prof. W. P. Wynne.

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.

Date and Place	Presidents	Secretaries
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geog.*, G.B.Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
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. ...	F. 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.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham, 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, F.R.S.	S. 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. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.

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[1] Geography was constituted a separate Section, see page lxiv.

Date and Place	Presidents	Secretaries
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.	J. Lomas, Prof. H. A. Miers, C. Reid.
1897. Toronto ...	Dr. G. M. Dawson, C.M.G., F.R.S.	Prof. A. P. Coleman, G. W. Lamplugh, Prof. H. A. Miers.
1898. Bristol	W. H. Hudleston, F.R.S.	G. W. Lamplugh, Prof. H. A. Miers, H. Pentecost.
1899. Dover	Sir Arch. Geikie, F.R.S.	J. W. Gregory, G. W. Lamplugh, Capt. McDakin, Prof. H. A. Miers.

Date and Place	Presidents	Secretaries

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. lxiii.]

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.

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

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.

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[1] The title of Section D was changed to Biology.

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.	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.	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[1]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal ...	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.
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.

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[1] Anthropology was made a separate Section, see p. lxx.

Date and Place	Presidents	Secretaries
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.
1897. Toronto	Prof. L. C. Miall, F.R.S.	W. Garstang, W. E. Hoyle, Prof. E. E. Prince.
1898. Bristol	Prof. W. F. R. Weldon, F.R.S.	Prof. R. Boyce, W. Garstang, Dr. A. J. Harrison, W. E. Hoyle.
1899. Dover	Adam Sedgwick, F.R.S.	W. Garstang, J. Graham Kerr.

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.

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[1] Physiology was made a separate Section, see p. lxxi.

[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.	T. 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 B. 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, 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. lvii.]

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.

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

[2] *Vide* note on page lxi.

Date and Place	Presidents	Secretaries
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, F. Galton, P. O'Callaghan, Dr. Norton Shaw, T. 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, C. 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. O. Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B.	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.
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.

Date and Place	Presidents	Secretaries
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.
1897. Toronto ...	J. Scott-Keltie, LL.D.	Col. F. Bailey, Capt. Deville, Dr. H. R. Mill, J. B. Tyrrell.
1898. Bristol......	Col. G. Earl Church, F.R.G.S.	H. N. Dickson, Dr. H. R. Mill, H. C. Trapnell.
1899. Dover	Sir John Murray, F.R.S.	H. N. Dickson, Dr. H. O. Forbes, Dr. H. R. Mill.

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.

Date and Place	Presidents	Secretaries
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich	Sir John P. Boileau, Bart.	J. Fletcher, Prof. Hancock.
1852. Belfast	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow	R. Monckton Milnes, M.P.	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

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

Date and Place	Presidents	Secretaries
1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
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	W. 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.
1897. Toronto	Prof. E. C. K. Gonner, M.A.	E. Cannan, H. Higgs, Prof. A. Shortt.
1898. Bristol	J. Bonar, M.A., LL.D.	E. Cannan, Prof. A. W. Flux, H. Higgs, W. E. Tanner.
1899. Dover	H. Higgs, LL.B.	A. L. Bowley, E. Cannan, Prof. A. W. Flux, Rev. G. Sarson.

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.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	William Cubitt, F.R.S.	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, 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.	C. 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.
1897. Toronto	G. F. Deacon, M.Inst.C.E.	Prof. T. Hudson Beare, Prof. Callendar, W. A. Price.
1898. Bristol	Sir J. Wolfe-Barry, K.C.B., F.R.S.	Prof. T. H. Beare, Prof. J. Munro, H. W. Pearson, W. A. Price.
1899. Dover	Sir W. White, K.C.B., F.R.S.	Prof. T. H. Beare, W. A. Price, H. E. Stilgoe.

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.
1897. Toronto	Sir W. Turner, F.R.S.	A. F. Chamberlain, H. O. Forbes, Prof. A. C. Haddon, J. L. Myres.
1898. Bristol	E. W. Brabrook, C.B.	H. Balfour, J. L. Myres, G. Parker.
1899. Dover	C. H. Read, F.S.A.	H. Balfour, W. H. East, Prof. A. C. Haddon, J. L. Myres.

SECTION I.—PHYSIOLOGY (including EXPERIMENTAL PATHOLOGY AND EXPERIMENTAL PSYCHOLOGY).

Date and Place	Presidents	Secretaries
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.
1897. Toronto	Prof. Michael Foster, F.R.S.	Prof. R. Boyce, Prof. C. S. Sherrington, Dr. L. E. Shore.
1899. Dover	J. N. Langley, F.R.S.	Dr. Howden, Dr. L. E. Shore, Dr. E. H. Starling.

SECTION K.—BOTANY.

Date and Place	Presidents	Secretaries
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.
1897. Toronto	Prof. Marshall Ward, F.R.S.	Prof. J. B. Farmer, E. C. Jeffrey, A. C. Seward, Prof. F. E. Weiss.
1898. Bristol	Prof. F. O. Bower, F.R.S.	A. C. Seward, H. Wager, J. W. White.
1899. Dover	Sir George King, F.R.S.	G. Dowker, A. C. Seward, H. Wager.

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.

Date and Place	Lecturer	Subject of Discourse
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.
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.

Date and Place	Lecturer	Subject of Discourse
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.
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.

Date and Place	Lecturer	Subject of Discourse
1888. Bath.........	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.
1897. Toronto ...	Prof. Roberts Austen, F.R.S.	Canada's Metals.
	J. Milne, F.R.S..................	Earthquakes and Volcanoes.
1898. Bristol......	Prof. W. J. Sollas, F.R.S. ...	Funafuti: the Study of a Coral Island.
	Herbert Jackson	Phosphorescence.
1899. Dover	Prof. Charles Richet............	La vibration nerveuse.
	Prof. J. Fleming, F.R.S.	The Centenary of the Electric Current.

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. ...	The modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool...	Sir John Lubbock, Bart., 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....	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., 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.
1897. Toronto ...	Dr. H. O. Forbes	New Guinea.
1898. Bristol......	Prof. E. B. Poulton, F.R.S.	The ways in which Animals Warn their enemies and Signal to their friends.

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Secretaries.—G. Dowker ; A. C. Seward, F.R.S. (*Recorder*) ; Harold Wager.

Dr.

THE GENERAL TREASURER'S ACCOUNT,

1898-99.

RECEIPTS.

				£	s.	d.
Balance brought forward				1704	4	0
Life Compositions (including Transfers)				366	0	0
New Annual Members' Subscriptions				230	0	0
Annual Subscriptions				564	0	0
Sale of Associates' Tickets				1028	0	0
Sale of Ladies' Tickets				639	0	0
Sale of Publications				174	12	1
Interest on Deposit at Liverpool and Bristol Banks				31	14	3
Dividend on Consols				200	7	4
Dividend on India 3 per Cents				104	8	0
Unexpended Balances of Grants returned:—						
Committee on the Fauna of the Singapore Caves	25	0	0			
Corresponding Societies Committee	0	18	0			
Committee on the North-West Tribes of Canada	7	18	3			
Committee on Wave-length Tables	7	0	0			
				40	16	3
				£5083	1	11

Investments.

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

G. Carey Foster, *General Treasurer.*

from July 1, 1898, to June 30, 1899. *Cr.*

1898–99. EXPENDITURE.

	£	s.	d.	£	s.	d.
Expenses of Bristol Meeting, including Grant to Local Fund, Printing, Advertising, Payment of Clerks, &c.				282	3	10
Rent and Office Expenses				59	19	8
Salaries				510	0	0
Printing, Binding, &c.				1251	3	0
Payment of Grants made at Bristol:						
Electrical Standards	225	0	0			
Seismological Observations	65	14	8			
Science Abstracts	100	0	0			
Heat of Combination of Metals in Alloys	20	0	0			
Radiation in a Magnetic Field	50	0	0			
Calculation of certain Integrals	10	0	0			
Action of Light upon Dyed Colours	4	19	6			
Relation between Absorption Spectra and Constitution of Organic Substances	50	0	0			
Erratic Blocks	15	0	0			
Photographs of Geological Interest	10	0	0			
Remains of Irish Elk in the Isle of Man	15	0	0			
Pleistocene Flora and Fauna in Canada	30	0	0			
Records of Disappearing Drift Section at Moel Tryfaen	5	0	0			
Ty Newydd Caves	40	0	0			
Ossiferous Caves at Uphill	30	0	0			
Table at the Zoological Station, Naples	100	0	0			
Table at the Biological Laboratory, Plymouth	20	0	0			
Index Generum et Specierum Animalium	100	0	0			
Migration of Birds	15	0	0			
Apparatus for Keeping Aquatic Organisms under Definite Physical Conditions	15	0	0			
Plankton and Physical Conditions of the English Channel during 1899	100	0	0			
Exploration of Socotra	35	0	0			
Lake Village at Glastonbury	50	0	0			
Silchester Excavation	10	0	0			
Ethnological Survey of Canada	35	0	0			
New Edition of 'Anthropological Notes and Queries'	40	0	0			
Age of Stone Circles	20	0	0			
Physiological Effects of Peptone	30	0	0			
Electrical Changes accompanying Discharge of Respiratory Centres	20	0	0			
Influence of Drugs upon the Vascular Nervous System	10	0	0			
Histological Changes in Nerve Cells	20	0	0			
Micro-chemistry of Cells	40	0	0			
Histology of Suprarenal Capsules	20	0	0			
Comparative Histology of Cerebral Cortex	10	0	0			
Fertilisation in Phæophyceæ	20	0	0			
Assimilation in Plants	20	0	0			
Zoological and Botanical Publication	5	0	0			
Corresponding Societies Committee	25	0	0			
				1430	14	2

	£	s.	d.	£	s.	d.	£	s.	d.
In hands of General Treasurer:									
At Bank of England, Western Branch	£342	4	3						
Less Cheque not presented	59	19	6						
				282	4	9			
At Capital and Counties Bank, Bristol				1254	2	1			
Cash				13	1	6			
				1549	8	4			
Less Petty Cash				0	7	1			
							1549	1	3
							£5083	1	11

I have examined the above Account with the books and vouchers of the Association, and certify the same to be correct. I have also verified the balances at the Bankers on Current and Deposit Accounts, and have ascertained that the Investments are duly registered in the names of the Trustees.

W. B. KEEN, *Chartered Accountant,*
3 Church Court, Old Jewry, E.C.
July 21, 1899.

Approved—
J. H. GLADSTONE, } *Auditors.*
D. H. SCOTT, }

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, 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, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec.R.S.	296	20

* 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	1834
—	—	—	—	—	—	—	167 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
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899

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

OFFICERS AND COUNCIL, 1899–1900.

PRESIDENT.

Professor SIR MICHAEL FOSTER, K.C.B., M.D., D.C.L., LL.D., Sec. R.S.

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The MAJOR-GENERAL COMMANDING THE SOUTH-EASTERN DISTRICT.
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The Very Rev. F. W. FARRAR, D.D., F.R.S., Dean of Canterbury.
Sir J. NORMAN LOCKYER, K.C.B., F.R.S.
Professor G. H. DARWIN, M.A., LL.D., F.R.S.

PRESIDENT ELECT.

Professor Sir WILLIAM TURNER, M.B., D.C.L., F.R.S.

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The Right Rev. the LORD BISHOP OF RIPON, D.D.
The Right Hon. LORD MASHAM.
The MAYOR OF BRADFORD.
The Hon. H. E. BUTLER, Lord of the Manor, Bradford.
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Professor RÜCKER, M.A., D.Sc., Sec.R.S.
Dr. T. E. THORPE, Sc.D., F.R.S., Pres.C.S.
Dr. N. BODINGTON, M.A.
Professor L. C. MIALL, F.R.S.

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Professor Sir W. C. ROBERTS-AUSTEN, K.C.B., D.C.L., F.R.S., Royal Mint, London, E.

ASSISTANT GENERAL SECRETARY.

G. GRIFFITH, Esq., M.A., Harrow, Middlesex.

GENERAL TREASURER.

Professor G. CAREY FOSTER, B.A., F.R.S., Burlington House, London, W.

LOCAL SECRETARIES FOR THE MEETING AT BRADFORD.

RAMSDEN BACCHUS, Esq. | J. E. FAWCETT, Esq. | FREDERICK STEVENS, Esq.

LOCAL TREASURER FOR THE MEETING AT BRADFORD.

W. C. LUPTON, Esq., MAYOR OF BRADFORD.

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CREAK, Captain E. W., R.N., F.R.S.
DARWIN, F., Esq., F.R.S.
DARWIN, Major L., Sec.R.G.S.
FREMANTLE, Hon. Sir C. W., K.C.B.
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HALLIBURTON, Professor W. D., F.R.S.
HARCOURT, Professor L. F. VERNON, M.A.
HERDMAN, Professor W. A., F.R.S.
KELTIE, J. SCOTT, Esq., LL.D.
LODGE, Professor O. J., F.R.S.
MACMAHON, Major P. A., F.R.S.
MARR, J. E., Esq., F.R.S.
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THOMSON, Professor J. M., F.R.S.
TILDEN, Professor W. A., F.R.S.
TYLOR, Professor E. B., F.R.S.
WHITE, Sir W. H., K.C.B., F.R.S.
WOLFE-BARRY, Sir JOHN, K.C.B., F.R.S.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, the President and President Elect, the Presidents of former years, the Vice-Presidents and Vice-Presidents Elect, the General and Assistant General Secretaries for the present and former years, the Secretary, the General Treasurers for the present and former years, and the Local Treasurer and Secretaries for the ensuing Meeting.

TRUSTEES (PERMANENT).

The Right Hon. Sir JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., F.L.S.
The Right Hon. Lord RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S.
Professor A. W. RÜCKER, M.A., D.Sc., Sec. R.S.

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Sir G. G. Stokes, Bart., F.R.S.
Lord Kelvin, G.C.V.O., F.R.S.
Prof. A. W. Williamson, F.R.S.
Sir John Lubbock, Bart., F.R.S.
Lord Rayleigh, D.C.L., F.R.S.
Sir H. E. Roscoe, D.C.L., F.R.S.
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The Marquis of Salisbury, K.G., F.R.S.
Lord Lister, D.C.L., Pres.R.S.
Sir John Evans, K.C.B., F.R.S.
Sir William Crookes, F.R.S.

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F. Galton, Esq., F.R.S.
Prof. Sir Michael Foster, K.C.B., Sec.R.S.
G. Griffith, Esq., M.A.
P. L. Sclater, Esq., Ph.D., F.R.S.
Prof. T. G. Bonney, D.Sc., F.R.S.
Prof. A. W. Williamson, F.R.S.
A. Vernon Harcourt, Esq., F.R.S.
Prof. A. W. RÜCKER, Sec.R.S.

AUDITORS.

Dr. D. H. Scott, F.R.S. | Sir H. Trueman Wood, M.A. | Dr. Horace Brown, F.R.S.

REPORT OF THE COUNCIL.

Report of the Council for the Year 1898–99, *presented to the General Committee at Dover on Wednesday, September* 13, 1899.

THE Meeting this year will be memorable from the fact that for the first time in the history of the Association the time and place of meeting have been fixed in conjunction with and in response to an invitation of the French Association for the Advancement of Science, with the object of affording an opportunity for the members of the sister Associations to exchange visits and to participate in scientific discussions in their several Sections. To carry out this intention, arrangements have been made for our Association to receive a visit from the members of the French Association on Saturday, September 16, and the Association Française has, on its part, invited the members of the British Association to pay a return visit on the following Thursday, and has expressed a desire that some of our members should join in an excursion to places of interest which has been planned for the following days.

The Council have to deplore the loss by death of Sir Douglas Galton, who, for twenty-four years, occupied the responsible office of General Secretary, a post which he resigned only on becoming President of the Association in 1895, at the Ipswich Meeting. The Council desire to place on record their sense of the invaluable services rendered by Sir Douglas Galton to the Association.

The Council regret to announce that a vacancy has been caused in the list of Vice-Presidents for this meeting in consequence of the lamented death of Lord Herschell.

An invitation was received from the Vice-Chancellor of the University of Cambridge to nominate a delegate to represent the Association at the Jubilee of Sir George Gabriel Stokes, which was celebrated on June 1 and June 2. The President, Sir William Crookes, was appointed to represent the Association, and to present the following Address :—

To SIR GEORGE GABRIEL STOKES, *Bart., D.C.L., LL.D., F.R.S.*

The Council of the British Association for the Advancement of Science desire to offer you their cordial congratulations on the completion of fifty years of your tenure of the Lucasian Professorship in the University of Cambridge.

You have been a Member of the Association for more than half a century, and have served it in many capacities during that period. You were appointed Secretary of the Section of Mathematical and Physical Science in 1845, and continued in this laborious office until 1851. In the two following years you were a Vice-President of the Section, and became President in 1854 and again in 1862. Many times Vice-President, you were President of the Association in 1869, at the meeting in Exeter, and have been a permanent Member of the Council for the last thirty years.

Your services to the Association, and to the cause for which it exists, are far from being fully told by a mere enumeration of the offices you have held. In 1852 you gave an Evening Lecture to the Members at the Belfast Meeting on a branch of Optics which has been chiefly elucidated by your own researches; and from 1845, the first year of your membership, till the meeting last year at Bristol, the Reports of the Association have been enriched year by year by your contributions. Your celebrated reports on 'Researches in Hydrodynamics,' published in 1846, and on 'Double Refraction,' in 1862, are constantly referred to as classical writings by the cultivators of those branches of Physics, and have conferred abiding lustre on the publications of the Association.

Of your other conspicuous services to the cause of Science it is almost needless to speak, but your association with the Royal Society as Secretary for thirty-one years, and subsequently as President, has given you a place which is without a parallel among those who, during the last half-century, have fostered the progress of Science.

That you may long continue among our leaders in the advance of knowledge is the earnest desire of the Association.

The following letter has been received from the Secretaries of the Royal Society :—

The Royal Society, Burlington House, London, W.,
November 29, 1898.

DEAR SIR,—We are directed by the President and Council of the Royal Society to inform you that a Committee, consisting of Fellows of the Royal Society acting in conjunction with representatives of the Royal Geographical Society, was formed some time since for considering the steps that should be taken for organising an expedition to the Antarctic regions.

As you are probably aware, an appeal to H.M. Government to organise such an expedition has met with no encouragement, and the Royal Geographical Society has consequently taken steps for raising a fund for the purposes of such an expedition by private subscription. To this fund the Royal Society hopes to be able to contribute through the medium of the Government Grant for Scientific Research, and at a recent meeting of the Antarctic Committee the following resolutions were passed, which we are directed to bring to your notice, and to request you, so far as they concern the British Association, to lay them before the Council of that body at the earliest opportunity:

> '(1) That the Treasurer of the Royal Society be requested to apply to the Government Grant Committee for a grant of 1,000*l.* (payable in instalments), in aid of an Antarctic Expedition.
>
> '(2) That an application be also made to the Council of the British Association for a grant of 1,000*l.* for the same purpose.'

We remain, very faithfully yours,
M. FOSTER,
ARTHUR W. RÜCKER,
Secretaries, R.S.

The General Secretary of the British Association.

After due consideration the Council have resolved to recommend the General Committee to contribute the sum of 1,000*l.* to the National Antarctic Expedition, and that the grant be given out of the accumulated funds of the Association, and not out of the sum allocated to annual grants.

The following resolutions, referred to the Council by the General Committee for consideration and action if desirable, have been considered and acted upon as follows :—

(1) That having regard to the letter of December 15, 1897, from Sir E. Maunde Thompson, the Council be requested to take further action with regard to a Bureau of Ethnology, by renewing the correspondence with the Trustees of the British Museum.

The following statement, in response to a letter from the President, has been received from Sir E. Maunde Thompson :—

British Museum, December 1, 1898.

DEAR SIR,—In reply to your letter of the 23rd ultimo, with reference to the establishment of an Ethnographical Bureau in connection with the British Museum, I beg to say that unforeseen delays in carrying out certain rearrangements affecting space within our walls have hitherto prevented the Trustees from taking up the matter. Now, however, a room has been found which may serve as an office for making a start with the scheme.

But while the Trustees have accepted in principle the proposal, I beg to observe that the desired end would scarcely be obtained without the influential co-operation of the British Association, upon which I assume the Trustees may rely.

May I then suggest that, as a preliminary step in maturing the scheme, one or more members of the British Association should be appointed to confer with the officers of the British Museum as to the most advisable course to follow?

A Committee, consisting of the President, the President-Elect, the General Officers, Mr. Francis Galton, and Professor Tylor, was accordingly appointed for the purpose of conferring with the officers of the British Museum, as proposed by Sir E. Maunde Thompson. The President has also been in correspondence with the Marquess of Salisbury regarding this matter, and the Council have the pleasure to announce that satisfactory arrangements have been made for the establishment of such a Bureau, and that Lord Salisbury has directed that reports prepared by officers in the various Protectorates under the administration of the Foreign Office be forwarded to the British Museum.[1]

(2) That the Council be requested to consider the desirability of representing to the Colonial Government that the early establishment of a Magnetic Observatory at the Cape of Good Hope would be of the highest utility to the Science of Terrestrial Magnetism, especially in view of the Antarctic Expeditions which are about to leave Europe, and that the Observatory should be established at such a distance from electric railways and tramways as to avoid all possibility of disturbance from them.

The question having been considered, the Council requested the President to make the necessary representation to the Colonial Government, and the following letter was accordingly sent to Sir Alfred Milner, the High Commissioner and Governor of Cape Colony, for presentation to the Government :—

British Association for the Advancement of Science,
Burlington House, W., March 1899.

Sir,—I have the honour to inform you that at the Annual Meeting of the British Association for the Advancement of Science, held last September at Bristol, an International Conference met for the purpose of discussing questions connected with Terrestrial Magnetism. One of the resolutions, which was adopted by the Conference in the following terms, was referred to the Council of the Association for further consideration :—

> 'That the Council be requested to consider the desirability of representing to the Colonial Government that the early establishment of a Magnetic Observatory at the Cape of Good Hope would be of the highest utility to the Science of Terrestrial Magnetism, especially in view of the Antarctic Expeditions which are about to leave Europe, and that the Observatory should be established at such a distance from electric railways and tramways as to avoid all possibility of disturbance from them.'

I have been requested by the Council to inform you that they have considered this resolution, and have decided to transmit it to you for your favourable consideration.

If you should require any further information in regard to this proposal, I shall be glad to furnish it.

I am, your obedient servant,
William Crookes, *President.*

The Council have received the following minute of the Government of Cape Colony through the High Commissioner :—

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[1] The correspondence is given in the Appendix, p. lxxxix.

Prime Minister's Office, Cape Town, May 13, 1899.

Ministers have the honour to acknowledge the receipt of His Excellency the Governor and High Commissioner's Minute, No. 71, of the 19th ultimo, forwarding for their consideration a copy of a letter from Sir William Crookes, President of the British Association for the Advancement of Science, urging the establishment of a Magnetic Observatory at the Cape.

In reply thereto, Ministers have the honour to state that they have much sympathy with the suggestion to establish a Magnetic Observatory, and do not overlook the scientific and practical aspects of the project, but do not regard as practicable the immediate provision by this Colony of funds for the carrying out of the scheme.

(Signed) W. P. SCHREINER.

(3) That the Council be requested to consider the advisability of urging Her Majesty's Government to place at the disposal of the Seismological Committee of the British Association a suitable building for the housing of apparatus for continuous seismological observations.

A Committee, consisting of the President, the President-Elect, the General Officers, Professor Rücker, Professor Ewing, and Professor Judd, was appointed to report on this resolution.

The Committee, having received and considered a memorandum, drawn up by Professor Milne, on the position and requirements of the Seismological Investigation Committee of the Association, reported that in their opinion it is desirable that a Central Station should be established, and recommended the Council to request the Government to place a suitable building at the disposal of the Seismological Committee which could be used as a station for carrying on observations, and would serve as a centre for the stations (now twenty-three in number) in various parts of the world which, at the request of the Committee, have been supplied with seismographic apparatus of the pattern they have recommended.

The Council decided to reappoint the Committee for the purpose of reporting further on the best situation for the proposed Central Seismological Station, and on the cost of its maintenance.

(4) That the Council be requested to urge strongly on the Indian Government the desirability, in the interests both of administration and of science, to promote an inquiry, under the direction of skilled anthropologists, into the physical and mental characteristics of the various races throughout the Empire, including their institutions, customs, and traditions, and a carefully organised photographic survey.

A Committee, consisting of the President, the President-Elect, the General Officers, Sir John Evans, Professor Tylor, Mr. F. Galton, Mr. C. H. Read, and Mr. J. L. Myres, which was appointed to consider this question, reported that in their opinion the resolution in its present form is of too comprehensive and costly a character to justify the Council in submitting it to the Indian Government. A more definite and less ambitious scheme would in their opinion be more likely to be entertained by the Indian Government.

(5) That the Council be recommended to issue the collected Reports on the North-Western Tribes of Canada in a single volume at a moderate price, reprinting so many of the Reports as may be necessary.

The Council, having been informed that a sufficient number of separate copies of the Fifth and the following Reports of the Committee on the North-Western Tribes of Canada were in stock for supplying those

Libraries, Public Institutions, and persons who required copies for completing sets, resolved that the Reports be not reprinted.

(6) That the Council be requested to bring under the notice of the Admiralty the importance of securing systematic observations upon the Erosion of the Sea-coast of the United Kingdom, and that the co-operation of the Coastguard might be profitably secured for this purpose.

A Committee, consisting of the President, the President-Elect, the General Officers, Sir Archibald Geikie, Mr. Whitaker, Captain Creak, Mr. A. T. Walmisley, and Professor L. Vernon Harcourt, having been appointed to report on the above resolution, recommended that the Council inquire whether the Admiralty would be willing to arrange that observations of a simple character on changes in the sea-coast be recorded and reported by the Coastguards. The Committee pointed out that if the Admiralty consented to carry out this proposal it would be necessary to appoint a committee for the purpose of drawing up a scheme of instructions for the observers, making arrangements for starting the work, and subsequently examining from time to time such localities as may seem to require special attention. This recommendation having been adopted by the Council, the President was requested to approach the Admiralty upon the subject, and in response to his letter the following reply has been received from the Admiralty :—

Admiralty, March 25, 1899.

SIR,—In reply to your letter of the 15th instant, inquiring if instructions can be given to the Coastguard to watch and report any changes taking place round the shores of the British Islands, I am commanded by my Lords Commissioners of the Admiralty to inform you that they see no objection to this proposal, as the required observations can be made by the men in the ordinary course of their duty.

On the receipt, therefore, of the instructions referred to in your letter, their Lordships, if they concur in them, will cause them to be issued accordingly.

Forms on which it is desired that the reports shall be made should also be drawn up for communication to the Coastguard.

I am, sir, your obedient servant,
EVAN MACGREGOR.

The President of the British Association for the
Advancement of Science.

The following have been appointed a Committee to carry out the necessary arrangements as to the despatch of forms, the receiving and tabulating reports, and such inspection of coast erosion or upheaval as may from time to time appear desirable, viz. :—Sir Archibald Geikie, Captain Creak, Professor L. Vernon Harcourt, Mr. W. Whitaker, Mr. A. T. Walmisley, and the General Officers.

(7) That the Council be requested to take into consideration whether any alterations in the hours of meeting of the Sectional Committees and of the General Committee on the first day of the Annual Meeting of the Association are desirable, and to report to the General Committee at the Dover Meeting.

A Committee, consisting of the President, the President-Elect, the General Officers, Sir Douglas Galton, Mr. Francis Galton, Mr. A. G. Vernon Harcourt, Professor Bonney, Professor Rücker, Professor Oliver Lodge, Sir W. T. Thiselton-Dyer, Professor Herdman, Professor Hudson Beare, and Dr. H. Forster Morley, was appointed to consider this resolution, and as a result of their inquiries the Council has resolved to recommend to the

General Committee that the meeting of the General Committee be held in future at 4 P.M. on the first day of the Annual Meeting, instead of at 1 P.M. as has heretofore been customary, and that the Organising Committees of the Sections should meet at 2 P.M. on that day instead of at 11 A.M., and should, until the Sectional Officers are definitely appointed by the General Committee, exercise the functions of Sectional Committees, with power to add to their number.

The Report of the Corresponding Societies Committee for the past year, together with 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, 1899, has been received.

The Corresponding Societies Committee, consisting of Mr. Francis Galton, Professor R. Meldola (*Chairman*), 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, Sir Cuthbert Peek, Mr. Horace T. Brown, Rev. J. O. Bevan, Professor W. W. Watts, and Rev. T. R. R. Stebbing, is hereby nominated for reappointment by the General Committee.

The Council nominate the Rev. T. R. R. Stebbing, F.R.S., Chairman, and Mr. T. V. Holmes, Secretary, to the Conference of Delegates of Corresponding Societies to be held during the Meeting at Dover.

The Council have received Reports from the General Treasurer during the past year, and his accounts from July 1, 1898, to June 30, 1899, which have been audited, are presented to the General Committee.

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

Boys, C. Vernon, Esq., F.R.S.
Meldola, Professor R., F.R.S.
Reynolds, Professor J. Emerson, M.D., F.R.S.
Thompson, Professor S. P., F.R.S.
Unwin, Professor W. C., F.R.S.

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 :—

*Armstrong, Professor H. E., F.R.S.
*Bonar, J., Esq., LL.D.
Creak, Captain E. W., R.N., F.R.S.
Darwin, F., Esq., F.R.S.
Darwin, Major L., Sec. R.G.S.
Fremantle, The Hon. Sir C. W., K.C.B.
Gaskell, Dr. W. H., F.R.S.
Halliburton, Professor W. D., F.R.S.
Harcourt, Professor L. F. Vernon, M.A.
Herdman, Professor W. A., F.R.S.
Keltie, J. Scott, Esq., LL.D.
*Lodge, Professor Oliver, F.R.S.
MacMahon, Major P. A., F.R.S.
Marr, J. E., Esq., F.R.S.
Poulton, Professor E. B., F.R.S.
Preece, Sir W. H., K.C.B., F.R.S.
Price, L. L., Esq., M.A.
Shaw, W. N., Esq., F.R.S.
Teall, J. J. H., Esq., F.R.S.
Thiselton-Dyer, Sir W. T., K.C.M.G., F.R.S.
Thomson, Professor J. M., F.R.S.
Tilden, Professor W. A., F.R.S.
Tylor, Professor E. B., F.R.S.
White, Sir W. H., K.C.B., F.R.S.
*Wolfe-Barry, Sir John, K.C.B., F.R.S.

APPENDIX TO THE REPORT OF THE COUNCIL

Bureau of Ethnology for Greater Britain

Foreign Office: May 24, 1899.

SIR,—I am directed by the Marquess of Salisbury to transmit to you the annexed correspondence which has passed between this Department and the British Association for the Advancement of Science, respecting the establishment of a Bureau of Ethnology for Greater Britain in connection with the British Museum, and the desire of the Association to obtain from Her Majesty's Officers in the various Protectorates under the administration of the Foreign Office information of an ethnological character with respect to the numerous uncivilised races with whom they come in contact.

Lord Salisbury is of opinion that Her Majesty's Officers should be encouraged to furnish information desired by the Bureau, so far as their duties will allow of their doing so, and I am to request you to inform Officers under your administration accordingly.

All reports which may be drawn up in answer to questions forwarded by the Bureau should be forwarded under flying seal through the Foreign Office.

I am, sir, your most obedient, humble servant,
(Signed) MARTIN GOSSELIN.

H.M.'s Commissioners in the Uganda and East and Central Africa Protectorates.
H.M.'s Consul-General in the Somali Coast Protectorate.

Foreign Office: May 24, 1899.

SIR,—I am directed by the Marquess of Salisbury to transmit to you for your information, and for such effect as you may be able to give to the instructions contained in it, a copy of a despatch which has been addressed to Her Majesty's Commissioners in the Uganda, and East and Central Africa Protectorates, and Her Majesty's Consul-General in the Somali Coast Protectorate, on the subject of procuring information for the Bureau of Ethnology which is about to be established in connection with the British Museum.

I am, sir, your most obedient, humble servant,
(Signed) MARTIN GOSSELIN.

H.M.'s Acting Agent at Zanzibar.
H.M.'s Consul at Brunei.

INCLOSURE 1.

Letter from the President of the British Association to the Marquess of Salisbury :—

Burlington House: March 30, 1899.

MY LORD,—I have the honour to inform you that a proposal to establish a Bureau of Ethnology for Greater Britain has been discussed at several recent meetings of the British Association for the Advancement of Science, and that the Council of the Association were subsequently requested to consider the possibility of establishing such a Bureau.

The Council appointed a Committee to consider the proposal, and having adopted the report of the Committee, requested the Trustees of the British Museum to allow the proposed Bureau to be established in connection with that Institution. The Trustees have expressed their willingness to undertake the working of the Bureau, and the necessary space for its establishment has now been provided at Bloomsbury.

In forwarding to your Lordship copies of the report of the Committee appointed by the Council, I would desire to call special attention to the following paragraph viz.: 'The collecting of the necessary information for the Bureau could be done with but little expense and with a very small staff only, if the scheme were recognised and forwarded by the Government. If instructions were issued, for instance, by the Colonial Office, the Foreign Office, the Admiralty, and the Intelligence Branch of the War Office, to the officers acting under each of these departments, not only that they were at liberty to conduct these inquiries, but that credit would be given to them officially for good work in this direction, there is little doubt that many observers qualified by their previous training would at once put themselves and their leisure at the disposal of the Bureau.'

If the proposed Bureau is to work successfully, it is necessary to have the approval and co-operation of the several Departments of the Government concerned with the primitive races to be dealt with. The Council have reason to believe that a large proportion of the officers now employed in dealing with these savage people would gladly undertake scientific work of the character required by the Report, if only they could be assured that such work would not be regarded unfavourably by the authorities at home. There is reason to believe that such an impression exists, but it is probably the result of some misunderstanding; and, in order to make the matter quite clear, I would venture to ask from your Lordship an expression of opinion favourable to the terms of the paragraph above quoted.

The Report itself gives in concise form a statement of the benefit likely to accrue from the establishment of such a Bureau, as to the general principle of which I feel sure the British Association may count upon your Lordship's entire sympathy.

I am, my Lord, your obedient servant,
(Signed) WILLIAM CROOKES, *President.*

INCLOSURE 2.

Report of the Committee appointed by the Council to consider the following Resolution:—

'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.'

A central establishment in England, to which would come information with regard to the habits, beliefs, and methods of government of the primitive peoples now existing would be of great service to science, and of no inconsiderable utility to the Government.

1. The efforts of the various societies which have during the last twenty years devoted themselves to collecting and publishing ethnological information have necessarily produced somewhat unequal, and therefore unsatisfactory, results. Such societies had, of course, to depend upon the reports of explorers, who usually travelled for another purpose than that in which the societies were interested; and such reports were naturally unsystematic, the observers being mostly untrained in the science. Again, whole regions would be unrepresented in the transactions of the societies, perhaps from the absence of the usual attractions of travellers, *e.g.* big game or mineral riches. This has been to some extent corrected, at least as to the systematic nature of the reports, by the publication of 'Anthropological Notes and Queries' by the Anthropological Institute, with the help of the British Association.

If it be admitted that the study of the human race is an important branch of science, no further argument is needed to commend the gathering of facts with regard to the conditions under which aboriginal races now live, and, if this work is worth doing, it should be done without delay. With the exception, perhaps, of the negro it would seem that none of the lower races are capable of living side by side with whites. The usual result of such contact is demoralisation, physical decline, and steady diminution of numbers; in the case of the Tasmanians, entire disappearance. Such will probably soon be the fate of the Maories, the Andamanese, the North American Indians, and the blacks of Australia. While these exist it is possible to preserve their traditions and folk-lore, and to record their habits of life, their arts, and the like, and such direct evidence is necessarily more valuable than accounts filtered through the recollection of the most intelligent white man.

It is scarcely necessary to enlarge upon this point, as no one will seriously question the value to science of such information. But it does seem necessary to urge that no time be lost.

2. As to the benefit to the Government of these inquiries, the history of our relations with native tribes in India and the Colonies is rich in examples. No one who has read of the ways of the African can doubt that a thorough study of his character, his beliefs and superstitions, is a necessity for those who have to deal with him. And what is true of the natives of Africa is also true, in a greater or less degree, of all uncivilised races. Their ideas of common things and common acts are so radically different from those of civilised man that it is impossible for him to understand them without a special training.

Even in dealing with the highly civilised natives of India it is most necessary that an inquirer should be familiar with their religion, and with the racial prejudices which the natives of India possess in common with other civilised nations.

A training in knowledge of native habits is now gone through by our officers, traders, and missionaries on the spot; and by experience—sometimes dearly bought—they, after many failures, learn how to deal with the natives. By the establishment of such a Bureau as is here advocated much might be done to train our officers before they go out, as is now done by the Dutch Government, who have a handbook and a regular course of instruction as to the life, laws, religion, &c., of the inhabitants of the Dutch Indies. The experience thus gained would then mature rapidly, and they would become valuable servants to the State more quickly.

The collecting of the necessary information for the Bureau could be done with but little expense and with a very small staff only, if the scheme were recognised and forwarded by the Government. If instructions were issued, for instance, by the Colonial Office, the Foreign Office, the Admiralty, and the Intelligence Branch of the War Office, to the officers acting under each of these departments, not only that they were at liberty to conduct these inquiries, but that credit would be given to them officially for good work in this direction, there is little doubt that many observers qualified by their previous training would at once put themselves and their leisure at the disposal of the Bureau.

The Bureau itself, the central office, would be of necessity in London—in no other place could it properly serve its purpose—and preferably, for the sake of economy and official control, it should be under the administration of some existing Government office. But the various interests involved make it somewhat difficult to recommend where it should be placed. The Colonial Office would obviously present some advantages. The British Museum has been suggested, with good reason, and there appears to be no insuperable difficulty if the trustees are willing to undertake the responsibility of controlling such a department.

The staff would not be numerous. A director accustomed to deal with ethnological matter would necessarily direct the conduct of the inquiries, and until the material assumed large proportions two or three clerks would probably suffice. If the value of the results were considered to justify it, the increase of the area of operations over the world would probably call for additional assistance after the Bureau had been at work for a few years.

The Bureau of Ethnology in the United States aims chiefly at publishing its reports, but its area is limited to America. The scope of the present proposal is so much wider that the Committee think it better not to deal with the question of publication at present.

INCLOSURE 3.

Letter from the Foreign Office to the British Association.—

Foreign Office, April 7, 1899.

SIR,—I am directed by the Marquess of Salisbury to acknowledge the receipt of your letter of the 30th ult. on the subject of the establishment of a Bureau of Ethnology for Greater Britain; and I am to request that you will inform his lordship whether it is correctly understood that what the British Association for the Advancement of Science desires, so far as this Department is concerned, is that Her Majesty's officers in the various Protectorates administered under the Foreign Office should report on occasion to the best of their ability on the ethnology of the various native races in those Protectorates.

If this be the correct interpretation of the wishes of the British Association, Lord Salisbury would be obliged if some more precise definition can be furnished as to the points to which attention should be directed, with a view to framing instructions for the guidance of the officers concerned.

I am, sir, your most obedient, humble servant,
(Signed) MARTIN GOSSELIN.

The President of the British Association for the
Advancement of Science.

INCLOSURE 4.

Letter from the British Association to the Foreign Office:—

Burlington House, London, May 3, 1899.

SIR,—I have to acknowledge the receipt of the letter from Sir Martin Gosselin of April 7, with regard to the proposed establishment of a Bureau of Ethnology for Greater Britain in connection with the British Museum.

The purpose of the British Association in applying to the Foreign Office has been correctly understood so far that it is desired to obtain from the agents and officers of the Foreign Office information of an ethnological character with respect to the numerous uncivilised races with whom they come into daily contact.

But it is not contemplated to give the Foreign Office any trouble in conducting these inquiries. The officers of the Bureau will prepare the questions and forward them to the various officers, who, it is hoped, may be willing to furnish the answers. All the material thus gathered will be systematically arranged in the British Museum, so as to be available both for scientific research and for the purposes of the Government.

The Council of the British Association felt, however, that before entering into communication with those officers it would be wise to ask for Lord Salisbury's approval of the scheme, in order that the gentlemen who were disposed to undertake such work as is contemplated by the Bureau might be assured that the work would be favourably regarded by their Department.

In the event, therefore, of the scheme meeting with the approval of Lord Salisbury I would venture to ask his lordship to be good enough to express this approval in such terms that the letter can be used in opening the correspondence with the agents of the Foreign Office.

I am, sir, your obedient servant,
(Signed) WILLIAM CROOKES, *President.*

The Under-Secretary of State for Foreign Affairs.

INCLOSURE 5.

Letter from Foreign Office to the British Association, May 24, 1899 :—

Foreign Office, May 24, 1899.

SIR,—With reference to your letter of the 3rd instant, I am directed by the Marquess of Salisbury to transmit to you for your information, copies of despatches which have been addressed to Her Majesty's Commissioners in the Uganda and East and Central Africa Protectorates, Her Majesty's Consul-General in the Somali Coast Protectorate, Her Majesty's Acting Agent at Zanzibar, and Her Majesty's Consul at Brunei, on the subject of procuring information for the Bureau of Ethnology which is about to be established in connection with the British Museum.

I am, sir, your most obedient, humble servant,
(Signed) MARTIN GOSSELIN.

The President of the British Association for the
Advancement of Science, Burlington House, W.

COMMITTEES APPOINTED BY THE GENERAL COMMITTEE AT THE DOVER MEETING IN SEPTEMBER 1899.

1. *Receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ *s. d.*
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements. [And 300*l.* in hand.]	*Chairman.*—Lord Rayleigh. *Secretary.*—Mr. R. T. Glazebrook. Lord Kelvin, Professors W. E. Ayrton, J. Perry, W. G. Adams, Oliver J. Lodge, and G. Carey Foster, Dr. A. Muirhead, Sir W. H. Preece, Professors J. D. Everett and A. Schuster, Dr. J. A. Fleming, Professors G. F. FitzGerald 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. J. Rennie, Mr. E. H. Griffiths, Professor A. W. Rücker, Professor H. L. Callendar, Sir W. C. Roberts-Austen, and Mr. G. Matthey.	25 0 0
Seismological Observations.	*Chairman.*—Prof. J. W. Judd. *Secretary.*—Professor J. Milne. Lord Kelvin, Sir F. J. Bramwell, Professor G. H. Darwin, Mr. Horace Darwin, Major L. Darwin, Professor J. A. Ewing, Professor C. G. Knott, Professor R. Meldola, Professor J. Perry, Professor J. H. Poynting, Professor T. G. Bonney, Mr. C. V. Boys, Professor H. H. Turner, Mr. G. J. Symons, Mr. Clement Reid, Mr. R. D. Oldham, and Mr. W. E. Plummer.	60 0 0
Radiation from a Source of Light in a Magnetic Field.	*Chairman.*—Professor G. F. FitzGerald. *Secretary.*—Professor T. Preston. Professor A. Schuster, Professor O. J. Lodge, Professor S. P. Thompson, Dr. Gerald Molloy, and Dr. W. E. Adeney.	25 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
To consider the most suitable Method of Determining the Components of the Magnetic Force on board Ship.	*Chairman.* — Professor A. W. Rücker. *Secretary.*—Dr. C. H. Lees. Lord Kelvin, Professor A. Schuster, Captain Creak, Professor W. Stroud, Mr. C. V. Boys, and Mr. W. Watson.	10 0 0
To establish a Meteorological Observatory on Mount Royal, Montreal.	*Chairman.*—Professor H. L. Callendar. *Secretary.*—Professor C. H. McLeod. Professor F. Adams, and Mr. R. F. Stupart.	20 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 Kelvin. *Secretary.*—Lieut.-Colonel Allan Cunningham. Dr. J. W. L. Glaisher, Professor A. G. Greenhill, Professor W. M. Hicks, Major P. A. MacMahon, and Professor A. Lodge.	75 0 0
The relation between the Absorption Spectra and Chemical Constitution of Organic Substances.	*Chairman* and *Secretary.*—Professor W. Noel Hartley. Professor F. R. Japp, and Professor J. J. Dobbie.	30 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. Sir J. N. Lockyer, Professors J. Dewar, G. D. Liveing, A. Schuster, W. N. Hartley, and Wolcott Gibbs, and Captain Abney.	5 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.	5 0 0
The Study of Isomorphous Sulphonic Derivatives of Benzene.	*Chairman.*—Professor H. A. Miers. *Secretary.*—Professor H. E. Armstrong. Dr. W. P. Wynne.	20 0 0
The Nature of Alloys.	*Chairman and Secretary.*—Mr. F. H. Neville. Mr. C. T. Heycock, and Mr. E. H. Griffiths.	30 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
To investigate the Erratic Blocks of the British Isles, and to take measures for their preservation. [6*l*. in hand.]	*Chairman.*—Professor E. Hull. *Secretary.*—Prof. 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, Mr. J. Lomas, Mr. A. R. Dwerryhouse, Mr. J. W. Stather, and Mr. R. D. Tucker.	—
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor J. Geikie. *Secretary.*—Professor W. W. Watts. Professor T. G. Bonney, Dr. T. Anderson, and Messrs. A. S. Reid, E. J. Garwood, W. Gray, H. B. Woodward, R. Kidston, J. J. H. Teall, J. G. Goodchild, H. Coates, C. V. Crook, G. Bingley, and R. Welch.	10 0 0
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. M. C. Kermode. His Honour Deemster Gill, Mr. G. W. Lamplugh, and Canon E. B. Savage.	5 0 0
To further investigate the Fauna and Flora of the Pleistocene Beds in Canada.	*Chairman.*—Sir J. W. Dawson. *Secretary.*—Professor A. P. Coleman. Professor D. P. Penhallow, Dr. H. Ami, and Mr. G. W. Lamplugh.	10 0 0
The Excavation of the Ossiferous Caves at Uphill, near Weston-super-Mare. [8*l*. in hand.]	*Chairman.*—Professor C. Lloyd Morgan. *Secretary.*—Mr. H. Bolton. Professor W. Boyd Dawkins, Mr. W. R. Barker, Mr. S. H. Reynolds, and Mr. E. T. Newton.	10 0 0
The movements of Underground Waters of Craven.	*Chairman.*—Professor W. W. Watts. *Secretary.*—Captain A. R. Dwerryhouse. Professor A. Smithells, Rev. E. Jones, Mr. Walter Morrison, M.P., Mr. G. Bray, Mr. W. L. Carter, Mr. W. Fairley, Professor P. F. Kendall, and Mr. J. E. Marr.	40 0 0
To explore Irish Caves. [Collections to be placed in the Science and Art Museum, Dublin.]	*Chairman.*—Dr. R. F. Scharff. *Secretary.*—Mr. R. Lloyd Praeger. Mr. G. Coffey, Professor Grenville Cole, Dr. Cunningham, Mr. A. McHenry, and Mr. R. J. Ussher.	20 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £	s.	d.
To enable Mr. H. M. Kyle and Professor Herdman, or, failing them, some other competent investigator, to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Professor G. B. Howes. Professor E. Ray Lankester, Professor W. F. R. Weldon, Professor S. J. Hickson, Mr. A. Sedgwick, and Professor W. C. McIntosh.	100	0	0
To enable Mr. Martin T. Woodward to study the Embryology of the Mollusca; Mr. S. D. Scott to investigate the Excretory Organs of the Tunicata; and Mr. G. Brebner to continue his studies on the Reproduction of Marine Algæ, and to enable other competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.	*Chairman.*—Mr. G. C. Bourne. *Secretary.* — Professor E. Ray Lankester. Professor Sydney H. Vines, Mr. A. Sedgwick, Professor W. F. R. Weldon, and Mr. W. Garstang.	20	0	0
Compilation of an Index Generum et Specierum Animalium.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. F. A. Bather. Dr. P. L. Sclater, Rev. T. R. R. Stebbing, Mr. R. McLachlan, and Mr. W. E. Hoyle.	50	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.*—Rev. E. P. Knubley. Mr. John A. Harvie-Brown, Mr. R. M. Barrington, Mr. A. H. Evans, and Dr. H. O. Forbes.	15	0	0
The Periodic Investigation of the Plankton and Physical Conditions of the English Channel.	*Chairman.*—Professor E. Ray Lankester. *Secretary.*—Mr. Walter Garstang. Professor W. A. Herdman, and Mr. H. N. Dickson.	40	0	0
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, Dr. P. L. Sclater, Mr. F. Du Cane Godman, and Mr. Edgar A. Smith.	100	0	0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
To investigate the structure, formation, and growth of the Coral Reefs of the Indian Region, with special observations on the inter-relationship of the reef organisms, the depths at which they grow, the food of corals, effects of currents and character of the ocean bottom, &c. The land flora and fauna will be collected, and it is intended that observations shall be made on the manners, &c., of the natives in the different parts of the Maldive group.	*Chairman.*—Mr. A. Sedgwick. *Secretary.*—J. Graham Kerr. Professor J. W. Judd, Mr. J. J. Lister, and Mr. S. F. Harmer.	30 0 0
The revision of the Physical and Chemical Constants of Sea-water.	*Chairman.*—Sir John Murray. *Secretary.*—Mr. H. N. Dickson. Mr. J. Y. Buchanan, and Dr. H. R. Mill.	100 0 0
Future dealings in Raw Produce.	*Chairman.*—Mr. L. L. Price. *Secretary.*—Prof. A. W. Flux. Major P. G. Craigie, Professor W. Cunningham, Professor Edgeworth, Professor Gonner, Mr. R. H. Hooker, and Mr. H. R. Rathbone.	5 0 0
State Monopolies in other Countries. [Balance of grant unexpended, 13*l.* 13*s.* 6*d.*]	*Chairman.*—Professor H. Sidgwick. *Secretary.*—Mr. H. Higgs. Mr. W. M. Acworth, the Rt. Hon. L. H. Courtney, and Professor H. S. Foxwell.	—
To consider whether the British Association form of Thread for Small Screws should be modified, and, if so, in what direction. [Balance of grant unexpended, 17*l.* 1*s.* 2*d.*]	*Chairman.*—Sir W. H. Preece. *Secretary.*—Mr. W. A. Price. 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, Mr. Conrad W. Cooke, and Mr. Vernon Boys.	—
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.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants		
		£	*s.*	*d.*
To organise an Ethnological Survey of Canada.	*Chairman.*—Professor D. P. Penhallow. *Secretary.*—Dr. George Dawson. Mr. E. W. Brabrook, Professor A. C. Haddon, Mr. E. S. Hartland, Sir J. G. Bourinot, Abbé Cuoq, Mr. B. Sulte, Abbé Tanquay, Mr. C. Hill-Tout, Mr. David Boyle, Rev. Dr. Scadding, Rev. Dr. J. Maclean, Dr. Merée Beauchemin, Rev. Dr. G. Patterson, Mr. C. N. Bell, Professor E. B. Tylor, Hon. G. W. Ross, Professor J. Mavor, Mr. A. F. Hunter, and Dr. W. F. Ganong.	50	0	0
Preparing a new edition of 'Notes and Queries on Anthropology.'	*Chairman.*—Professor E. B. Tylor. *Secretary.*—Dr. J. G. Garson. General Pitt-Rivers, Mr. C. H. Read, and Mr. J. L. Myres.	40	0	0
To conduct Explorations with the object of ascertaining the age of Stone Circles. [Balance in hand.]	*Chairman.*—Dr. J. G. Garson. *Secretary.*—Mr. H. Balfour. Gen. Pitt-Rivers, Sir John Evans, Mr. C. H. Read, Professor Meldola, Mr. A. J. Evans, Dr. R. Munro, and Professor Boyd-Dawkins.	—		
The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. J. L. Myres. Dr. J. G. Garson, Mr. H. Ling Roth, Mr. H. Balfour, Mr. E. S. Hartland, and Professor Flinders Petrie.	10	0	0
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.*—Mr. E. W. Brabrook. *Secretary.*—Dr. Francis Warner. Dr. J. G. Garson, Mr. White Wallis, and Dr. W. H. R. Rivers.	5	0	0
To examine the Natural History and Ethnography of the Malay Peninsula.	*Chairman.*—Mr. C. H. Read. *Secretary.*—Mr. W. Crooke. Professor A. Macalister, and Professor W. Ridgeway.	25	0	0
The Physiological Effects of Peptone and its Precursors when introduced into the circulation.	*Chairman.* — Professor E. A. Schäfer. *Secretary.* — Professor W. H. Thompson. Professor R. Boyce and Professor C. S. Sherrington.	20	0	0
Comparative Histology of Suprarenal Capsules.	*Chairman.*—Professor E. A. Schäfer. *Secretary*—Mr. Swale Vincent. Mr. Victor Horsley.	20	0	0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
Comparative Histology of Cerebral Cortex.	*Chairman.*—Professor F. Gotch. *Secretary.*—Dr. G. Mann. Professor E. H. Starling.	5 0 0
The Electrical Changes in Mammalian Nerve.	*Chairman.*—Professor F. Gotch. *Secretary.*—Mr. J. S. Macdonald. Professor E. H. Starling.	20 0 0
Vascular Supply of Secreting Glands.	*Chairman.*—Prof. E. H. Starling. *Secretary.*—Dr. J. L. Bunch. Dr. L. E. Shore.	10 0 0
Experimental Investigation of Assimilation in Plants. [6*l.* 6*s.* 8*d.* in hand.]	*Chairman.*—Mr. F. Darwin. *Secretary.*—Professor J. R. Green. Professor Marshall Ward.	—
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, Mr. G. J. Symons, Dr. J. G. Garson, Sir John Evans, Mr. J. Hopkinson, Professor T. G. Bonney, Mr. W. Whitaker, Sir Cuthbert E. Peek, Mr. Horace T. Brown, Rev. J. O. Bevan, Professor W. W. Watts, and Rev. T. R. R. Stebbing.	20 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. Prof. 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. Sir John Murray, Dr. A. Buchan, and Professor R. Copeland.
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.*—Professor W. Watson. Professor A. Schuster, and Professor H. H. Turner.

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

Subject for Investigation or Purpose.	Members of the Committee.
Comparing and Reducing Magnetic Observations.	*Chairman.*—Professor W. G. Adams. *Secretary.*—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 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, Mr. E. H. Griffiths, and Mr. S. Skinner.
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. Lord Kelvin, Mr. G. J. Symons, Sir Archibald 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, Professor Michie Smith, and Professor H. L. Callendar.
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.
Considering the best Methods of Recording the Direct Intensity of Solar Radiation.	*Chairman.*—Dr. G. Johnstone Stoney. *Secretary.*—Professor H. McLeod. Sir G. G. Stokes, Professor A. Schuster, Sir H. E. Roscoe, Captain W. de W. Abney, Dr. C. Chree, Professor G. F. FitzGerald, Professor H. L. Callendar, Mr. G. J. Symons, Mr. W. E. Wilson, and Professor A. A. Rambaut.
That Miss Hardcastle be requested to draw up a Report on the present state of the Theory of Point-Groups.	—
The Continuation of the Bibliography of Spectroscopy.	*Chairman.*—Professor H. McLeod. *Secretary.*—Sir W. C. Roberts-Austen. Mr. H. G. Madan, and Mr. D. H. Nagel.
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, Dr. Silvanus P. Thompson, and Professor A. Smithells.

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

Subject for Investigation or Purpose	Members of the Committee
The Promotion of Agriculture: to report on the means by which in various Countries Agriculture is advanced by research, by special Educational Institutions, and by the dissemination of information and advice among Agriculturists.	*Chairman.*—Sir John Evans. *Secretary.*—Professor H. E. Armstrong. Sir Michael Foster, Professor Marshall Ward, Sir J. H. Gilbert, Right Hon. J. Bryce, Professor J. W. Robertson, Dr. W. Saunders, Professor Mills, Professor J. Mavor, Professor Poulton, and Mr. S. U. Pickering.
Isomeric Naphthalene Derivatives.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Professor H. E. Armstrong.
To establish a Uniform System of Recording the Results of the Chemical and Bacterial Examination of Water and Sewage.	*Chairman.*—Professor W. Ramsay. *Secretary.*—Dr. S. Rideal. Professor F. Clowes, Professor P. F. Frankland, Professor R. Boyce, and Mr. W. J. Dibdin.
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.
The Collection, Preservation, and Systematic Registration of Canadian Photographs of Geological Interest.	*Chairman.*—Professor A. P. Coleman. *Secretary.*—Mr. Parks. Professor A. B. Willmott, Professor F. D. Adams, Mr. J. B. Tyrrell, and Professor W. W. Watts.
To report upon the Present State of our Knowledge of the Structure of Crystals.	*Chairman.*—Professor N. Story Maskelyne. *Secretary.*—Professor H. A. Miers. Mr. L. Fletcher, Professor W. J. Sollas, Mr. W. Barlow, Mr. G. F. H. Smith, and the Earl of Berkeley.
To study Life-zones in the British Carboniferous Rocks.	*Chairman.*—Mr. J. E. Marr. *Secretary.*—Dr. Wheelton Hind. Mr. F. A. Bather, Mr. G. C. Crick, Mr. A. H. Foord, Mr. H. Fox, Mr. E. J. Garwood, Dr. G. J. Hinde, Professor P. F. Kendall, Mr. J. W. Kirkby, Mr. R. Kidston, Mr. G. W. Lamplugh, Professor G. A. Lebour, Mr. G. H. Morton, Mr. B. N. Peach, Mr. A. Strahan, and Dr. H. Woodward.
To promote the Systematic Collection of Photographic and other Records of Pedigree Stock.	*Chairman.*—Mr. Francis Galton. *Secretary.*—Professor W. F. R. Weldon.
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.

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

Subject for Investigation or Purpose	Members of the Committee
The Present State of Anthropological Teaching in the United Kingdom and Elsewhere.	*Chairman.*—Professor E. B. Tylor. *Secretary.*—Mr. H. Ling Roth. Professor A. Macalister, Professor A. C. Haddon, Mr. C. H. Read, Mr. H. Balfour, Mr. F. W. Rudler, Dr. R. Munro, and Professor Flinders Petrie.
The Lake Village at Glastonbury.	*Chairman.*—Dr. R. Munro. *Secretary.*—Mr. A. Bulleid. Professor W. Boyd Dawkins, General Pitt-Rivers, Sir John Evans, Mr. Arthur J. Evans, and Mr. C. H. Read.
To enquire into the Effectiveness of the System of Identification by Finger-prints now in use throughout India, and on the Probable Limits of its Applicability.	*Chairman.*—Mr. Francis Galton. *Secretary.*—Mr. L. Gomme. Colonel R. C. Temple, Mr. C. H. Read, Mr. W. Crooke, Professor Karl Pearson, and Professor W. F. R. Weldon.
The Micro-chemistry of Cells.	*Chairman.*—Professor E. A. Schäfer. *Secretary.*—Professor A. B. Macallum. Professor E. Ray Lankester, Professor W. D. Halliburton, and Mr. G. C. Bourne.

Communications ordered to be printed in extenso.

'The new Alexander III. Bridge in Paris,' by M. Amédée Alby.
'The Dover Harbour Works,' by J. C. Coode and W. Matthews.

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

That in view of the opportunities of ethnographical inquiry which will be presented by the Indian Census, the Council of the Association be requested to urge the Government of India to make use of the Census Officers for the purposes enumerated below, and to place photographers at the service of the Census Officers.

That the Council be requested to represent to Her Majesty's Government the importance of giving more prominence to Botany in the training of Indian Forest Officers.

That the attention of the Council be called to the wording of the rule regarding specimens collected by Committees appointed by the Association, with a view to its revision.

That the complete investigation of the Ichthyology of the West African rivers promises extremely important scientific results, and that the Council of the Association be requested to take such means as may seem to it advisable to bring the matter to the notice of the Trustees of the British Museum.

Change of Hours of Meetings, &c.

That the Organising Committees meet at 2 P.M. instead of at 11 A.M.; and shall, until the Sectional Officers are definitely appointed by the General Committee, exercise the functions of Sectional Committees, with power to appoint members of the Sectional Committees.

That the first meeting of the General Committee be held at 4 P.M. instead of at 1 P.M.

That the proceedings of the opening meeting begin at 8.30 P.M. instead of at 8 P.M. as heretofore.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Dover Meeting, September, 1899. The Names of the Members entitled to call on the General Treasurer for the respective Grants are prefixed.

	£	s.	d.
Mathematics.			
*Rayleigh, Lord—Electrical Standards (and £300 in hand)...	25	0	0
*Judd, Professor J. W.—Seismological Observations...........	60	0	0
*FitzGerald, Professor G. F.—Radiation in a Magnetic Field	25	0	0
*Rücker, Professor A. W.—Magnetic Force on board Ship...	10	0	0
*Callendar, Professor H. L.—Meteorological Observatory, Montreal	20	0	0
*Kelvin, Lord—Tables of Mathematical Functions	75	0	0
Chemistry.			
*Hartley, Professor W. N.—Relation between Absorption Spectra and Constitution of Organic Bodies	30	0	0
*Roscoe, Sir H. E.—Wave-length Tables	5	0	0
*Reynolds, Professor J. E.—Electrolytic Quantitative Analysis	5	0	0
Miers, Professor H. A.—Isomorphous Sulphonic Derivatives of Benzene	20	0	0
Neville, Mr. F. H.—The Nature of Alloys	30	0	0
Geology.			
*Hull, Professor E.—Erratic Blocks (£6 in hand)..............	—		
*Geikie, Professor J.—Photographs of Geological Interest ...	10	0	0
*Dawkins, Professor W. B.—Remains of Elk in the Isle of Man	5	0	0
*Dawson, Sir J. W.—Pleistocene Fauna and Flora in Canada	10	0	0
*Lloyd-Morgan, Professor C.—Ossiferous Caves at Uphill (£8 in hand)	10	0	0
Watts, Professor W. W.—Movements of Underground Waters of Craven	40	0	0
Scharff, Dr.—Exploration of Irish Caves	20	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	20	0	0
*Woodward, Dr. H.—Index Generum et Specierum Animalium	50	0	0
*Newton, Professor A.—Migration of Birds	15	0	0
*Lankester, Professor E. Ray—Plankton and Physical Conditions of the English Channel..................................	40	0	0
*Newton, Professor—Zoology of the Sandwich Islands.........	100	0	0
Sedgwick, Mr. A.—Coral Reefs of the Indian Regions	30	0	0
Carried forward	755	0	0

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* Reappointed.

	£	s.	d.
Brought forward	755	0	0
Geography.			
Murray, Sir John—Physical and Chemical Constants of Sea Water	100	0	0
Economic Science and Statistics.			
*Price, Mr. L. L.—Future Dealings in Raw Produce	5	0	0
*Sedgwick, Professor H.—State Monopolies in other Countries (£13 13*s.* 6*d.* in hand)	—		
Mechanical Science.			
*Preece, Sir W. H.—Small Screw Gauge (£17 1*s.* 2*d.* in hand)	—		
Anthropology.			
*Evans, Mr. A. J.—Silchester Excavation	10	0	0
*Penhallow, Professor D. P.—Ethnological Survey of Canada	50	0	0
*Tylor, Professor E. B.—New Edition of 'Anthropological Notes and Queries'	40	0	0
*Garson, Dr. J. G.—Age of Stone Circles (balance in hand)...	—		
*Read, Mr. C. H.—Photographs of Anthropological Interest	10	0	0
*Brabrook, Mr. E. W.—Mental and Physical Condition of Children	5	0	0
Read, Mr. C. H.—Ethnography of the Malay Peninsula	25	0	0
Physiology.			
*Schäfer, Professor E. A.—Physiological Effects of Peptone...	20	0	0
*Schäfer, Professor E. A.—Comparative Histology of Suprarenal Capsules	20	0	0
*Gotch, Professor F.—Comparative Histology of Cerebral Cortex	5	0	0
Gotch, Professor F.—Electrical Changes in Mammalian Nerves	20	0	0
Starling, Dr.—Vascular Supply of Secreting Glands	10	0	0
Botany.			
*Darwin, Mr. F.—Assimilation in Plants (£6 6*s.* 8*d.* in hand)	—		
*Farmer, Professor J. B.—Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies.			
*Meldola, Professor R.—Preparation of Report	20	0	0
	£1,115	0	0

* Reappointed.

The Annual Meeting in 1900.

The Annual Meeting of the Association in 1900 will be held at Bradford, commencing on September 5.

The Annual Meeting in 1901.

The Annual Meeting of the Association in 1901 will be held at Glasgow.

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	6
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	50	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.

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.

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 Seed	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.

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.

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.

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.

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 Sodaceto-acetate	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 Sodaceto-acetate	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.

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.

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	
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

1897.

	£	s.	d.
Mathematical Tables	25	0	0
Seismological Observations...	100	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Electrolysis and Electrochemistry	50	0	0
Electrolytic Quantitative Analysis	10	0	0
Isomeric Naphthalene Derivatives	50	0	0
Erratic Blocks	10	0	0
Photographs of Geological Interest	15	0	0
Remains of the Irish Elk in the Isle of Man	15	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	9	10	8
Zoological Bibliography and Publication	5	0	0
Index Generum et Specierum Animalium	100	0	0
Zoology and Botany of the West India Islands	40	0	0
The Details of Observations on the Migration of Birds	40	0	0
Climatology of Tropical Africa	20	0	0
Ethnographical Survey	40	0	0
Mental and Physical Condition of Children	10	0	0
Silchester Excavation	20	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	180	0	0
Oysters and Typhoid	30	0	0
Physiological Applications of the Phonograph	15	0	0
Physiological Effects of Peptone and its Precursors	20	0	0
Fertilisation in Phæophyceæ	20	0	0
Corresponding Societies Committee	25	0	0
	£1,059	10	8

1898.

Electrical Standards	75	0	0
Seismological Observations...	75	0	0
Abstracts of Physical Papers	100	0	0
Calculation of Certain Integrals	10	0	0
Electrolysis and Electro-chemistry	35	0	0
Meteorological Observatory at Montreal	50	0	0

	£	s.	d.
Wave-length Tables of the Spectra of the Elements	20	0	0
Action of Light upon Dyed Colours	8	0	0
Erratic Blocks	5	0	0
Investigation of a Coral Reef	40	0	0
Photographs of Geological Interest	10	0	0
Life-zones in British Carboniferous Rocks	15	0	0
Pleistocene Fauna and Flora in Canada	20	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	14	0	0
Index Generum et Specierum Animalium	100	0	0
Healthy and Unhealthy Oysters	30	0	0
Climatology of Tropical Africa	10	0	0
State Monopolies in other Countries	15	0	0
Small Screw Gauge	20	0	0
North-Western Tribes of Canada	75	0	0
Lake Village at Glastonbury	37	10	0
Silchester Excavation	7	10	0
Ethnological Survey of Canada	75	0	0
Anthropology and Natural History of Torres Straits	125	0	0
Investigation of Changes associated with the Functional Activity of Nerve Cells and their Peripheral Extensions	100	0	0
Fertilisation in Phæophyceæ	15	0	0
Corresponding Societies Committee	25	0	0
	£1,212	0	0

1899.

	£	s.	d.
Electrical Standards	225	0	0
Seismological Observations	65	14	8
Science Abstracts	100	0	0
Heat of Combination of Metals in Alloys	20	0	0
Radiation in a Magnetic Field	50	0	0
Calculation of Certain Integrals	10	0	0
Action of Light upon Dyed Colours	4	19	6
Relation between Absorption Spectra and Constitution of Organic Substances	50	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	10	0	0
Remains of Irish Elk in the Isle of Man	15	0	0
Pleistocene Flora and Fauna in Canada	30	0	0
Records of Disappearing Drift Section at Moel Tryfaen	5	0	0
Ty Newydd Caves	40	0	0
Ossiferous Caves at Uphill	30	0	0
Table at the Zoological Station, Naples	100	0	0
Table at the Biological Laboratory, Plymouth	20	0	0
Index Generum et Specierum Animalium	100	0	0
Migration of Birds	15	0	0
Apparatus for Keeping Aquatic Organisms under Definite Physical Conditions	15	0	0
Plankton and Physical Conditions of the English Channel during 1899	100	0	0
Exploration of Sokotra	35	0	0
Lake Village at Glastonbury	50	0	0
Silchester Excavation	10	0	0
Ethnological Survey of Canada	35	0	0
New Edition of 'Anthropological Notes and Queries'	40	0	0
Age of Stone Circles	20	0	0
Physiological Effects of Peptone	30	0	0
Electrical Changes accompanying Discharge of Respiratory Centres	20	0	0
Influence of Drugs upon the Vascular Nervous System	10	0	0
Histological Changes in Nerve Cells	20	0	0
Micro-chemistry of Cells	40	0	0
Histology of Suprarenal Capsules	20	0	0
Comparative Histology of Cerebral Cortex	10	0	0
Fertilisation in Phyæophyceæ	20	0	0
Assimilation in Plants	20	0	0
Zoological and Botanical Publication	5	0	0
Corresponding Societies Committee	25	0	0
	£1430	14	2

General Meetings.

On Wednesday, September 13, at 8 P.M., in the Connaught Hall, Dover, Sir William Crookes, F.R.S., V.P.C.S., resigned the office of President to Sir Michael Foster, K.C.B., Sec.R.S., who took the Chair, and delivered an Address, for which see page 3.

On Thursday, September 14, at 8.30 P.M., a Soirée took place in the School of Art.

On Friday, September 15, at 8.30 P.M., in the Connaught Hall, Professor Charles Richet delivered a discourse on 'La Vibration Nerveuse.'

On Saturday, September 16, members of the Association Française pour l'Avancement des Sciences visited the British Association at Dover.

On Monday, September 18, at 8.30 P.M., in the Connaught Hall, Professor Fleming, F.R.S., delivered a discourse on 'The Centenary of the Electric Current.'

On Tuesday, September 19, at 8.30 P.M., a Soirée took place in the Granville Gardens.

On Wednesday, September 20, at 11 A.M., in the Connaught 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 Bradford. [The Meeting is appointed to commence on Wednesday, September 5, 1900.]

On Thursday, September 21, members of the Association visited the Association Française at Boulogne.

PRESIDENT'S ADDRESS.

ADDRESS

BY

PROFESSOR SIR MICHAEL FOSTER, K.C.B., SEC.R.S.

PRESIDENT.

He who until a few minutes ago was your President said somewhere at the meeting at Bristol, and said with truth, that among the qualifications needed for the high honour of Presidency of the British Association for the Advancement of Science, that of being old was becoming more and more dominant. He who is now attempting to speak to you feels that he is rapidly earning that distinction. But the Association itself is older than its President; it has seen pass away the men who, wise in their generation, met at York on September 27, 1831, to found it; it has seen other great men who in bygone years served it as Presidents, or otherwise helped it on, sink one after another into the grave. Each year, indeed, when it plants its flag as a signal of its yearly meeting, that flag floats half-mast high in token of the great losses which the passing year has brought. This year is no exception; the losses, indeed, are perhaps unwontedly heavy. I will not attempt to call over the sad roll-call; but I must say a word about one who was above most others a faithful and zealous friend of the Association. Sir Douglas Galton joined the Association in 1860. From 1871 to 1895, as one of the General Secretaries, he bore, and bore to the great good of the Association, a large share of the burden of the Association's work. How great that share was is perhaps especially known to the many men, among whom I am proud to count myself, who during his long term of office served in succession with him as brother General Secretary. In 1895, at Ipswich, he left the post of General Secretary, but only to become President. So long and so constantly did he labour for the good of the Association that he seemed to be an integral part of it, and meeting as we do to-day, and as we henceforward must do, without Douglas Galton, we feel something greatly missing. This year, perhaps even more than in other years, we could have wished him to be among us; for to-day the Association may look with joy, not unmixed with pride, on the realisation of a project in forwarding which it has had a conspicuous share, on the commencement of an undertaking which is not only a great thing in itself, but which, we trust, is the beginning of still greater things to come. And the share which the Association has had in this was largely Sir Douglas Galton's doing. In his Address as President of Section A, at the meeting of the Association at Cardiff in 1891, Professor Oliver Lodge expounded with pregnant words how urgently, not pure science only, but industry and the constructive arts—for the interests of these are ever at bottom the same—needed the aid of some national establishment for the prosecution of prolonged and costly physical researches, which private enterprise could carry out in a lame fashion only, if at all. Lodge's words found an echo in many men's minds; but the response was for a long while in men's minds only. In 1895, Sir Douglas Galton, having previously made a personal study of an institution analogous to the one desired—namely, the Reichsanstalt at Berlin—seized the opportunity offered to him as President of the Association at Ipswich to insist, with the authority not only of the head for the time being of a great scientific body, but also of one who himself knew the ways and wants at once of science and of practical life, that the thing which Lodge and others had hoped for was a thing which could be done, and ought to be done at once. And now to-day we can say it has been done. The National Physical Laboratory has been founded. The Address at Ipswich marked the beginning of an organised effort which has at last been crowned with success. A feeling of sadness cannot but come over us when we think that Sir Douglas Galton was not spared to see the formal completion of the scheme whose birth he did so much to help, and which, to his last days, he aided in more ways than one. It is the old story—the good which men do lives after them.

Still older than the Association is this nineteenth century, now swiftly drawing to its close. Though the century itself has yet some sixteen months to run, this is the last meeting of the British Association which will use the numbers eighteen hundred to mark its date.

The eyes of the young look ever forward; they take little heed of the short though ever-lengthening fragment of life which lies behind them; they are wholly bent on that which is to come. The eyes of the aged turn wistfully again and again to the past; as the old glide down the inevitable slope their present becomes a living over again the life which has gone before, and the future takes on the shape of a brief lengthening of the past. May I this evening venture to give rein to the impulses of advancing years? May I, at this last meeting of the Association in the eighteen hundreds, dare to dwell for a while upon the past, and to call to mind a few of the changes which have taken place in the world since those autumn days in which men were saying to each other that the last of the seventeen hundreds was drawing towards its end?

Dover in the year of our Lord seventeen hundred and ninety-nine was in many ways unlike the Dover of to-day. On moonless nights men groped their way in its narrow streets by the help of swinging lanterns and smoky torches, for no lamps lit the ways. By day the light of the sun struggled into the houses through narrow panes of blurred glass. Though the town then, as now, was one of the chief portals to and from the countries beyond the seas, the means of travel were scanty and dear, available for the most part to the rich alone, and, for all, beset with discomfort and risk. Slow and uncertain was the carriage of goods, and the news of the world outside came to the town—though it from its position learnt more than most towns—tardily, fitfully, and often falsely. The people of Dover sat then much in dimness, if not in darkness, and lived in large measure on themselves. They who study the phenomena of living beings tell us that light is the great stimulus of life, and that the fulness of the life of a being or of any of its members may be measured by the variety, the swiftness, and the certainty of the means by which it is in touch with its surroundings. Judged from this standpoint life at Dover then, as indeed elsewhere, must have fallen far short of the life of to-day.

The same study of living beings, however, teaches us that while from one point of view the environment seems to mould the organism, from another point the organism seems to be master of its environment. Going behind the change of circumstances, we may raise the question, the old question, Was life in its essence worth more then than now? Has there been a real advance?

Let me at once relieve your minds by saying that I propose to leave this question in the main unanswered. It may be, or it may not be, that man's grasp of the beautiful and of the good, if not looser, is not firmer than it was a hundred years ago. It may be, or it may not be, that man is no nearer to absolute truth, to seeing things as they really are, than he was then. I will merely ask you to consider with me for a few minutes how far, and in what ways, man's laying hold of that aspect of or part of truth which we call natural knowledge, or sometimes science, differed in 1799 from what it is to-day, and whether that change must not be accounted a real advance, a real improvement in man.

I do not propose to weary you by what in my hands would be the rash effort of attempting a survey of all the scientific results of the nineteenth century. It will be enough if for a little while I dwell on some few of the salient features distinguishing the way in which we nowadays look upon, and during the coming week shall speak of, the works of Nature around us—though those works themselves, save for the slight shifting involved in a secular change, remain exactly the same—from the way in which they were looked upon and might have been spoken of at a gathering of philosophers at Dover in 1799. And I ask your leave to do so.

In the philosophy of the ancients, earth, fire, air, and water were called 'the elements.' It was thought, and rightly thought, that a knowledge of them and of their attributes was a necessary basis of a knowledge of the ways of Nature. Translated into modern language, a knowledge of these 'elements of old means a knowledge of the composition of the atmosphere, of water, and of all the other things which we call matter, as well as a knowledge of the general properties of gases, liquids, and solids, and of the nature and effects of combustion. Of all these things our knowledge to-day is large and exact, and, though ever enlarging, in some respects complete. When did that knowledge begin to become exact?

To-day the children in our schools know that the air which wraps round the globe is not a single thing, but is made up of two things, oxygen and nitrogen,[1] mingled together. They know, again, that water is not a single thing, but the product of two things, oxygen and hydrogen, joined together. They know that when the air makes the fire burn and gives the animal life, it is the oxygen in it which does the work. They know that all round them things are undergoing that union with oxygen which we call oxidation, and that oxidation is the ordinary source of heat and light. Let me ask you to picture to yourselves what confusion there would be to-morrow, not only in the discussions at the sectional meetings of our Association, but in the world at large, if it should happen that in the coming night some destroying touch should wither up certain tender structures in all our brains, and wipe out from our memories all traces of the ideas which cluster in our minds around the verbal tokens, oxygen and oxidation. How could any of us, not the so-called man of science alone, but even the man of business and the man of pleasure, go about his ways lacking those ideas? Yet those ideas were in 1799 lacking to all but a few.

Although in the third quarter of the seventeenth century the light of truth about oxidation and combustion had flashed out in the writings of John Mayow, it came as a flash only, and died away as soon as it had come. For the rest of that century, and for the greater part of the next, philosophers stumbled about in darkness, misled for the most of the time by the phantom conception which they called phlogiston. It was not until the end of the third quarter of the eighteenth century that the new light, which has burned steadily ever since, lit up the minds of the men of science. The light came at nearly the same time from England and from France. Rounding off the sharp corners of controversy, and joining, as we may fitly do to-day, the two countries as twin bearers of a common crown, we may say that we owe the truth to Priestley, to Lavoisier, and to Cavendish. If it was Priestley who was the first to demonstrate the existence of what we now call oxygen, it is to Lavoisier we owe the true conception of the nature of oxidation and the clear exposition of the full meaning of Priestley's discovery, while the knowledge of the composition of water, the necessary complement of the knowledge of oxygen, came to us through Cavendish and, we may perhaps add, through Watt.

The date of Priestley's discovery of oxygen is 1774, Lavoisier's classic memoir 'on the nature of the principle which enters into combination

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[1] Some may already know that there is at least a third thing, argon.

with metals during calcination' appeared in 1775, and Cavendish's paper on the composition of water did not see the light until 1784.

During the last quarter of the eighteenth century this new idea of oxygen and oxidation was struggling into existence. How new was the idea is illustrated by the fact that Lavoisier himself at first spoke of that which he was afterwards, namely in 1778, led to call oxygen, the name by which it has since been known, as 'the principle which enters into combination.' What difficulties its acceptance met with is illustrated by the fact that Priestley himself refused to the end of his life to grasp the true bearings of the discovery which he had made. In the year 1799 the knowledge of oxygen, of the nature of water and of air, and indeed the true conception of chemical composition and chemical change, was hardly more than beginning to be, and the century had to pass wholly away before the next great chemical idea, which we know by the name of the Atomic Theory of John Dalton, was made known. We have only to read the scientific literature of the time to recognise that a truth which is now not only woven as a master-thread into all our scientific conceptions, but even enters largely into the everyday talk and thoughts of educated people, was a hundred years ago struggling into existence among the philosophers themselves. It was all but absolutely unknown to the large world outside those select few.

If there be one word of science which is writ large on the life of the present time, it is the word 'electricity'; it is, I take it, writ larger than any other word. The knowledge which it denotes has carried its practical results far and wide into our daily life, while the theoretical conceptions which it signifies pierce deep into the nature of things. We are to-day proud, and justly proud, both of the material triumphs and of the intellectual gains which it has brought us, and we are full of even larger hopes of it in the future.

At what time did this bright child of the nineteenth century have its birth?

He who listened to the small group of philosophers of Dover, who in 1799 might have discoursed of natural knowledge, would perhaps have heard much of electric machines, of electric sparks, of the electric fluid, and even of positive and negative electricity; for frictional electricity had long been known and even carefully studied. Probably one or more of the group, dwelling on the observations which Galvani, an Italian, had made known some twenty years before, developed views on the connection of electricity with the phenomena of living bodies. Possibly one of them was exciting the rest by telling how he had just heard that a professor at Pavia, one Volta, had discovered that electricity could be produced, not only by rubbing together particular bodies, but by the simple contact of two metals, and had thereby explained Galvani's remarkable results. For, indeed, as we shall hear from Professor Fleming, it was in that very year, 1799, that electricity as we now know it took its birth. It was then that Volta brought to light the apparently simple truths out of which so much has sprung. The world, it is true, had to wait for yet some twenty years before both the practical and the theoretic worth of Volta's discovery became truly pregnant, under the fertilising influence of another discovery. The loadstone and magnetic virtues had, like the electrifying power of rubbed amber, long been an old story. But, save for the compass, not much had come from it. And even Volta's discovery might have long remained relatively barren had it been left to itself. When, however, in 1819, Oersted made known his remarkable observations on the relations of electricity to magnetism, he made the contact needed for the flow of a new current of ideas. And it is perhaps not too much to say that those ideas, developing during the years of the rest of the century with an ever-accelerating swiftness, have wholly changed man's material relations to the circumstances of life, and at the same time carried him far in his knowledge of the nature of things.

Of all the various branches of science, none perhaps is to-day, none for these many years past has been, so well known to, even if not understanded by, most people as that of geology. Its practical lessons have brought wealth to many ; its fairy tales have brought delight to more ; and round it hovers the charm of danger, for the conclusions to which it leads touch on the nature of man's beginning.

In 1799, the science of geology, as we now know it, was struggling into birth. There had been from of old cosmogonies, theories as to how the world had taken shape out of primæval chaos. In that fresh spirit which marked the zealous search after natural knowledge pursued in the middle and latter part of the seventeenth century, the brilliant Stenson, in Italy, and Hooke, in our own country, had laid hold of some of the problems presented by fossil remains ; and Woodward, with others, had laboured in the same field. In the eighteenth century, especially in its latter half, men's minds were busy about the physical agencies determining or modifying the features of the earth's crust ; water and fire, subsidence from a primæval ocean and transformation by outbursts of the central heat, Neptune and Pluto, were being appealed to, by Werner on the one hand, and by Desmarest on the other, in explanation of the earth's phenomena. The way was being prepared, theories and views were abundant, and many sound observations had been made ; and yet the science of geology, properly so called, the exact and proved knowledge of the successive phases of the world's life, may be said to date from the closing years of the eighteenth century.

In 1783, James Hutton put forward in a brief memoir his 'Theory of the Earth,' which in 1795, two years before his death, he expanded into a book ; but his ideas failed to lay hold of men's minds until the century had passed away, when, in 1802, they found an able expositor in John Playfair. The very same year that Hutton published his theory, Cuvier came to Paris and almost forthwith began, with Brongniart, his immortal researches into the fossils of Paris and its neighbourhood. And four years later, in the year 1799 itself, William Smith's tabular list of strata and fossils saw the light. It is, I believe, not too much to say that out of these geology, as we now know it, sprang. It was thus in the closing years of the eighteenth century that was begun the work which the nineteenth century has carried forward to such great results. But at that time only the select few had grasped the truth, and even they only the beginning of it. Outside a narrow circle the thoughts, even of the educated, about the history of the globe were bounded by the story of the Deluge—though the story was often told in a strange fashion—or were guided by fantastic views of the plastic forces of a sportive Nature.

In another branch of science, in that which deals with the problems presented by living beings, the thoughts of men in 1799 were also very different from the thoughts of men to-day. It is a very old quest, the quest after the knowledge of the nature of living beings, one of the earliest on which man set out; for it promised to lead him to a knowledge of himself, a promise which perhaps is still before us, but the fulfilment of which is as yet far off. As time has gone on, the pursuit of natural knowledge has seemed to lead man away from himself into the furthermost parts of the universe, and into secret workings of Nature in which he appears to be of little or no account; and his knowledge of the nature of living things, and so of his own nature, has advanced slowly, waiting till the progress of other branches of natural knowledge can bring it aid. Yet in the past hundred years, the biologic sciences, as we now call them, have marched rapidly onward.

We may look upon a living body as a machine doing work in accordance with certain laws, and may seek to trace out the working of the inner wheels, how these raise up the lifeless dust into living matter, and let the living matter fall away again into dust, giving rise to movement and heat. Or we may look upon the individual life as a link in a long chain, joining something which went before to something about to come, a chain whose beginning lies hid in the farthest past, and may seek to know the ties which bind one life to another. As we call up to view the long series of living forms, living now or flitting like shadows on the screen of the past, we may strive to lay hold of the influences which fashion the garment of life. Whether the problems of life are looked upon from the one point of view or the other, we to-day, not biologists only, but all of us, have gained a knowledge hidden even from the philosophers a hundred years ago.

Of the problems presented by the living body viewed as a machine, some may be spoken of as mechanical, others as physical, and yet others as chemical, while some are, apparently at least, none of these. In the seventeenth century William Harvey, laying hold of the central mechanism of the blood stream, opened up a path of inquiry which his own age and the century which followed trod with marked success. The knowledge of the mechanics of the animal and of the plant advanced apace; but the physical and chemical problems had yet to wait. The eighteenth century, it is true, had its physics and its chemistry; but, in relation at least to the problems of the living being, a chemistry which knew not oxygen and a physics which knew not the electricity of chemical action were of little avail. The philosopher of 1799, when he discussed the functions of the animal or of the plant involving chemical changes, was fain for the most part, as were his predecessors in the century before, to have recourse to such vague terms as 'fermentation' and the like; to-day our treatises on physiology are largely made up of precise and exact expositions of the play of physical agencies and chemical bodies in the living organism. He made use of the words 'vital force' or 'vital principle' not as an occasional, but as a common, explanation of the phenomena of the living body. During the present century, especially during its latter half, the idea embodied in those words has been driven away from one seat after another; if we use it now when we are dealing with the chemical and physical events of life we use it with reluctance, as a *deus ex machina* to be appealed to only when everything else has failed.

Some of the problems—and those, perhaps, the chief problems—of the living body have to be solved neither by physical nor by chemical methods, but by methods of their own. Such are the problems of the nervous system. In respect to these the men of 1799 were on the threshold of a pregnant discovery. During the latter part of the present century, and especially during its last quarter, the analysis of the mysterious processes in the nervous system, which issue as feeling, thought, and power to move, has been pushed forward with a success conspicuous in its practical, and full of promise in its theoretical, gains. That analysis may be briefly described as a following up of threads. We now know that what takes place along a tiny thread which we call a nerve-fibre differs from that which takes place along its fellow-threads, that differing nervous impulses travel along different nerve-fibres, and that nervous and psychical events are the outcome of the clashing of nervous impulses as they sweep along the closely-woven web of living threads of which the brain is made. We have learnt by experiment and by observation that the pattern of the web determines the play of the impulses, and we can already explain many of the obscure problems not only of nervous disease, but of nervous life, by an analysis which is a tracking out the devious and linked paths of nervous threads. The very beginning of this analysis was unknown in 1799. Men knew that nerves were the agents of feeling and of the movements of muscles; they had learnt much about what this part or that part of the brain could do; but they did not know that one nerve-fibre differed from another in the very essence of its work. It was just about the end of the past century, or the beginning of the present one, that an English surgeon began to ponder over a conception which, however, he did not make known until some years later, and which did not gain complete demonstration and full acceptance until still more years had passed away. It was in 1811, in a tiny pamphlet published privately, that Charles Bell put forward his 'New Idea' that the nervous system was constructed on the principle that 'the nerves are not single nerves possessing various powers, but bundles of different nerves, whose filaments are united for the convenience of distribution, but which are distinct in office as they are in origin from the brain.'

Our present knowledge of the nervous system is to a large extent only an exemplification and expansion of Charles Bell's 'New Idea,' and has its origin in that.

If we pass from the problems of the living organism viewed as a machine to those presented by the varied features of the different creatures who have lived or who still live on the earth, we at once call to mind that the middle years of the present century mark an epoch in biologic thought such as never came before, for it was then that Charles Darwin gave to the world the 'Origin of Species.'

That work, however, with all the far-reaching effects which it has had, could have had little or no effect, or, rather, could not have come into existence, had not the earlier half of the century been in travail preparing for its coming. For the germinal idea of Darwin appeals, as to witnesses, to the results of two lines of biologic investigation which were almost unknown to the men of the eighteenth century.

To one of these lines I have already referred. Darwin, as we know, appealed to the geological record; and we also know how that record, imperfect as it was then, and imperfect as it must always remain, has since his time yielded the most striking proofs of at least one part of his general conception. In 1799 there was, as we have seen, no geological record at all.

Of the other line I must say a few words.

To-day the merest beginner in biologic study, or even that exemplar of acquaintance without knowledge, the general reader, is aware that every living being, even man himself, begins its independent existence as a tiny ball, of which we can, even acknowledging to the full the limits of the optical analysis at our command, assert with confidence that in structure, using that word in its ordinary sense, it is in all cases absolutely simple. It is equally well known that the features of form which supply the characters of a grown-up living being, all the many and varied features of even the most complex organism, are reached as the goal of a road, at times a long road, of successive changes; that the life of every being, from the ovum to its full estate, is a series of shifting scenes, which come and go, sometimes changing abruptly, sometimes melting the one into the other, like dissolving views, all so ordained that often the final shape with which the creature seems to begin, or is said to begin, its life in the world is the outcome of many shapes, clothed with which it has in turn lived many lives before its seeming birth.

All or nearly all the exact knowledge of the laboured way in which each living creature puts on its proper shape and structure is the heritage of the present century. Although the way in which the chick is moulded in the egg was not wholly unknown even to the ancients, and in later years had been told, first in the sixteenth century by Fabricius, then in the seventeenth century in a more clear and striking manner by the great Italian naturalist Malpighi, the teaching thus offered had been neglected or misinterpreted. At the close of the eighteenth century the dominant view was that in the making of a creature out of the egg there was no putting on of wholly new parts, no epigenesis. It was taught that the entire creature lay hidden in the egg, hidden by reason of the very transparency of its substance, lay ready-made but folded up, as it were, and that the process of development within the egg or within the womb was a mere unfolding, a simple evolution. Nor did men shrink from accepting the logical outcome of such a view—namely, that within the unborn creature itself lay in like manner, hidden and folded up, its offspring also, and within that again its offspring in turn, after the fashion of a cluster of ivory balls carved by Chinese hands, one within the other. This was no fantastic view put forward by an imaginative dreamer; it was seriously held by sober men, even by men like the illustrious Haller, in spite of their recognising that as the chick grew in the egg some changes of form took place. Though so early as the middle of the eighteenth century Friedrich Caspar Wolff and, later on, others had strenuously opposed such a view, it held its own not only to the close of the century, but far on into the next. It was not until a quarter of the present century had been added to the past that Von Baer made known the results of researches which once and for all swept away the old view. He and others working after him made it clear that each individual puts on its final form and structure not by an unfolding of pre-existing hidden features, but by the formation of new parts through the continued differentiation of a primitively simple material. It was also made clear that the successive changes which the embryo undergoes in its progress from the ovum to maturity are the expression of morphologic laws, that the progress is one from the general to the special, and that the shifting scenes of embryonic life are hints and tokens of lives lived by ancestors in times long past.

If we wish to measure how far off in biologic thought the end of the last century stands, not only from the end but even from the middle of this one, we may imagine Darwin striving to write the 'Origin of Species' in 1799. We may fancy him being told by philosophers that one group of living beings differed from another group because all its members and all their ancestors came into existence at one stroke when the first-born progenitor of the race, within which all the rest were folded up, stood forth as the result of a creative act. We may fancy him listening to a debate between the philosopher who maintained that all the fossils strewn in the earth were the remains of animals or plants churned up in the turmoil of a violent universal flood, and dropped in their places as the waters went away, and him who argued that such were not really the 'spoils of living creatures,' but the products of some playful plastic power which out of the superabundance of its energy fashioned here and there the lifeless earth into forms which imitated, but only imitated, those of living things. Could he amid such surroundings by any flight of genius have beat his way to the conception for which his name will ever be known ?

Here I may well turn away from the past. It is not my purpose, nor, as I have said, am I fitted, nor is this perhaps the place, to tell even in outline the tale of the work of science in the nineteenth century. I am content to have pointed out that the two great sciences of chemistry and geology took their birth, or at least began to stand alone, at the close of the last century, and have grown to be what we know them now within about a hundred years, and that the study of living beings has within the same time been so transformed as to be to-day something wholly different from what it was in 1799. And, indeed, to say more would be to repeat almost the same story about other things. If our present knowledge of electricity is essentially the child of the nineteenth century, so also is our present knowledge of many other branches of physics. And those most ancient forms of exact knowledge, the knowledge of numbers and of the heavens, whose beginning is lost in the remote past, have, with all other kinds of natural knowledge, moved onward during the whole of the hundred years with a speed which is ever increasing. I have said, I trust, enough to justify the statement that in respect to natural knowledge a great gulf lies between 1799 and 1899. That gulf, moreover, is a two-fold one : not only has natural knowledge been increased, but men have run to and fro spreading it as they go. Not only have the few driven far back round the full circle of natural knowledge the dark clouds of the unknown which wrap us all about, but also the many walk in the zone of light thus increasingly gained. If it be true that the few to-day are, in respect to natural knowledge, far removed from the few of those days, it is also true that nearly all which the few alone knew then, and much which even they did not know, has now become the common knowledge of the many.

What, however, I may venture to insist upon here is that the difference in respect to natural knowledge, whatever be the case with other differences between then and now, is undoubtedly a difference which means progress. The span between the science of that time and the science of to-day is beyond all question a great stride onwards.

We may say this, but we must say it without boasting. For the very story of the past which tells of the triumphs of science bids the man of science put away from him all thoughts of vainglory. And that by many tokens.

Whoever, working at any scientific problem, has occasion to study the inquiries into the same problem made by some fellow-worker in the years long gone by, comes away from that study humbled by one or other of two different thoughts. On the one hand he may find, when he has translated the language of the past into the phraseology of to-day, how near was his forerunner of old to the conception which he thought, with pride, was all his own, not only so true but so new. On the other hand, if the ideas of the investigator of old, viewed in the light of modern knowledge, are found to be so wide of the mark as to seem absurd, the smile which begins to play upon the lips of the modern is checked by the thought, Will the ideas which I am now putting forth, and which I think explain so clearly, so fully, the problem in hand, seem to some worker in the far future as wrong and as fantastic as do these of my forerunner to me? In either case his personal pride is checked. Further, there is written clearly on each page of the history of science, in characters which cannot be overlooked, the lesson that no scientific truth is born anew, coming by itself and of itself. Each new truth is always the offspring of something which has gone before, becoming in turn the parent of something coming after. In this aspect the man of science is unlike, or seems to be unlike, the poet and the artist. The poet is born, not made: he rises up, no man knowing his beginnings; when he goes away, though men after him may sing his songs for centuries, he himself goes away wholly, having taken with him his mantle, for this he can give to none other. The man of science is not thus creative; he is created. His work, however great it be, is not wholly his own; it is in part the outcome of the work of men who have gone before. Again and again a conception which has made a name great has come not so much by the man's own effort as out of the fulness of time. Again and again we may read in the words of some man of old the outlines of an idea which in later days has shone forth as a great acknowledged truth. From the mouth of the man of old the idea dropped barren, fruitless; the world was not ready for it, and heeded it not; the concomitant and abutting truths which could give it power to work were wanting. Coming back again in later days, the same idea found the world awaiting it; things were in travail preparing for it; and someone, seizing the right moment to put it forth again, leapt into fame. It is not so much the men of science who make science, as some spirit which, born of the truths already won, drives the man of science onward and uses him to win new truths in turn.

It is because each man of science is not his own master, but one of many obedient servants of an impulse which was at work long before him, and will work long after him, that in science there is no falling back. In respect to other things there may be times of darkness and times of light, there may be risings, decadences, and revivals. In science there is only progress. The path may not be always a straight line, there may be swerving to this side and to that, ideas may seem to return again and again to the same point of the intellectual compass ; but it will always be found that they have reached a higher level—they have moved, not in a circle, but in a spiral. Moreover science is not fashioned as is a house, by putting brick to brick, that which is once put remaining as it was put to the end. The growth of science is that of a living being. As in the embryo phase follows phase, and each member of the body puts on in succession different appearances, though all the while the same member, so a scientific conception of one age seems to differ from that of a following age, though it is the same one in the process of being made ; and as the dim outlines of the early embryo, as the being grows, become more distinct and sharp, like a picture on a screen brought more and more into focus, so the dim gropings and searchings of the men of science of old are by repeated approximations wrought into the clear and exact conclusions of later times.

The story of natural knowledge, of science, in the nineteenth century, as, indeed, in preceding centuries, is, I repeat, a story of continued progress. There is in it not so much as a hint of falling back, not even of standing still. What is gained by scientific inquiry is gained for ever ; it may be added to, it may seem to be covered up, but it can never be taken away. Confident that the progress will go on, we cannot help peering into the years to come and straining our eyes to foresee what science will become and what it will do as they roll on. While we do so, the thought must come to us, Will all the increasing knowledge of Nature avail only to change the ways of man—will it have no effect on man himself ?

The material good which mankind has gained and is gaining through the advance of science is so imposing as to be obvious to everyone, and the praises of this aspect of science are to be found in the mouths of all. Beyond all doubt science has greatly lessened and has markedly narrowed hardship and suffering ; beyond all doubt science has largely increased and has widely diffused ease and comfort. The appliances of science have, as it were, covered with a soft cushion the rough places of life, and that not for the rich only, but also for the poor. So abundant and so prominent are the material benefits of science that in the eyes of many these seem to be the only benefits which she brings. She is often spoken of as if she were useful and nothing more, as if her work were only to administer to the material wants of man.

Is this so ?

We may begin to doubt it when we reflect that the triumphs of science which bring these material advantages are in their very nature intellectual triumphs. The increasing benefits brought by science are the results of man's increasing mastery over Nature, and that mastery is increasingly a mastery of mind; it is an increasing power to use the forces of what we call inanimate nature in place of the force of his own or other creatures' bodies; it is an increasing use of mind in place of muscle.

Is it to be thought that that which has brought the mind so greatly into play has had no effect on the mind itself? Is that part of the mind which works out scientific truths a mere slavish machine producing results it knows not how, having no part in the good which in its working it brings forth?

What are the qualities, the features of that scientific mind which has wrought, and is working, such great changes in man's relation to Nature? In seeking an answer to this question we have not to inquire into the attributes of genius. Though much of the progress of science seems to take on the form of a series of great steps, each made by some great man, the distinction in science between the great discoverer and the humble worker is one of degree only, not of kind. As I was urging just now, the greatness of many great names in science is often, in large part, the greatness of occasion, not of absolute power. The qualities which guide one man to a small truth silently taking its place among its fellows, as these go to make up progress, are at bottom the same as those by which another man is led to something of which the whole world rings.

The features of the fruitful scientific mind are in the main three.

In the first place, above all other things, his nature must be one which vibrates in unison with that of which he is in search; the seeker after truth must himself be truthful, truthful with the truthfulness of Nature. For the truthfulness of Nature is not wholly the same as that which man sometimes calls truthfulness. It is far more imperious, far more exacting. Man, unscientific man, is often content with 'the nearly' and 'the almost.' Nature never is. It is not her way to call the same two things which differ, though the difference may be measured by less than the thousandth of a milligramme or of a millimetre, or by any other like standard of minuteness. And the man who, carrying the ways of the world into the domain of science, thinks that he may treat Nature's differences in any other way than she treats them herself, will find that she resents his conduct; if he in carelessness or in disdain overlooks the minute difference which she holds out to him as a signal to guide him in his search, the projecting tip, as it were, of some buried treasure, he is bound to go astray, and the more strenuously he struggles on, the farther will he find himself from his true goal.

In the second place, he must be alert of mind. Nature is ever making signs to us, she is ever whispering to us the beginnings of her secrets; the scientific man must be ever on the watch, ready at once to lay hold of Nature's hint, however small, to listen to her whisper, however low.

In the third place, scientific inquiry, though it be pre-eminently an intellectual effort, has need of the moral quality of courage—not so much the courage which helps a man to face a sudden difficulty as the courage of steadfast endurance. Almost every inquiry, certainly every prolonged inquiry, sooner or later goes wrong. The path, at first so straight and clear, grows crooked and gets blocked; the hope and enthusiasm, or even the jaunty ease, with which the inquirer set out leave him and he falls into a slough of despond. That is the critical moment calling for courage. Struggling through the slough he will find on the other side the wicket-gate opening up the real path; losing heart he will turn back and add one more stone to the great cairn of the unaccomplished.

But, I hear someone say, these qualities are not the peculiar attributes of the man of science, they may be recognised as belonging to almost everyone who has commanded or deserved success, whatever may have been his walk of life. That is so. That is exactly what I would desire to insist, that the men of science have no peculiar virtues, no special powers. They are ordinary men, their characters are common, even commonplace. Science, as Huxley said, is organised common sense, and men of science are common men, drilled in the ways of common sense.

For their life has this feature. Though in themselves they are no stronger, no better than other men, they possess a strength which, as I just now urged, is not their own but is that of the science whose servants they are. Even in his apprenticeship, the scientific inquirer, while learning what has been done before his time, if he learns it aright, so learns it that what is known may serve him not only as a vantage ground whence to push off into the unknown, but also as a compass to guide him in his course. And when fitted for his work he enters on inquiry itself, what a zealous anxious guide, what a strict and, because strict, helpful schoolmistress does Nature make herself to him! Under her care every inquiry, whether it bring the inquirer to a happy issue or seem to end in nought, trains him for the next effort. She so orders her ways that each act of obedience to her makes the next act easier for him, and step by step she leads him on towards that perfect obedience which is complete mastery.

Indeed, when we reflect on the potency of the discipline of scientific inquiry we cease to wonder at the progress of scientific knowledge. The results actually gained seem to fall so far short of what under such guidance might have been expected to have been gathered in that we are fain to conclude that science has called to follow her, for the most part, the poor in intellect and the wayward in spirit. Had she called to her service the many acute minds who have wasted their strength struggling in vain to solve hopeless problems, or who have turned their energies to things other than the increase of knowledge; had she called to her service the many just men who have walked straight without the need of a rod to guide them, how much greater than it has been would have been the progress of science, and how many false teachings would the world have been spared! To men of science themselves, when they consider their favoured lot, the achievements of the past should serve not as a boast, but as a reproach.

If there be any truth in what I have been urging, that the pursuit of scientific inquiry is itself a training of special potency, giving strength to the feeble and keeping in the path those who are inclined to stray, it is obvious that the material gains of science, great as they may be, do not make up all the good which science brings or may bring to man. We especially, perhaps, in these later days, through the rapid development of the physical sciences, are too apt to dwell on the material gains alone. As a child in its infancy looks upon its mother only as a giver of good things, and does not learn till in after days how she was also showing her love by carefully training it in the way it should go, so we, too, have thought too much of the gifts of science, overlooking her power to guide.

Man does not live by bread alone, and science brings him more than bread. It is a great thing to make two blades of grass grow where before one alone grew ; but it is no less great a thing to help a man to come to a just conclusion on the questions with which he has to deal. We may claim for science that while she is doing the one she may be so used as to do the other also. The dictum just quoted, that science is organised common sense, may be read as meaning that the common problems of life which common people have to solve are to be solved by the same methods by which the man of science solves his special problems. It follows that the training which does so much for him may be looked to as promising to do much for them. Such aid can come from science on two conditions only. In the first place, this her influence must be acknowledged ; she must be duly recognised as a teacher no less than as a hewer of wood and a drawer of water. And the pursuit of science must be followed not by the professional few only, but, at least in such measure as will ensure the influence of example, by the many. But this latter point I need not urge before this great Association, whose chief object during more than half a century has been to bring within the fold of science all who would answer to the call. In the second place, it must be understood that the training to be looked for from science is the outcome not of the accumulation of scientific knowledge, but of the practice of scientific inquiry. Man may have at his fingers' ends all the accomplished results and all the current opinions of any one or of all the branches of science, and yet remain wholly unscientific in mind ; but no one can have carried out even the humblest research without the spirit of science in some measure resting upon him. And that spirit may in part be caught even without entering upon an actual investigation in search of a new truth. The learner may be led to old truths, even the oldest, in more ways than one. He may be brought abruptly to a truth in its finished form, coming straight to it like a thief climbing over the wall ; and the hurry and press of modern life tempt many to adopt this quicker way. Or he may be more slowly guided along the path by which the truth was reached by him who first laid hold of it. It is by this latter way of learning the truth, and by this alone, that the learner may hope to catch something at least of the spirit of the scientific inquirer.

This is not the place, nor have I the wish, to plunge into the turmoil of controversy; but, if there be any truth in what I have been urging, then they are wrong who think that in the schooling of the young science can be used with profit only to train those for whom science will be the means of earning their bread. It may be that from the point of view of the pedagogic art the experience of generations has fashioned out of the older studies of literature an instrument of discipline of unusual power, and that the teaching of science is as yet but a rough tool in unpractised hands. That, however, is not an adequate reason why scope should not be given for science to show the value which we claim for it as an intellectual training fitted for all sorts and conditions of men. Nor need the studies of humanity and literature fear her presence in the schools, for if her friends maintain that that teaching is one-sided, and therefore misleading, which deals with the doings of man only, and is silent about the works of Nature, in the sight of which he and his doings shrink almost to nothing, she herself would be the first to admit that that teaching is equally wrong which deals only with the works of Nature and says nothing about the doings of man, who is, to us at least, Nature's centre.

There is yet another general aspect of science on which I would crave leave to say a word. In that broad field of human life which we call politics, in the struggle not of man with man, but of race with race, science works for good. If we look only on the surface it may at first sight seem otherwise. In no branch of science has there during these later years been greater activity and more rapid progress than in that which furnishes the means by which man brings death, suffering, and disaster on his fellow-men. If the healer can look with pride on the increased power which science has given him to alleviate human suffering and ward off the miseries of disease, the destroyer can look with still greater pride on the power which science has given him to sweep away lives and to work desolation and ruin; while the one has slowly been learning to save units, the other has quickly learnt to slay thousands. But, happily, the very greatness of the modern power of destruction is already becoming a bar to its use, and bids fair—may we hope before long?—wholly to put an end to it; in the words of Tacitus, though in another sense, the very preparations for war, through the character which science gives them, make for peace.

Moreover, not in one branch of science only, but in all, there is a deep undercurrent of influence sapping the very foundations of all war. As I have already urged, no feature of scientific inquiry is more marked than the dependence of each step forward on other steps which have been made before. The man of science cannot sit by himself in his own cave weaving out results by his own efforts, unaided by others, heedless of what others have done and are doing. He is but a bit of a great system, a joint in a great machine, and he can only work aright when he is in due touch with his fellow-workers. If his labour is to be what it ought to be, and is to have the weight which it ought to have, he must know what is being done, not by himself, but by others, and by others not of his own land and speaking his tongue only, but also of other lands and of other speech. Hence it comes about that to the man of science the barriers of manners and of speech which pen men into nations become more and more unreal and indistinct. He recognises his fellow-worker, wherever he may live and whatever tongue he may speak, as one who is pushing forward shoulder to shoulder with him towards a common goal, as one whom he is helping and who is helping him. The touch of science makes the whole world kin.

The history of the past gives us many examples of this brotherhood of science. In the revival of learning throughout the sixteenth and seventeenth centuries, and some way on into the eighteenth century, the common use of the Latin tongue made intercourse easy. In some respects in those earlier days science was more cosmopolitan than it afterwards became. In spite of the difficulties and hardships of travel, the men of science of different lands again and again met each other face to face, heard with their ears, and saw with their eyes what their brethren had to say or to show. The Englishman took the long journey to Italy to study there; the Italian, the Frenchman, and the German wandered from one seat of learning to another; and many a man held a chair in a country not his own. There was help, too, as well as intercourse. The Royal Society of London took upon itself the task of publishing nearly all the works of the great Italian Malpighi, and the brilliant Lavoisier, two years before his own countrymen in their blind fury slew him, received from the same body the highest token which it could give of its esteem.

In these closing years of the nineteenth century this great need of mutual knowledge and of common action felt by men of science of different lands is being manifested in a special way. Though nowadays what is done anywhere is soon known everywhere, the news of a discovery being often flashed over the globe by telegraph, there is an increasing activity in the direction of organisation to promote international meetings and international co-operation. In almost every science inquirers from many lands now gather together at stated intervals in international congresses to discuss matters which they have in common at heart, and go away each one feeling strengthened by having met his brother. The desire that in the struggle to lay bare the secrets of Nature the least waste of human energy should be incurred is leading more and more to the concerted action of nations combining to attack problems the solution of which is difficult and costly. The determination of standards of measurement, magnetic surveys, the solution of great geodetic problems, the mapping of the heavens and of the earth—all these are being carried on by international organisations.

In this and in other countries men's minds have this long while past been greatly moved by the desire to make fresh efforts to pierce the dark secrets of the forbidding Antarctic regions. Belgium has just made a brave single-handed attempt; a private enterprise sailing from these shores is struggling there now, lost for the present to our view; and this year we in England and our brethren in Germany are, thanks to the promised aid of the respective Governments, and no less to private liberality, in which this Association takes its share, able to begin the preparation of carefully organised expeditions. That international amity of which I am speaking is illustrated by the fact that in this country and in that there is not only a great desire, but a firm purpose, to secure the fullest co-operation between the expeditions which will leave the two shores. If in this momentous attempt any rivalry be shown between the two nations, it will be for each a rivalry, not in forestalling, but in assisting the other. May I add that if the story of the past may seem to give our nation some claim to the seas as more peculiarly our own, that claim bespeaks a duty likewise peculiarly our own to leave no effort untried by which we may plumb the seas' yet unknown depths and trace their yet unknown shores? That claim, if it means anything, means that when nations are joining hands in the dangerous work of exploring the unknown South, the larger burden of the task should fall to Britain's share; it means that we in this country should see to it, and see to it at once, that the concerted Antarctic expedition which in some two years or so will leave the shores of Germany, of England, and, perhaps, of other lands, should, so far as we are concerned, be so equipped and so sustained that the risk of failure and disaster may be made as small, and the hope of being able not merely to snatch a hurried glimpse of lands not yet seen, but to gather in with full hands a rich harvest of the facts which men not of one science only, but of many, long to know, as great as possible.

Another international scientific effort demands a word of notice. The need which every inquirer in science feels to know, and to know quickly, what his fellow-worker, wherever on the globe he may be carrying on his work or making known his results, has done or is doing, led some four years back to a proposal for carrying out by international co-operation a complete current index, issued promptly, of the scientific literature of the world. Though much labour in many lands has been spent upon the undertaking, the project is not yet an accomplished fact. Nor can this, perhaps, be wondered at, when the difficulties of the task are weighed. Difficulties of language, difficulties of driving in one team all the several sciences which, like young horses, wish each to have its head free with leave to go its own way, difficulties mechanical and financial of press and post, difficulties raised by existing interests—these and yet other difficulties are obstacles not easy to be overcome. The most striking and the most encouraging features of the deliberations which have now been going on for three years have been the repeated expressions, coming not from this or that quarter only, but from almost all quarters, of an earnest desire that the effort should succeed, of a sincere belief in the good of international co-operation, and of a willingness to sink as far as possible individual interests for the sake of the common cause. In the face of such a spirit we may surely hope that the many difficulties will ultimately pass out of sight.

Perhaps, however, not the least notable fact of international co-operation in science is the proposal which has been made within the last two years that the leading academies of the world should, by representatives, meet at intervals to discuss questions in which the learned of all lands are interested. A month hence a preliminary meeting of this kind will be held at Wiesbaden; and it is at least probable that the closing year of that nineteenth century in which science has played so great a part may at Paris, during the great World's Fair—which every friend, not of science only, but of humanity, trusts may not be put aside or even injured through any untoward event, and which promises to be an occasion not of pleasurable sight-seeing only, but also, by its many international congresses, of international communing in the search for truth—witness the first select Witenagemote of the science of the world.

I make no apology for having thus touched on international co-operation. I should have been wanting, had I not done so, to the memorable occasion of this meeting. A hundred years ago two great nations were grappling with each other in a fierce struggle, which had lasted, with pauses, for many years, and was to last for many years to come; war was on every lip and in almost every heart. To-day this meeting has, by a common wish, been so arranged that those two nations should, in the persons of their men of science, draw as near together as they can, with nothing but the narrow streak of the Channel between them, in order that they may take counsel together on matters in which they have one interest and a common hope. May we not look upon this brotherly meeting as one of many signs that science, though she works in a silent manner and in ways unseen by many, is steadily making for peace?

Looking back, then, in this last year of the eighteen hundreds, on the century which is drawing to its close, while we may see in the history of scientific inquiry much which, telling the man of science of his shortcomings and his weakness, bids him be humble, we also see much, perhaps more, which gives him hope. Hope is indeed one of the watchwords of science. In the latter-day writings of some who know not science, much may be read which shows that the writer is losing or has lost hope in the future of mankind. There are not a few of these; their repeated utterances make a sign of the times. Seeing in matters lying outside science few marks of progress and many tokens of decline or of decay, recognising in science its material benefits only, such men have thoughts of despair when they look forward to the times to come. But if there be any truth in what I have attempted to urge to-night, if the intellectual, if the moral influences of science are no less marked than her material benefits, if, moreover, that which she has done is but the earnest of that which she shall do, such men may pluck up courage and gather strength by laying hold of her garment. We men of science at least need not share their views or their fears. Our feet are set, not on the shifting sands of the opinions and of the fancies of the day, but on a solid foundation of verified truth, which by the labours of each succeeding age is made broader and more firm. To us the past is a thing to look back upon, not with regret, not as something which has been lost never to be regained, but with content, as something whose influence is with us still, helping us on our further way. With us, indeed, the past points not to itself, but to the future; the golden age is in front of us, not behind us; that which we do know is a lamp whose brightest beams are shed into the unknown before us, showing us how much there is ahead and lighting up the way to reach it. We are confident in the advance because, as each one of us feels that any step forward which he may make is not ordered by himself alone and is not the result of his own sole efforts in the present, but is, and that in large measure, the outcome of the labours of others in the past, so each one of us has the sure and certain hope that as the past has helped him, so his efforts, be they great or be they small, will be a help to those to come.

REPORTS

ON THE

STATE OF SCIENCE.

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Corresponding Societies' Committee.—Report of the Committee, consisting of Professor R. MELDOLA (*Chairman*), Mr. T. V. HOLMES (*Secretary*), Mr. FRANCIS GALTON, Mr. G. J. SYMONS, Dr. J. G. GARSON, Sir JOHN EVANS, Mr. J. HOPKINSON, Professor T. G. BONNEY, Mr. W. WHITAKER, Sir CUTHBERT PEEK, Mr. HORACE T. BROWN, Rev. J. O. BEVAN, Professor W. W. WATTS, *and* Rev. T. R. R. STEBBING.

THE Corresponding Societies' Committee of the British Association beg leave to submit to the General Committee the following Report.

The Committee have pleasure in being able to state that the resolution passed at the Bristol Conference of Delegates last year, respecting the desirability of securing the co-operation of the Coastguard for carrying on systematic observations on Coast Erosion, having been adopted by the British Association, has been favourably received by the Admiralty. The Committee were informed that the Council of the British Association appointed a Committee to consider and report on the proposal. The Committee having reported favourably, the Council approached the Admiralty, and in their Report give an account of their application.

The necessary forms, prepared by the Committee of the Council, have been issued by the Admiralty. Many have already been returned, filled in by the Coastguard. As a knowledge of their nature may be useful to the Corresponding Societies, and may tend to promote uniformity in the observations made by such of their members as are interested in Coast Erosion, copies of Forms I. and II. are appended.

The Committee regret to have to report that the East of Scotland Union of Naturalists' Societies (which was founded in 1884) has ceased to exist. The Secretary of the Union, in reply to inquiries as to the cause of its dissolution, replied :—'I think that the chief reason of the downfall of this Union is that the majority of those men who originally founded it and who took an active part in its work are now dead, and that those left do not see the same necessity for combined work.' He added that many of the smaller societies which belonged to the Union perished through the decease of the older members and the want of a supply of new ones from the younger people.

FORM NO. I.—*Observations of Coast Changes. To be filled in and returned as soon as convenient.*

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,
Burlington House, London, W.

Instructions to Observers in regard to Changes that are taking place along the Coast-line of the British Isles.

1. Mention the part of the coast on which you report, and give its limits.
2. State whether the coast is cliffy or low; whether rocky, sandy, gravelly, or muddy. If it is cliffy, give the average height of the cliffs, and, if possible, the nature of the material of which they consist, especially whether hard rock, chalk, clay, &c. State also the nature of the beach.
3. What is the vertical range of ordinary spring-tides?
4. Is the sea encroaching on the coast? If so, state briefly the proofs of this change.
5. Is the land gaining on the sea? If so, give shortly the evidence of such advance.
6. Are there any artificial causes which tend to increase or retard the natural changes on the coast? For instance, are there any groynes along the shore, and if so, what effect have they on the travelling shingle or sand? Are the shingle, sand, or slabs of stone, removed for industrial or other purposes?

______________________________ *Signature of person reporting.*

____________________________________ *Coast Guard Station.*

[Additional Copies of this Form can be had on application.]

FORM NO. II.—*Observations of Coast Changes. To be retained until there are some actual changes to be reported, after which the form should b filled up and returned without delay, in order that if needful a more careful survey of the changes reported on may be made by the Committee of the British Association.*

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,
Burlington House, London, W.

Instructions to Observers in regard to Changes that may take place along the Coast-line of the British Isles.

A. When changes are actually observed to be taking place on the coast, either as to advance or retreat of the sea, it is very desirable that information regarding them should be forwarded as soon as possible. For example, when any fall of a portion of shore cliff occurs, note of the circumstances should be taken, with measurements (if that be found practicable) or estimates of the area or amount of material that has been dislodged. When any groynes or other artificial protections of the coast are washed away, this should also be reported, and likewise when any new groynes or other works on the coast are constructed.

B. The Council of the British Association will be glad to receive any other information of which the observer may be in possession, bearing upon the changes that are taking place along the shore.

[The answers to these two paragraphs A and B can be written below, or if necessary on other sheets of foolscap paper.]

______________________________ *Signature of person reporting.*

____________________________________ *Coast Guard Station.*

[Additional Copies of this Form can be had on application.]

Report of the Proceedings of the Conference of Delegates of Corresponding Societies held at Dover.

The Council nominated the Rev. T. R. R. Stebbing, Chairman, and Mr. T. V. Holmes, Secretary, to the Dover Conference. These nominations were confirmed by the General Committee at a meeting held at Dover on Wednesday, September 13. The meetings of the Conference were held in the Mayor's Parlour at the Town Hall on Thursday, September 14, and Tuesday, September 19, at 3 P.M. The following Corresponding Societies nominated as delegates to represent them at the Dover meeting :—

Andersonian Naturalists' Society	Professor M. Laurie, D.Sc.
Belfast Naturalists' Field Club	William Gray, M.R.I.A.
Belfast Natural History and Philosophical Society	T. Workman.
Berwickshire Naturalists' Club	G. P. Hughes, J.P.
Birmingham Natural History and Philosophical Society	Professor T. W. Bridge, D.Sc.
Buchan Field Club	John Gray, B.Sc.
Caradoc and Severn Valley Field Club	Professor W. W. Watts, F.G.S.
Chester Society of Natural Science, Literature, and Art	A. O. Walker, F.L.S.
Dorset Natural History and Antiquarian Field Club	Vaughan Cornish, B.Sc.
East Kent Scientific and Natural History Society	A. S. Reid, F.G.S.
Essex Field Club	T. V. Holmes, F.G.S.
Glasgow Geological Society	J. B. Murdoch.
Glasgow Natural History Society	J. R. Gemmill, M.B.
Hampshire Field Club	T. W. Shore, F.G.S.
Hertfordshire Natural History Society	W. Whitaker, F.R.S.
Hull Geological Society	J. W. Stather.
Institution of Mining Engineers	Professor Henry Louis, M.A.
Isle of Man Natural History and Antiquarian Society	P. M. C. Kermode.
Leeds Geological Association	Professor P. F. Kendall, F.G.S.
Liverpool Geographical Society	Captain Phillips, R.N.
Liverpool Geological Society	J. Lomas, F.G.S.
Malton Field Naturalists' and Scientific Society	M. B. Slater, F.L.S.
Manchester Geographical Society	Eli Sowerbutts, F.R.G.S.
Manchester Geological Society	Mark Stirrup, F.G.S.
Manchester Microscopical Society	F. W. Hembry, F.R.M.S.
Midland Institute of Mining, Civil, and Mechanical Engineers	Professor Henry Louis, M.A.
Norfolk and Norwich Naturalists' Society	J. T. Hotblack.
North Staffordshire Naturalists' Field Club	Dr. Wheelton Hind, F.G.S.
North of England Institute of Mining and Mechanical Engineers	J. H. Merivale, M.A.
Nottingham Naturalists' Society	Professor J. W. Carr, F.L.S.
Perthshire Society of Natural Science	A. M. Rodger.
Rochdale Literary and Scientific Society	James Ogden.
Scotland, Mining Institute of	James Barrowman.
South-Eastern Union of Scientific Societies	Dr. G. Abbott.
South Staffordshire and East Worcestershire Institute of Mining Engineers	Professor Henry Louis, M.A.
Warwickshire Naturalists' and Archæologists' Field Club	Wm. Andrews, F.S.A.
Woolhope Naturalists' Field Club	Rev. J. O. Bevan, M.A
Yorkshire Geological and Polytechnic Society	Wm. Gregson, F.G.S
Yorkshire Naturalists' Union	Harold Wager, F.L.S.

First Conference, Dover, September 14, 1899.

The Corresponding Societies Committee were represented by Rev. T. R. R. Stebbing (Chairman), Rev. J. O. Bevan, Mr. G. J. Symons, Professor W. W. Watts, and Mr. T. V. Holmes (Secretary).

The Report of the Corresponding Societies Committee (see p. 27), a copy of which was in the hands of every delegate present, was taken as read.

After briefly calling attention to the forms for recording observations of coast changes, a result of the discussion on Coast Erosion at the Bristol Conference, the Chairman delivered the following Address:

The Living Subterranean Fauna of Great Britain and Ireland.

It would have been easy to enlarge the subject of this address and extend its interest by omission of the word 'living,' and joining the flora to the fauna. All the province of the palæontologist would thus have been included, and we should have been free to discuss the distribution of truffles and pignuts. But better results may be hoped for from a more restricted ambition. The cave-bear must be passed over with a fond regret. We are concerned only with animals still living. If among vertebrates we have to content ourselves with birds and bats and rats, with badgers and foxes and rabbits and moles, and in general a group of creatures not prominent for size or ferocity, there are compensations which none but a very ardent sportsman will despise. Our country is too much overrun by that digging, delving, and destructive species, *homo sapiens*, to allow us any hope of turning up a *Neomylodon* (or *Glossotherium*), or even a mudfish. The animals above-mentioned are of course only in a modified sense subterranean. They seek their shelters or make them in caves or holes of the earth, but are still both free and forced to come abroad for various purposes into the light of day or beneath the nocturnal sky.

Like so many other terms applied to natural knowledge, the word 'subterranean' is highly indefinite. How much earth must I put on my head, and how long must I keep it there to make me truly a Troglodyte? There is the giant Enceladus, whose uneasy turnings cause, as you know, the eruptions of Mount Etna, under which he is permanently imprisoned. From him, then, the conception of an underground animal may vary to Virgil's angry bees lulled for a few moments by the sprinkling of a handful of dust. Under loose stones a crowd of creatures take refuge, frame their dwellings, lay snares, and in various ways make themselves at home. Among these are vipers and lizards, ants and bees and beetles, centipedes, spiders, and woodlice, with slugs and other slimy and seductive specimens to suit almost every imaginable taste. Of burrowing spiders, none in Great Britain has yet been found making a door to its trap. Whether the discredit attaches to the British spider's want of ingenuity or to the British arachnologist's want of research is still an open question. As to the distribution of the mole cricket, of the bee that burrows in footpaths, and the history of mining insects in general within our islands, there may still be information worth gleaning. The soils they favour, the temperatures they can endure, their modes of working, their means of subsistence, the good and the evil they do to mankind are among the obvious points of interest connected with them. One has, however, to remember that entomology is a science with innumerable students, a boundless literature, and an infinite subject. There is, therefore, always a risk that in suing for its assistance one may suffer the fate of the husbandman who, in a drought, incautiously prayed to Jupiter for rain, without specifying the quantity required, and presently had to swim for his life from his flooded farm.

There is the same chance of a surplus, of having, so to speak, rather too much of a good thing, were we to take into our survey all those marine species which on the shore or in the sea hide under stones or bury themselves in sand and ooze—sea-anemones and sand-eels, annelids and amphipods, sea-urchins and starfishes, cockles and razor-shells, friends and foes, the blind and the seeing, the brilliant and the dull, the agile and the slow—a list that might be extended into details of inexhaustible interest, but interminable length.

From these fields of research, so well known and so bewilderingly wide, I turn to one which is by comparison exceedingly small and obscure, to one which has certainly not been overworked or exhausted in this country—to one, moreover, in which the organisation of affiliated societies might easily render essential service. The animals which are born and bred and pass their lives in wells and caverns may be regarded as the true underground fauna. Though in wells they may have no ground actually overhead, still they live far below the surface, and, whether in well or cave, they are the permanent occupants, distinct from those creatures which scuttle in and out, and do most of their fighting, feeding, and foregathering in the external world.

The first undoubted mention of an underground crustacean seems to be that of an amphipod found in London, and named by Dr. Leach of the British Museum in 1813, nor in earlier times do any important researches appear to have been made as to the subterranean fauna of any part of the globe. But, whatever the novelty and narrowness of the subject may be, there are now scores of valuable treatises upon it, in a variety of European languages, Polish and others. In the long list of authors one may note in passing the names of Fries and Gustav Joseph, Wrzeóniśowski and Vejdovski and Moniez, leaving the majority to be discovered in two admirable works, of which the English student will be well advised to make himself master. One of these is 'The Cave Fauna of North America,' by Dr. Alpheus Spring Packard, published in the 'Memoirs of the National Academy of Sciences,' vol. iv., Washington, 1888. The other is 'The Subterranean Crustacea of New Zealand,' by Dr. Charles Chilton, published in the 'Transactions of the Linnean Society of London for 1894.'

Packard enumerates 308 European cave animals and 102 American. This total of 410 includes a few Protozoa, a sponge, two hydras, a few worms, one mollusc, several Crustacea and myriapods, numerous arachnids, and a host of Coleoptera, the other insects being chiefly Thysanura. The vertebrates are limited to four American fishes and one European batrachian, the celebrated *Proteus anguineus.* In the specific names of these animals there are, as might be expected, abundant references to their peculiar choice of residence, as in the designations *cavaticus, cavicola, cavicolens, cavernarum, speluncarum,* and, with more particularity, *wyandottensis, nickajackensis, mammothia,* not to speak of the blood-curdling *stygius, orcinus,* and *infernalis.* To the colouring, or, rather, want of colouring in many of them, the epithets *albus, pallidus, niveus, pellucidus,* bear their testimony. To the feature, or, rather, want of feature, which in cave animals has attracted more attention than anything else, notice is called in several of the generic as well as the specific names, as in *Typhlichthys* and *Amblyopsis,* the blind fishes, in *Adelovs, Aphænops,* and

Anophthalmus, eyeless genera of beetles. To the locality, or, rather, want of locality, which in these lists more immediately concerns ourselves, attention is directed only by a single name. As our inquiring eyes scrutinise the European assemblage, and take note of the famous caverns and countries through which this fauna is distributed, we find mention of France and Germany, of Hungary and Spain, of Italy and Sicily, but never a word of England. Only a veiled allusion occurs in the entry, without specified locality, of the name *Niphargus subterraneus* (Leach). So far as Dr. Packard's list is concerned, the explanation is simple, in that the species in question has not been recorded from any English cavern, though it belongs to the spelæan fauna of the Continent. To put a better face upon the affair, it may be stated that the well fauna of England and Ireland includes four species of Amphipoda, though even this quartette was audaciously reduced to a single species by De Rougemont. From the deep recesses of a disused coal mine near Glasgow *Tinea ustella* was recorded by John Scott in 1850. A copepod has been described by Dr. G. S. Brady from a Northumbrian coal mine. Whether coal mines any more than coal cellars can properly be included among caverns, we need not now pause to inquire. Unless the entomologists can come to the rescue with a goodly supply of cave-dwelling beetles and spring-tails, the subterranean fauna of Great Britain and Ireland will perhaps never prove to be rich in numbers. Still, when records are collected and investigations extended, we may reasonably hope that the balance of over three hundred against us in the European catalogue will be seriously diminished. Since the scientific history of life below ground may be said to have begun in England, it should be our pride to take what share we can in the sequel. In the last fifty years, and more especially in the last twenty, a series of remarkable forms have been discovered in subterranean waters in various parts of the world. Even since Dr. Chilton's paper appeared in 1894 many curious additions have been made to the well fauna of North America, such as the woodlouse, *Haplophthalmus puteus*, described by Mr. P. Hay, from an old well in Indiana, and the *Sphæroma thermophilum*, described by Miss Harriet Richardson, from a warm spring in New Mexico, the one genus belonging to the land and the other to the sea, and neither of them having till recently been thought of in connection with fresh water, either hot or cold. In 1896 'the United States Fish Commission completed an artesian well at San Marcos, Texas. The depth of the well is 188 feet. The flow of water obtained amounts to more than 1,000 gallons per minute. The water is pure and of excellent quality, and has a temperature of 73° Fahrenheit.' To these interesting particulars Mr. James E. Benedict, of the U.S. National Museum, adds information which reminds one of the two girls in the fairy tale, with pearls and rubies falling from the lips of the one, and toads and lizards from the lips of the other, only that here the rewards are not distributed but combined. For not only is the water pure and excellent, but it delights the zoologist by sending up from the bowels of the earth isopods, amphipods, prawns, and salamanders. The species are all blind. The species are all new. The specimens are plentiful. The salamander has oddities of its own. The isopod has almost no excuse for not being marine. The prawn has eye-stalks, but they are totally devoid of ocular pigment. There is a theory that at one time the globe was overspread with a blind fauna, the remnants of which have been preserved in deep waters and dark holes, whither creatures endowed with sight have as a rule not cared to follow them. It would be interesting to know how that theory explains the eye-stalks of a sightless prawn. But this is verging on the controversial, and it will be more encouraging to research, if you will believe, to begin with, that, whether you are Darwinians or Neolamarckians or advocates of special creation, you will find support for your several opinions in the prizes and surprises that the subterranean fauna of every land, continental or insular, is capable of yielding.

The research suggested is not without difficulties, but they are not such as need daunt the brave explorers of British caverns, who have hunted down the sabre-toothed tiger and the prehistoric hyæna with candle and torch and pick-axe. The difficulties in searching for specimens of well fauna are partly moral and partly physical. Many wells in our country have, for sound reasons, been entirely closed. That in itself is a barrier to collecting specimens from them, but, according to my experience, the closure of some has indirectly barred the investigation of others. The distribution of the well shrimp (*Niphargus*) is known for the neighbourhood of Dublin and for the whole south of England from Devonshire to Kent. Yet for years I inquired for it in vain, though using a pertinacity something like that imputed to the fair Saracen, who, in the story, by constantly asking for London and for Gilbert, found her way all across Europe to her affianced lover, and, marrying Gilbert à Becket, became the mother of St. Thomas of Canterbury. Like hers, my perseverance was in the end rewarded; but, in the meantime, some met my inquiry with smiles, and some with frowns. I am inclined to suspect that the smiling ones were under a real incapacity of understanding what sort of object was being asked for, but that the frowning set understood pretty well, and that they took me for an inspector in disguise, seeking, under pretence of an idiotic enthusiasm, for evidence out of their own mouths on which to order the closing of their favourite spring. It is obvious that, if such was their point of view, they completely misjudged my motives, for evidence, so far as it goes, all favours the belief that the springs in which crustaceans are found living supply water that is wholesome.

In some introductory remarks I assumed that our Conference, though not a Section of the Association, was in fact an epitome of the whole. If now I conclude by inviting the members of the Conference to go shrimping with a bucket and a string, it may appear to be a terrible example of bathos. Bathos has ever been exposed to derision in connection with poetry and eloquence. But bathos has been otherwise called the art of sinking, and that art is profoundly essential in connection with wells.

It will be indeed extraordinary if the caverns and springs and artesian borings in Great Britain and Ireland do not yield, to a united effort of investigation, a fauna in some degree comparable in interest with that which, under similar circumstances, has been and is being found in other parts of the globe. It will be extraordinary if the research, whatever its direct results, does not stimulate, in many of those who pursue it, highly pleasurable and profitable activities both of body and mind. At the worst, if the old proverb may be trusted, while groping for creatures at the bottom of a well, you will always have the chance of combining two enjoyments, fishing for amphipods and finding Truth.

On the conclusion of his Address, the Chairman, in answer to a question as to the best way of catching the well shrimp, replied that it was best to wait till the well was almost empty, and then to let down a bucket and withdraw it as quickly as possible, lest the creatures, being scared, should have time to get away. Sometimes well shrimps were brought up when pumping was going on.

Rev. J. O. Bevan said that he had visited the Mammoth Cave of Kentucky, where he saw a great many bats which had apparently passed the whole of their lives within the cavern.

The Chairman felt inclined to agree with the late Mr. Cordeaux, who had stated that in many caverns bats and birds alternated—the birds going out when the day came and the bats going in. It was, however, a matter of opinion.

Mr. T. Workman had never seen birds in the Mammoth Cave of Kentucky, though he had caught bats there by day, and he thought they lived in the cave only in the daytime. They were not found in the depths of the cave, though they were in great numbers near the mouth. He asked the Chairman if the eyeless fishes found in caves belonged to any special species; also if the wells mentioned in connection with well shrimps were open wells?

The Chairman replied that all the blind species were special. There was a blind fish in caverns in Cuba. He included wells of all kinds. All along the south of England, in Dublin, and, he believed, in Jersey, there were records of these amphipods. Four species of well shrimps could be obtained, and he thought that if England were searched more thoroughly a greater number of species would be found.

Mr. Hotblack thought that there was no evidence then existing of bats which spent all their time in caverns. Consequently they should not be classed as subterranean fauna. A member of the Society he represented not long ago brought to one of their meetings a well shrimp obtained at Norwich. All would probably agree with him in believing that these well shrimps did not get into a well from its mouth, but from underground water percolating into the well.

Mr. Mark Stirrup said that some few years ago a society was started in Yorkshire for cavern exploration, with which the search for subterranean fauna might well be combined. The subject appeared to have attracted more attention in America than in England, perhaps because the underground waters in the great caverns of America had been more productive. The Chairman doubtless wished the delegates to bring the subject before the Societies they represented. He had certainly opened out for them a new field of research.

The Chairman remarked that two gentlemen had written to him on this subject, Mr. E. S. Goodrich, of the Department of Comparative Anatomy, Oxford, who would be glad to have any specimens of blind crustacea from wells and caves for experimental purposes, and Dr. Charles Chilton (to whose work on the underground fauna of New Zealand he had referred in his paper), who was living in Edinburgh. Dr. Chilton was collecting particulars of the English well amphipods, and would be glad of specimens.

Mr. Hotblack asked whether either of the gentlemen mentioned would name specimens and return them.

The Chairman thought that they would be only too glad to do it.

Mr. William Gray expressed the hope that in the Report of the Conference the Chairman's address would be printed in full. And Mr. Hotblack suggested that proof copies should be supplied to the delegates, so that they might bring the subject before their Societies at an early date. Both propositions received the unanimous support of the meeting.

Second Meeting of the Conference, September 19.

The Corresponding Societies Committee were represented by Rev. T. R. R. Stebbing (Chairman), Dr. Garson, Mr. G. J. Symons, Professor W. W. Watts, and Mr. T. V. Holmes (Secretary).

The Chairman opened the proceedings by reading the following letter, which he had received since their last meeting :

Reception Room, British Association: September 18, 1899.

SIR,—A feeling by quite a number of those interested in the work of Delegates at our British Association Meetings, exists, that the interchange of ideas regarding the organisation and development of the Local Societies is not offered an opportunity of being discussed at the Conference of Delegates at yearly meetings of the British Association. I should feel much obliged if, as Chairman of our Conference, you could set aside a few minutes for a discussion on 'the working by sections of large scientific Societies, whether in Exact or Natural History Science' at our meeting on Tuesday the 19th inst.

I am, yours faithfully,
(Signed) G. P. Hughes, F.R.G.S.,
Representing the Berwickshire Naturalists' Club.

A long and desultory debate then followed, in which many delegates present took part, as to the best ways of making the meetings of the Conference more useful than they now are. While it was proceeding Mr. Stebbing was obliged to leave, and Professor W. W. Watts became Chairman. At length it was decided that the best course would be for individual delegates to send their views to the Corresponding Societies Committee not later than the first week in November. Letters received by that date would be considered by the Committee when they met later in that month. And, as some delegates were not present, it was thought desirable that the Secretary should write, stating that this discussion had taken place, and that any recommendations from delegates must be sent in by the date mentioned.

Mr. Hugh Blakiston, the Secretary of the 'National Trust for Places of Historic Interest or Natural Beauty,' then read a paper on the aims and work of the Trust.

Mr. Blakiston remarked that the National Trust was founded in the year 1894 by the Duke of Westminster, the Earl of Carlisle, Lord Hobhouse, the Right Hon. James Bryce, Sir Robert Hunter, Miss Octavia Hill and others, and was incorporated as a Limited Liability Company 'to promote the permanent preservation, for the benefit of the nation, of lands and tenements (including buildings) of beauty or historic interest ; and as regards lands, to preserve (so far as practicable) their natural aspect, features, and animal and plant life ; and for this purpose to accept, from private owners of property, gifts of places of interest or beauty, and to hold the lands, houses, and other property thus acquired, in trust for the use and enjoyment of the nation.' The Memorandum of Association also declares that no property thus acquired shall be dealt with, in the event of the dissolution of the Trust, in a manner inconsistent with the objects of the Trust.

Mr. Blakiston then touched upon the wealth of the British Isles in buildings of historic interest, and on the non-existence here of a Minister of State one of whose functions was their preservation, though a Minister for this purpose existed in Austria, France, and Italy. The extraordinary growth in size of our towns during the reign of Queen Victoria had made the last fifty years a peculiarly disastrous period as regards the destruction of ancient monuments, apart from such destruction as altered circumstances had made inevitable. And our larger cities tended more and more to be divided into a central more ancient part, made up chiefly of shops, offices, and eating-houses, thronged only by day, and monotonous modern suburbs in which the bulk of the inhabitants slept and passed their leisure time. Children, therefore, to a much greater degree than in earlier periods, were brought up with little or nothing around them to stimulate their imaginations, or to help them to realise the history of the past. And these islands were looked upon as 'home' by millions of people scattered over the face of the earth, who might fairly expect to find that the ancient monuments existing only in the centre of the British Empire were carefully preserved by those dwelling around them.

Mr. Blakiston then referred to some of the work already done by the National Trust during its short life. It had purchased Barras Head opposite Tintagel Castle, and a most beautiful cliff overlooking Barmouth had been presented by a lady to the Trust. Toys' Hill near Oxted, Kent, and Ide Hill in the same district had also been acquired. The purchase and restoration of the old Clergy House at Alfriston, Sussex, and of Joiner's Hall, Salisbury, had secured to the nation two fine specimens of mediæval domestic architecture. The Falkland monument on the battlefield at Newbury was also under the care of the Trust. And it had recently purchased in Wicker Fen, Cambridgeshire, a piece of the primitive fenland, which will remain for ever undrained and untouched, with its original plant and animal life.

Turning to the question of further developments, he remarked that the task before them was one which could not be achieved either by a national society acting by itself or by local societies acting by themselves. No central society could possess the full and complete information in a given case which some local society possessed, nor could it influence local feeling to the same degree. On the other hand, no local society is so fully in touch with Parliament, or can appeal to so large a public as a great central society. Coming to practical details, the two important points were the creation of local committees to watch over the ancient monuments of each county or district, and the formation of a central fund. The Trust experienced much difficulty in obtaining timely information, and thought that a federation of local societies would provide machinery to obviate this difficulty. The creation of a central fund would enormously strengthen the hands of the federated societies, by enabling their representatives to purchase, or make grants towards the purchase of properties of national interest. With a small subscription and a large membership a very considerable sum might be raised, from which grants could be made in local cases as occasion arose. The details of the scheme would, of course, require careful consideration, and he would be glad to receive any suggestions regarding them from members of the Conference.

Mr. Gray said that in Belfast they had endeavoured to prevent a syndicate from enclosing the Giant's Causeway. The syndicate, however, prevailed, and railed in the Causeway. On appealing to the National Trust they received a grant of 5*l.*, and were now 1,500*l.* in debt.

Mr. Blakiston remarked that his society was a very young one, and not in a position to make a large grant. Had they possessed sufficient funds they would have bought the Causeway.

Mr. Gray rejoined that he had mentioned the matter to show the desirability of giving more adequate support to the Trust.

Dr. Abbott hoped that every delegate present would mention the usefulness of the Trust to his society, and that it would gain many additional supporters. He wished, also, that people would get into the way of leaving money to the Trust.

Mr. Blakiston remarked that the authorities of the Trust were going to make a proposal for federation to the natural history and archæological societies of the country, probably during next month.

Rev. H. H. Winwood inquired what constituted membership of the Trust, and Mr. Vaughan Cornish asked to what extent the aims and objects of the National Trust were those of the other societies.

Mr. Blakiston replied that there was another society for the protection of ancient buildings, which was almost entirely composed of architects. It had no power to hold buildings, as the National Trust could, and could intervene only when an ancient building was in danger of being injured. The National Trust was in close touch with the society, also with the Commons Preservation Society, the Selborne and other societies. He did not think there was any fear of overlapping as regards the work of these societies.

The Chairman proposed a hearty vote of thanks to Mr. Blakiston for his paper. He regretted that the discussion at the beginning of the meeting had occupied so much time, and was sure that they had since found out that it would have been better spent in listening to Mr. Blakiston, who had put before them things which might profitably engage the attention of all local societies.

A vote of thanks having been heartily accorded to Mr. Blakiston, the Chairman inquired if there were any representatives of the various Sections present wishing to bring some subject before the delegates.

SECTION A.

Mr. G. J. Symons, representing Section A, said that the Committee for Seismological Observations were badly in want of a home, and would be very glad if some ancient building could be allotted to them.

SECTION C.

The Chairman, representing Section C, could mention two investigations in which the local societies had been of much assistance. The Committee to investigate the Erratic Blocks of the British Isles presented a Report this year. The Committee for the Collection, Preservation, and Systematic Registration of Photographs of Geological Interest, of which he was secretary, would be glad to receive any contributions of such photographs. The Committee hoped to be able to undertake the publication of typical geological photographs in such a way as to render them easily obtainable by those who could make good use of them. It would greatly help the Committee if local societies would agree to purchase a series of these photographs. There was also a duplicate collection ot prints and lantern slides which could be sent to any local society wishing to exhibit them and to see what kind of work was being done, the only expense incurred by the society being that of carriage. They proposed, when publishing the photographs, to add letterpress descriptions.

SECTION D.

Rev. T. R. R. Stebbing, representing Section D, said that the secretary of that Section recommended the study of the fauna of wells and caverns by the Corresponding Societies.

SECTION K.

Mr. H. Wager, representing Section K, had to inform the delegates of the Corresponding Societies that the Section had appointed a Committee to consider the geographical distribution of mosses, a matter of interest to all the local societies.

Mr. Vaughan Cornish thought that the Corresponding Societies might congratulate themselves on the result of the discussion, at the Conference of Delegates last year, on Coast Erosion, initiated by Mr. Whitaker. Seldom, if ever, had the Admiralty been induced to act so promptly as in their consent to the co-operation of the Coastguard as observers of Coast Erosion.

Dr. Garson hoped that the delegates would come to Bradford next year well primed with any scheme of work they might wish should be taken up the following year at Glasgow. The meeting then came to an end.

The Corresponding Societies of the British Association for 1899-1900.

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
Andersonian Naturalists' Society, 1885	Andersonian Nat. Soc.	204 George Street, Glasgow. R. Barnett Johnstone	172	None	2*s.* 6*d.*	Annals, occasionally.
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	5*s.*	10*s.*	Proceedings, annually.
Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, B.A.	252	None	1*l.* 1*s.*	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	Belfast Nat. F. C.	Museum, College Square. William Gray and Dr. W. D. Donnan	400	5*s.*	5*s.*	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Berwicksh. Nat. Club	Rev. G. Gunn, M.A., Stichill, Kelso, N.B.	400	10*s.* 6*d.*	7*s.* 6*d.*	History of the Berwickshire Naturalists' Club, annually.
Birmingham Natural History and Philosophical Society, 1858	Birm. N. H. Phil. Soc.	Norwich Union Chambers, Congreve Street, Birmingham. W. P. Marshall and P. L. Gray	254	None	1*l.* 1*s.*	Proceedings, annually.
Brighton and Hove Natural History and Philosophical Society, 1854	Brighton N. H. Phil. Soc.	Museum, Church Street, Brighton. E. A. Pankhurst.	186	10*s.*	10*s.*	Report, annually.
Bristol Naturalists' Society, 1862	Bristol Nat. Soc.	Theodore Fisher, M.D., 25 Pembroke Road, Clifton, Bristol	157	5*s.*	10*s.*	Proceedings, annually.
Buchan Field Club, 1887	Buchan F. C.	J. F. Tocher, F.I.C., 5 Chapel Street, Peterhead	160	5*s.*	5*s.*	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc.	B. L. Oswell 30 High Street, Burton-on-Trent	220	None	5*s.*	Annual Report. Transactions occasionally.
Caradoc and Severn Valley Field Club, 1893	Car. & Sev. Vall. F. C.	H. E. Forrest, 37 Castle Street, Shrewsbury.	180	5*s.*	5*s.*	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	Cardiff Nat. Soc.	Walter Cook, 98 St. Mary Street, Cardiff	450	None	10*s.* 6*d.*	Transactions, annually.
Chester Society of Natural Science and Literature, 1871	Chester Soc. Nat. Sci.	Grosvenor Museum, Chester. G. P. Miln, and W. F. J. Shepheard	808	None	5*s.*	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	353	1*l.* 1*s.* None	Members 31*s.* 6*d.*; Associates and Students 20*s.*	Transactions of Institution of Mining Engineers, monthly.
Cornwall, Mining Association and Institute of, 1859	Cornw. Min. Assoc. Inst.	William Thomas, C.E., F.G.S., Penelvan, Camborne	200	10*s.* 6*d.*	Minimum, 10*s.* 6*d.*	Transactions, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc.	The Museum, Public Buildings, Penzance. John B. Cornish	98	None	1*l.* 1*s.*	Report and Transactions, annually.
Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C.	Public Hall, Croydon. R. F. Grundy	230	None	10*s.*	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C.	Nelson M. Richardson, Montevideo, Chickerel, Weymouth	350	None	10*s.*	Proceedings, annually.
Dublin Naturalists' Field Club, 1885	Dublin N. F. C.	Prof. T. Johnson, D.Sc. and N. H. Alcock, M.D., Royal Irish Academy, Dublin	200	5*s.*	5*s.*	'Irish Naturalist,' monthly; Report, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	Dr. J. Maxwell Ross, St. Ruth's, Dumfries	186	2*s.* 6*d.*	5*s.*	Transactions and Journal of Proceedings, annually.
East Kent Scientific and Natural History Society, 1857	E. Kent S. N. H. Soc.	H. Mead-Briggs, 8 High Street, Canterbury	67	None	10*s.*	'South Eastern Naturalist,' and Annual Report.
Edinburgh Geological Society, 1834	Edinb. Geol. Soc.	5 St. Andrew Square, Edinburgh. Jame Currie	267	10*s.* 6*d.*	12*s.* 6*d.*	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
Essex Field Club, 1880	Essex F. C.	William Cole, 7 Knighton Villas, Buckhurst Hill, Essex	300	None	15*s.*	'Essex Naturalist,' quarterly; 'Special Memoirs,' occasionally.
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	J. Barclay Murdoch, Capelrig, Mearns, Glasgow	216	None	10*s.*	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	S. M. Wellwood and R. D. Wilkie, 207 Bath Street, Glasgow	319 Memb. 25 Assoc.	None	Members 7*s.* 6*d.* Associates 5*s.*	Transactions and Proceedings, annually.
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc.	Freeland Fergus, M.D., 207 Bath Street, Glasgow	653	1*l.* 1*s.*	1*l.* 1*s.*	Proceedings, annually.
Halifax Scientific Society and Geological Field Club, 1874	Halifax S. S. G. F. C.	Literary and Philosophical Society's Rooms. F. Barker and W. E. Jenkinson	111	None	2*s.* 6*d.*	'Halifax Naturalist,' every two months.
Hampshire Field Club and Archæological Society, 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	210	10*s.*	10*s.*	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C.	A. J. Crosfield, Carr End, Reigate	88	10*s.*	10*s.*	Proceedings, every two or three years.
Hull Geological Society, 1887	Hull Geol. Soc.	Royal Institution. John W. Stather	65	None	5*s.*	Transactions, annually.
Institution of Mining Engineers	Fed. Inst. Min. Eng.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	2,500	None	None	Transactions, monthly.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc.	E. G. Critchley, 29 High Street, Inverness	175	None	5*s.* and 2*s.*	Transactions, occasionally.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland	J. Pim, W. Lawson, and C. H. Oldham, 35 Molesworth Street, Dublin	100	None	1*l.*	Journal, annually.
Leeds Geological Association, 1874	Leeds Geol. Assoc.	Philosophical Hall, Leeds. W. Parsons	93	None	5*s.*	Transactions, occasionally.
Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. C. Sci. Assoc.	H. B. Wilson, Westfield, Armley, Leeds	152	None	6*s.*	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	Corporation Museum. J. M. Gimson	320 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	402	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	750	None	1*l.* 1*s.*	Transactions and Report, annually.
Liverpool Geological Society, 1858	Liv'pool Geol. Soc.	Royal Institution. H. C. Beasley	55	None	21*s.*	Proceedings, annually.
Liverpool, Literary and Philosophical Society of, 1812	Liv'pool Lit. Phil. Soc.	Royal Institution. J. Maxwell McMaster	214	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. F. J. R. Young	96	None	5*s.* and 2*s.* 6*d.*	Report, annually.
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	154	2*s.* 6*d.*	Gentlemen 7*s.* 6*d.* Ladies and Non-Residents 5*s.*	Yn Lioar Manninagh, biennially.
Manchester Geographical Society, 1884	Manch. Geog. Soc.	Eli Sowerbutts, F.R.G.S., 16 St. Mary's Parsonage, Manchester	700	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. W. Saint and C. R. Lindsey	240	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	210	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	204	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 .	337	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, Mining Offices, Regent Street, Barnsley	253	None	1*l.* 10*s.*	Transactions of Institution of Mining Engineers, monthly.
Norfolk and Norwich Naturalists' Society, 1869	Norf. Norw. Nat. Soc. .	W. A. Nicholson, St. Helen's Square, Norwich	255	None	5*s.*	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst. . .	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,200	None	21*s.* and 42*s.*	Transactions of Institution of Mining Engineers, monthly.
North Staffordshire Field Club	N. Staff. F. C. . .	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs.; W. Wells Bladen, Stone, Staffs.	433	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., 23 East Park Parade, Northampton	160	None	10*s.*	Journal, quarterly.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc. .	Prof. J. W Carr, University College, Nottingham	100	2*s.* 6*d.*	5*s.*	Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst. .	J. Gardner, 3 County Place, Paisley	350 and 20 Associates	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. M. Montgomerie	71	None	10*s.* 6*d.*	Report, annually; Transactions, occasionally.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci. .	Tay Street, Perth. S. T. Ellison .	374	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	233	None	6*s.*	Transactions, biennially.
Rochester Naturalists' Club, 1878	Rochester N. C. . .	John Hepworth, Linden House, Rochester	144	None	5*s.*	'Rochester Naturalist,' quarterly.
Scotland, Mining Institute of, 1878	Mining Inst. Scot. .	James Barrowman, Staneacre, Hamilton, N.B.	468	None	42*s.* and 25*s.*	Transactions of the Mining Institute of Scotland, six times each year
Somersetshire Archæological and Natural History Society, 1848	Som'setsh. A. N. H. Soc.	The Castle, Taunton. Lt.-Col. J. R. Bramble and Rev. F. W. Weaver	633	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	126	None	2*l.* and 1*l.*	Transactions, annually.
South-Eastern Union of Scientific Societies, 1896	S.-E. Union . . .	George Abbott, M.R.C.S., 33 Upper Grosvenor Road, Tunbridge Wells	32 Societies; 4549 Membs.	None	5*s.*	Transactions, annually.
South Staffordshire and East Worcestershire Institute of Mining Engineers, 1867	S. Staff. Inst. Eng. .	Alexander Smith, M.Inst.C.E., 3 Newhall Street, Birmingham	173	1*l.* 1*s.* and 10*s.* 6*d.*	31*s.* 6*d.* and 21*s.*	Transactions of Institution of Mining Engineers, monthly.
Toronto, Astronomical and Physical Society of, 1884	Toronto Astr. Phys. Soc.	Technical School Buildings. Thos. Lindsay	120	None	2 dollars	Transactions, annually.
Tyneside Geographical Society, 1887	Tyneside Geog. Soc. .	Geographical Institute, Barras Bridge, Newcastle-on-Tyne. Herbert Shaw, B.A.	1,200	None	10*s.* and 5*s.*	Journal, half-yearly.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C. .	Museum, Warwick. T. W. Whitley, 20 Camberwell Terrace, Leamington	94	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	212	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	157	None	13*s.*	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union .	W. Denison Roebuck, F.L.S., 259 Hyde Park Road, Leeds	438 and 2,446 Associates.	None	10*s.* 6*d.*	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822	Yorks. Phil. Soc. . .	Museum, York. Dr. Tempest Anderson and C. E. Elmhirst	420	None	2*l.*	Report, annually.

List of the more important Papers, and especially those referring to Local Scientific Investigations, published by the Corresponding Societies during the year ending June 1, 1899.

⁂ This list 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.

ANDSON, Rev. WM. The Meteorology of Dumfries for 1897. 'Trans. Dum. Gal. N. H. A. Soc.' No. 14, 39–47, 1898.

BALDOCK, J. H. Photography in relation to Science. 'Trans. S.-E. Union,' III. 81–86, 1898.

BALFOUR, C. B. Meteorological Observations at Newton Don, 1893–1897. 'History Berwickshire Nat. Club,' XVI. 87–88, 1898.

BLACK, W. G. Ocean Rainfall by Rain-gauge Observations at Sea, 1864–75–81. General and Special Oceans. 'Journ. Manch. Geog. Soc.' XIV. 36–56, 1898.

BLADEN, W. WELLS. Report of the Meteorological Section. 'Trans. N. Staff. F. C.' XXXIII. 76–80, 1899.

BRANSON, F. W. On a Method of Measuring the Intensity of the X Rays. 'Trans. Leeds Nat. C. Sci. Assoc.' IV. 8, 1899.

CAMPBELL-BAYARD, F. Report of the Meteorological Sub-Committee for 1897. 'Trans. Croydon M. N. H. C.' 1897–98, 273–275 and Appendices, 1898.

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Radiation from a Source of Light in a Magnetic Field.—Preliminary Report of the Committee, consisting of Professor GEORGE FRANCIS FITZGERALD (*Chairman*), THOMAS PRESTON (*Secretary*), Professor A. SCHUSTER, Professor O. J. LODGE, Professor S. P. THOMPSON, Dr. GERALD MOLLOY, *and* Dr. W. E. ADENEY.

THE work undertaken by this Committee has not yet terminated. This occurs partly from the difficulties which arose in obtaining a satisfactory supply of electric current with which to excite the powerful electro-magnet now in the hands of the Committee, and partly from the circumstance that the Secretary was not always free to work at such times as the staff of the Royal University found it convenient to permit research work in the Physical Laboratory.

Considerable advance has been made, however, during the past session, and the magnetic perturbations of the spectral lines of several substances have been observed and photographed from one end to the other of the spectrum. A considerable amount of work remains to be done in this direction still, and this we hope to complete in the near future.

The chief points of interest determined by the Committee since its appointment are as follows :—

1. On Friday, September 9, 1898, Professor S. P. Thompson attracted the attention of the British Association (see 'Brit. Assoc. Report, 1898,' p. 789) to an elegant experiment devised by Professor Righi for the purpose of illustrating the absorption of light in a magnetic field. This experiment was stated by Professor Righi to succeed only when the light traversed the field along the lines of force, but it appeared to us from theoretical considerations that similar absorption should also take place when the light traverses the field across the lines of force. On trying the experiment on the following Tuesday (September 13, 1898), it was found at once that the experiment was capable of demonstrating absorption across the lines of force[1] as markedly as that ascertained by Professor Righi along the lines of force. This result was also ascertained subsequently, and independently, by M. Cotton.[2]

2. The next point of interest consisted in placing beyond doubt that the various modified forms of triplet, that is the quartets, octets, &c., are not produced by reversal or any other extraneous cause, but are true magnetic perturbations of the same kind as the normal triplet, which is to be expected from the simplest theoretical considerations. An account of the experiments by which this was determined will be found in the 'Philosophical Magazine' for February 1899 ('Phil. Mag.' vol. xlvii. p. 165).

In pursuing this inquiry it was found that in a very strong magnetic field the quartets ultimately became resolved into sextets, the side lines of the quartets splitting up into pairs and separating as the strength of the field gradually increased.

These quartet forms, and various other types of perturbation, were observed by Mr. Preston in the beginning of November 1897, and were shown at the following meeting of the Dublin University Experimental

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[1] See *Nature*, lix. 228–9, January 1899.

[2] *Comptes Rendus*, 1898, 127, p. 953.

Science Association. Subsequently the quartet form (which we have now proved in the cases observed to be really a sextet) was independently observed by M. Cornu[1] and others.

3. Finally, from the various observations of the character and measurements of the amount of the magnetic effect experienced by the various spectral lines of several substances, a general law has been inferred concerning the effect which may be stated as follows:[2]—

(1) The spectral lines of a given substance may be divided into groups such that all the members of one group suffer the same kind of perturbation in the magnetic field, but the kind of perturbation of all the members of another group is different. Thus, for example, in the series of triplets of zinc, the first of one triplet is similarly affected to the first of each of the other triplets, while the second of one triplet is affected in the same way as the second in each of the other triplets, but in a different way from first and third of the triplet. Hence the series of firsts of each triplet constitute a group all the members of which are similarly affected, and the series of seconds and thirds are other such groups.

(2) The character of the effect is the same in the corresponding lines of the spectra of chemically related elements. Thus, the triplets of cadmium are affected in the same way, both as regards the character and the magnitude of the effect, as are the triplets of zinc.

(3) If the magnitude of the effect be measured by the difference of wave-length of the lateral components of the magnetically resolved line, then throughout any one group the magnitude of the effect is inversely as the square of the wave-length of the line. This means that e/m is the same for all the lines of the same group, but not the same for all the lines of the spectrum. In other words, the difference of *frequency* between the lateral components of the magnetically resolved line is the same for all the lines of the same group; and if the *magnitude* of the effect be measured by this *difference of frequency*, then we may say that the effect is the same in *character* and *magnitude* for all the lines of the same group. It differs from group to group in any one substance, but is the same for corresponding groups in different substances.

Further information will be found in this connection in the 'Philosophical Magazine,' vol. xlvii. p. 165, February 1899, and the 'Phil. Trans. Royal Dublin Society,' vol. viii. series II. p. 7, 1899.

Determining Magnetic Force at Sea.—Report of the Committee, consisting of Professor A. W. RÜCKER (*Chairman*), Dr. C. H. LEES, (*Secretary*), Lord KELVIN, Professor A. SCHUSTER, Captain E. W. CREAK, Professor W. STROUD, Mr. C. V. BOYS, and Mr. W. WATSON, *appointed to investigate the Method of determining Magnetic Force at Sea.*

SOME information has been collected as to the methods used at sea by different countries, and Captain Creak has carried out experiments at Kew by Lloyd's method with encouraging results.

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[1] *Comptes Rendus*, 1898, 126, p. 181 and p. 300.

[2] This law was published in *Nature*, lix. 248, January 12, 1899.

Meteorological Observatory, Montreal.—Report of the Committee, consisting of Professor H. L. CALLENDAR (*Chairman*), Professor C. McLEOD (*Secretary*), Professor F. ADAMS, *and* Mr. R. F. STUPART, *appointed for the purpose of establishing a Meteorological Observatory on Mount Royal, Montreal, Canada.*

As reported last year, some very good records of temperature on the top of the mountain were obtained by means of a recorder set up in the College Observatory at the base, and connected by a line about a mile long to an electrical thermometer set up in the tower on the summit. Unfortunately, the grant for meteorological purposes had been reduced by the present Government, and the sum of money at the disposal of the Committee, amounting to only half the estimated cost, did not permit of protection for the line and the instruments in a sufficiently permanent manner. In the early part of the summer the lock was broken, and the instruments mischievously damaged. At a later date, the thermometer was struck by lightning, and the insulation of the line suffered. After some delay, owing to the winter, the cost of a new thermometer was defrayed by the Physics Building Committee, but it was found that the insulation of the line had deteriorated seriously in the course of the winter, and the accuracy of the records was considerably impaired. It is hoped that these defects will shortly be located and repaired, and that the apparatus will soon be in good working order.

The Committee ask for reappointment, with a further grant of 20*l.* for the more efficient protection of the line and instruments.

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

(1) In determining the area α of the curve

$$y = y_0 \frac{1}{\left\{1+\left(\frac{x}{a}\right)^2\right\}^{\frac{1}{2}(r+2)}} e^{-\nu \tan^{-1}\frac{x}{a}} \quad . \quad . \quad . \quad \text{(i.)}$$

where r, ν, a are constants of known numerical value in terms of the constant y_0, we find [1] :

$$\alpha = y_0 \, a \, e^{-\frac{1}{2}\nu\pi} \int_0^{\pi} \sin^r \theta \, e^{\nu\theta} \, d\theta. \quad . \quad . \quad . \quad \text{(ii.)}$$

This curve occurs frequently in certain forms of statistical investigation, and if we write

$$\mathrm{G}\ (r, \nu) = \int_0^{\pi} \sin^r \theta \, e^{\nu\theta} \, d\theta \quad . \quad . \quad . \quad . \quad \text{(iii.)}$$

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[1] See *Phil. Trans.*, vol. clxxxvi. A, p. 377.

We have:

$$y_0 = \frac{a}{a}\,\frac{1}{e^{-\frac{1}{2}\nu\pi}\,G(r,\nu)}$$

$$= \frac{a}{a}\,\frac{1}{F(r,\nu)} \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(iv.)}$$

where we write : $F(r,\nu) = e^{-\frac{1}{2}\nu\pi}\,G(r,\nu)$. . . . . . . (v.)

It was shown in a preliminary report[1] that:

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

where $\tan\phi = \nu$ and $\chi(r,\phi)$ is a function which can be fairly easily calculated, when certain preliminary functions have been tabulated. These $\chi_1, \chi_3, \chi_5, \chi_7$ functions were calculated in the preliminary report above referred to.[2]

Now, in actual statistical application r may take as large a value as 40 to 50. Hence, if $\cos\phi$ be taken from the tables $(\cos\phi)^{r+1}$ is liable to a large error often reaching to the fifth place of figures when we are tabulating $\log F(r,\nu)$. Clearly, for accuracy, it is better not to find $F(r,\nu)$ by interpolating between two tabular values of $\log F(r,\nu)$, but to deal with some new function in which $(\cos\phi)^{r+1}$ does not occur, and then multiply by the actual value of $(\cos\phi)^{r+1}$ deduced from the exact value of the angle ϕ and the quantity r. This will not, of course, free us from the error, which arises from a value of $\cos\phi$ tabulated to only seven figures being raised to a high power. The value of $(\cos\phi)^{r+1}$ must, therefore, be found from 10-figure logarithmic tables of trigonometrical functions like those of Vega's: 'Thesaurus Logarithmorum Completus' of 1794. But the error due to the determination of $(\cos\phi)^{r+1}$ from 7-figure tables is not significant in the case of statistical investigations. For y_0, as determined for any observed frequency series—probably not containing more than 1,000 to 4,000 observations at a maximum—is subject to a considerable percentage error.[3] It seemed, accordingly, desirable to tabulate for statistical purposes a function which is without the factor $(\cos\phi)^{r+1}$, and has yet a real statistical importance. This function is obtained in the following manner. The frequency y_1 per unit of variable x at the mean for the normal curve:

$$y = y_1\,e^{-\frac{1}{2}(x/\sigma)^2},$$

where σ is the standard deviation, is given by

$$y_1 = \frac{a}{\sigma}\,\frac{1}{\sqrt{2\pi}},$$

where a is the area of the normal curve. For the curve (i) it is given[4] by

$$y_1 = \frac{a}{\sigma}\,\frac{1}{\sqrt{2\pi}}\sqrt{\frac{\nu}{r-1}}\;e^{-2\chi(r,\phi)}. \quad . \quad . \quad . \quad \text{(vii.)}$$

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[1] *B. A. Trans.*, Report 1896.

[2] The following slip has been since discovered in the tables of that report: log χ, for $\phi = 25°$, should be $\bar{2}.677,7543$, and not $\bar{2}.667,7543$, as tabulated.

[3] See *Phil. Trans.* vol. cxci. A, p. 297 *et seq.*; numerically, perhaps, the error may amount in practice to ·5 to 2 *per cent.*

[4] See *Phil. Trans.* vol. cxci. A, p. 298 (equation cxxxvi.), where, however, the symbol χ is used for $2\chi(r,\phi)$ of the present notation and of that of the *Preliminary Report.*

This result we may write:

$$y_1 = \frac{a}{\sigma} \, \frac{1}{\mathrm{H}\,(r, \nu)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (\text{viii.})$$

where:

$$\mathrm{H}\,(r, \nu) = \sqrt{2\pi}\,\sqrt{\frac{r-1}{\nu}}\; e^{2\chi(r,\,\phi)} \quad . \quad . \quad . \quad . \quad (\text{ix.})$$

It is this function H (r, ν) which has been chosen for the purposes of tabulation. Equation (viii.) shows its statistical importance—it enables us, knowing the standard deviation σ of the observations—to at once determine the frequency of mean values. It will approximate more and more to $\sqrt{2\pi}$ as the frequency approaches a normal distribution, which it does when r is large. Hence the differences of H (r, ν) will be small, and are likely to be smooth, when r is large, and consequently F (r, ν), owing to the factor $(\cos \phi)^{r+1}$ is not capable of very accurate determination.

The relations between the three functions already mentioned are:

$$\mathrm{F}\,(r, \nu) = e^{-\frac{1}{2}\nu\pi}\,\mathrm{G}\,(r, \nu) \quad . \quad . \quad . \quad . \quad . \quad . \quad (\text{x.})$$

$$\mathrm{F}\,(r, \nu) = \frac{e^{\nu\phi}\,(\cos\phi)^{r+1}}{\sqrt{r-1}}\,\mathrm{H}\,(r, \nu) \quad . \quad . \quad . \quad . \quad (\text{xi.})$$

$$\mathrm{G}\,(r, \nu) = e^{\frac{1}{2}\nu\pi}\,\mathrm{F}\,(r, \nu) \quad . \quad . \quad . \quad . \quad . \quad . \quad (\text{xii.})$$

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

$$\mathrm{H}\,(r, \nu) = \frac{\sqrt{r-1}\;e^{-\nu\phi}}{(\cos\phi)^{r+1}}\,\mathrm{F}\,(r, \nu) \quad . \quad . \quad . \quad . \quad (\text{xiv.})$$

$$\mathrm{H}\,(r, \nu) = \frac{\sqrt{r-1}\;e^{-\nu\phi-\frac{1}{2}\nu\pi}}{(\cos\phi)^{r+1}}\,\mathrm{G}\,(r, \nu) \quad . \quad . \quad . \quad . \quad (\text{xv.})$$

so that any one can be found from either of the others.

(2) But while H (r, ν) is clearly the best function to tabulate when r is moderately large, it is not so satisfactory when r is small; for although in that case $(\cos \phi)^{r+1}$ may be fairly easily found from the tables in ordinary use, so that it might seem that F (r, ν) could be accurately determined, yet the expression for χ (r, ϕ) now becomes unsatisfactory. As has been shown in the *Preliminary Report*, § 2, we have to deal with a semi-convergent series, and cannot for small values of r go beyond χ_7; but this may involve an error as large as 6 in 10,000. Accordingly, as the tables only proceed by integers, we have used the following results which can, for $r =$ an integer, be deduced by direct integration:

$$\mathrm{F}\,(2r, \nu) = 2\sinh\tfrac{1}{2}\,\pi\nu\,\frac{\underline{|2r}}{\nu\,(\nu^2+2^2)\,(\nu^2+4^2)\,.\,.\,.\,(\nu^2+(2r)^2)} \quad (\text{xvi.})$$

$$\mathrm{F}\,(2r+1, \nu) = 2\cosh\tfrac{1}{2}\,\pi\nu\,\frac{\underline{|2r+1}}{(\nu^2+1)\,(\nu^2+3^2)\,.\,.\,(\nu^2+(2r+1)^2)} \quad (\text{xvii.})$$

The function H (r, ν) was then deduced from these values of F (r, ν) by (xiv.).

This process was used for values of F (r, ν) for $r=1$ to 7, and the values of F (r, ν) and H (r, ν) as found from the χ-functions of the tables of the *Preliminary Report* were compared and found to agree with these for $r=6$ and $r=7$. For $r=6$ to $r=50$ the χ-function tables were used. The values of ϕ are taken from 0° to 45° proceeding by degrees, for no instance has yet been found in statistical investigations in which ν is greater than r. Should such cases arise in future, then F (r, ν) or H (r, ν) must be calculated from the χ-tables for $\phi=46°$ to 90° given in the *Preliminary Report.*

(3) The whole of the arithmetical work (which proved far more laborious than was initially anticipated) has been undertaken by Miss Alice Lee, B.A., D.Sc., Assistant-Lecturer in Physics in Bedford College, London. The arithmetic has been done twice independently, Miss Lee having been most kindly assisted in the verification of the tables by Miss M. Fry, Miss C. D. Fawcett, B.Sc., Miss E. Bramley-Moore, B.A,, and Miss L. Bramley-Moore. To the extent of the methods used we think the accuracy of the tables is guaranteed by the agreement reached by the two sets of calculations. But sources of error common to both independent calculations have been already referred to, and may be indicated more particularly here. So far as H (r, ν) as obtained from (ix.) is concerned, 2χ has been worked to 9 figures and is certainly correct to 8 figures. $2\chi \log e$ was then found by actual multiplication. We consider, accordingly, that log H (r, ν) is correct to 7 figures in all cases, from $r=6$ to $r=50$. Any inaccuracy of log F (r, ν) arises from the extra factors in (xi.). To begin with, the factor $e^{\nu\phi}=e^{r\phi \tan \phi}$ appears as $r\phi \tan \phi \log e$. ϕ was obtained from $\frac{\pi}{180} \times n°$, using the Brunsviga calculator; tan ϕ was taken from Rheticus' 10-figure trigonometrical tables of 1596, and the product $r\phi \tan \phi \log e$ obtained by the Brunsviga. We consider, therefore, that $r\phi \tan \phi \log e$, like the previous product $2\chi \log e$, should be correct to at least 10 places of figures. $(r+1) \log \cos \phi$ was found from Vega's 10-figure trigonometrical tables by actual multiplication. It is unlikely, accordingly, that there will be an error in this product in the 8th place, and we feel fairly certain that the method, when all the factors are added in, cannot affect the value of log F (r, ν) to the 7th place. Still, the differences in the tabulated values of log F (r, ν) are in parts of the table considerable, and interpolated values, such as we get in practice, can hardly be considered as accurate beyond the 6th figure, or even at certain parts of the table beyond the 5th figure. This, of course, is sufficient for statistical purposes, but if for physical or mathematical calculations it should be needful to have the G (r, ν) integrals to a closer value, a table will have to be constructed for much smaller differences of r and ϕ. At present the physicist or mathematician must use our H (r, ν) integral and find $(\cos \phi)^{r+1}$ and $e^{r\phi \tan \phi}$ for the actual values of r and ϕ by 10-figure logarithmic tables. He will hardly be sure of being correct to the 6th figure, if he uses the usual 7-figure logarithmic tables.

For values of r less than 6, formulæ (xvi.) and (xvii.) have been used, as already noted. The factorial denominators were calculated by aid of the Brunsviga and Vega's 10-figure tables. For the hyperbolic sine and cosine tables have been calculated to 14 figures by J. W. L. Glaisher and F. Newman, but the differences were so large in the part of the tables required, that it seemed safer to recalculate $e^{\pm x}$ for the special values of

x needed.[1] In these cases H (r, ν) had to be derived from F (r, ν) by (xiv.), and the logarithms of the factors were obtained from Vega's 10-figure tables. The methods applied should give both log H (r, ν) and log F (r, ν) correct to seven figures.

On the whole we consider that the Table, if the calculations are not in error, ought to be correct to the number of figures tabulated. The calculations have been done with much labour and care, twice independently with 7-figure tables, and then again with 10-figure tables. The latter investigation modified generally the seventh figure, and occasionally the sixth, but gave a much smoother system of differences. Logarithms of the functions and their differences were worked to ten figures and then cut off at the nearest figure in the seventh place, thus *the recorded differences are the nearest values of the true differences, and not the differences of the recorded logarithms.*

(4) With regard to interpolation formulæ for tables of double entry, we have been unable to discover much consideration of the subject, possibly because hitherto such tables have been rather rare. We do not know of any formulæ, similar to those for interpolation on a curve, for interpolating on surfaces. The simplest formula, using second differences, is :

$$\begin{aligned} u_{x,y} = {} & u_{o,o} + x\,\Delta\, u_{o,o} + y\Delta' u_{o,o} \\ & + \tfrac{1}{2}\{x(x-1)\Delta^2 u_{o,o} + 2xy\ \Delta\,\Delta' u_{o,o} + y(y-1)\Delta'^2 u_{o,o}\} \quad . \quad . \quad \text{(xviii.)} \end{aligned}$$

where Δ denotes a difference with regard to x, and Δ' with regard to y. But if we consider $u_{x,y}$ to be the ordinate of a surface, and the figure to represent the xy plane of such a surface, then it is clear that, if P be the point x, y, and A, B, C, D, &c. the adjacent points at which the ordinates are known from the table of double entry, only the points A, B, C, D, J, and N are used by the formula ; and of these points, not equal weight is given to the fundamental points A, B, C, D, for C only appears in a second difference. If another point of the fundamental square other than A be taken as origin, we get a divergent, occasionally a widely divergent result. If we use only four points—A, B, C, D—to determine the value of the function at P, then we might take the ordinate at P of the plane which (by the method of least squares) most nearly passes through the four points of the surface vertically above A, B, C, D. We have then

$$\begin{aligned} u_{x,y} = {} & \tfrac{1}{4}(u_{o,o} + u_{1,o} + u_{o,1} + u_{1,1}) + \tfrac{1}{2}(u_{1,o} - u_{o,o} + u_{1,1} - u_{o,1})(x - {\cdot}5) \\ & + \tfrac{1}{2}(u_{o,1} - u_{o,o} + u_{1,1} - u_{1,o})(y - {\cdot}5) \quad . \quad \text{(xix.)} \end{aligned}$$

but by trial it has been found that this formula gives occasionally worse results than that for first differences, using only three points. To find by the methods of simple interpolation (with first or first and second differences) the points a and b,[2] and then interpolate P between them, generally gives a fairly good result ; but this result usually differs some-

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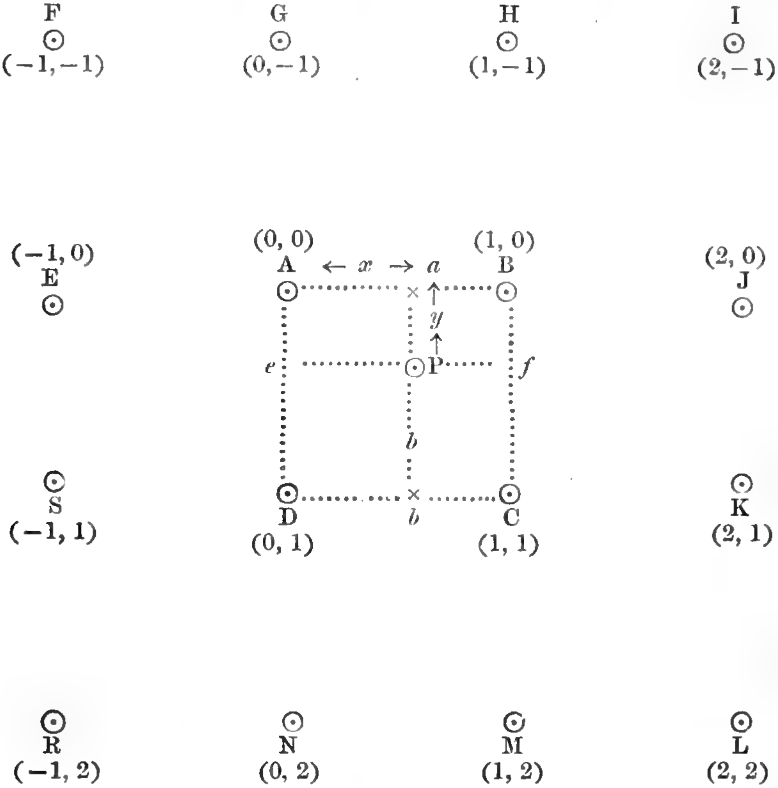
[1] For other investigations we have found,

$$e^{\pm x} = e^{\pm x_0 \pm (x - x_0)} = e^{\pm x_0}\left(1 \pm (x - x_0) + \frac{1}{|\underline{2}}(x - x_0)^2 \pm \frac{1}{|\underline{3}}(x - x_0)^3 + \;—\right),$$

where x_0 is the nearest value in Glaisher and Newman's tables, to give $e^{\pm x}$ with great accuracy when four or five terms of the exponential expansion are used. But this method was more laborious than direct calculation when some 600 values were needed.

[2] See diagram on p. 70.

what from that obtained by first finding the value of the function at e and f by simple interpolation, and then interpolating P between these. On the whole we consider that methods of interpolating in the case of tables of double or multiple entry require a full discussion and treatment which would be out of place here. The chief source of error which will arise in using the present tables will, we believe, be the error of interpolation; but this error with caution will not, we consider, amount to more than 3 or 4 in the 10,000, an error which is of no importance in statistical investigations.



(5) Should the G (r, ν) integrals ever become, like the Γ-integrals, of physical or mathematical importance, *e.g.* in relation to Γ-integrals with a complex variable, then the present table will serve as a skeleton table to be filled in for much smaller differences of r and ϕ. The present determination of G (r, ν) through a knowledge of H (r, ν), and the use of 10-figure tables like those of Vega, will serve for almost all purposes that are likely to arise, and even without such 10-figure tables for all statistical purposes. The latter were indeed those for which they were planned. To give greater accuracy for interpolated values we should have had to increase at least ten to twenty fold the 2,300 entries of the present table, and this could only be done by an amount of labour wholly incommensurable with our initial aims. The table as it is has involved between five and six thousand independent calculations, and has consumed an amount of time and energy which, had it been foreseen—which luckily it was not—would probably have sufficed to discourage any attempt to carry out the work.

$\phi°$	$r = 1$		
	log F (r, ν)	Δ log F (r, ν)	Δ^2 log F (r, ν)
0	0·301 0300	·000 0309	
1	·301 0609	928	·000 0619
2	·301 1538	1550	621
3	·301 3087	2175	625
4	·301 5262	2805	630
5	·301 8067	3441	636
6	·302 1508	4086	645
7	·302 5594	4740	654
8	·303 0335	5406	666
9	·303 5741	6085	679
10	·304 1825	6778	693
11	·304 8603	7488	710
12	·305 6091	8216	728
13	·306 4307	8964	749
14	·307 3271	9735	771
15	·308 3006	10532	796
16	·309 3538	11353	822
17	·310 4892	12206	853
18	·311 7098	13091	885
19	·313 0189	14011	919
20	·314 4200	14969	958
21	·315 9169	15968	999
22	·317 5137	17013	1045
23	·319 2150	18106	1093
24	·321 0256	19252	1146
25	·322 9507	20456	1204
26	·324 9963	21722	1266
27	·327 1685	23055	1334
28	·329 4740	24462	1407
29	·331 9202	25948	1486
30	·334 5150	27521	1573
31	·337 2672	29188	1667
32	·340 1860	30958	1769
33	·343 2818	32838	1881
34	·346 5656	34840	2002
35	·350 0496	36974	2134
36	·353 7469	39252	2279
37	·357 6722	41689	2436
38	·361 8410	44298	2609
39	·366 2708	47096	2799
40	·370 9805	50103	3007
41	·375 9908	53338	3235
42	·381 3246	56824	3486
43	·387 0070	60588	3764
44	·393 0658	64658	4069
45	·399 5316		

$\phi°$	$r = 2$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ² log H (ν
0	0·196 1199	0·196 1199	·000 0192	
1	·196 2052	·196 1391	575	·000 0383
2	·196 4614	·196 1966	958	383
3	·196 8890	·196 2924	1340	382
4	·197 4890	·196 4264	1722	381
5	·198 2627	·196 5985	2102	380
6	·199 2118	·196 8087	2480	379
7	·200 3385	·197 0567	2857	377
8	·201 6452	·197 3424	3231	375
9	·203 1349	·197 6655	3604	373
10	·204 8110	·198 0260	3974	370
11	·206 6774	·198 4234	4341	367
12	·208 7382	·198 8574	4705	364
13	·210 9985	·199 3280	5064	360
14	·213 4631	·199 8344	5420	356
15	·216 1383	·200 3764	5773	352
16	·219 0303	·200 9537	6120	347
17	·222 1462	·201 5657	6463	343
18	·225 4936	·202 2120	6801	338
19	·229 0807	·202 8921	7133	332
20	·232 9167	·203 6054	7460	327
21	·237 0114	·204 3514	7780	320
22	·241 3755	·205 1294	8093	313
23	·246 0203	·205 9387	8400	307
24	·250 9584	·206 7787	8700	300
25	·256 2034	·207 6487	8991	291
26	·261 7697	·208 5478	9275	284
27	·267 6733	·209 4753	9549	275
28	·273 9311	·210 4302	9816	266
29	·280 5618	·211 4118	1 0072	256
30	·287 5852	·212 4190	1 0319	247
31	·295 0232	·213 4509	1 0556	236
32	·302 8992	·214 5064	1 0782	226
33	·311 2388	·215 5846	1 0996	213
34	·320 0695	·216 6842	1 1199	203
35	·329 4214	·217 8041	1 1390	191
36	·339 3271	·218 9431	1 1569	178
37	·349 8221	·220 1000	1 1734	165
38	·360 9451	·221 2734	1 1886	152
39	·372 7382	·222 4621	1 2023	138
40	·385 2475	·223 6644	1 2148	125
41	·398 5232	·224 8791	1 2256	109
42	·412 6205	·226 1048	1 2350	94
43	·427 5995	·227 3397	1 2427	77
44	·443 5266	·228 5824	1 2489	62
45	·460 4745	·229 8313		

$\phi°$	$r = 6$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	0·124 9387	0·275 4537	·000 0137	
1	·125 0847	·275 4674	410	·000 0273
2	·125 5230	·275 5084	683	273
3	·126 2545	·275 5767	955	272
4	·127 2807	·275 6721	1226	271
5	·128 6039	·275 7948	1496	270
6	·130 2270	·275 9444	1766	269
7	·132 1533	·276 1209	2032	267
8	·134 3870	·276 3242	2298	266
9	·136 9331	·276 5540	2561	263
10	·139 7969	·276 8101	2822	261
11	·142 9850	·277 0923	3080	258
12	·146 5043	·277 4003	3336	256
13	·150 3626	·277 7338	3588	252
14	·154 5688	·278 0926	3837	249
15	·159 1322	·278 4762	4082	245
16	·164 0636	·278 8844	4323	241
17	·169 3743	·279 3167	4560	237
18	·175 0768	·279 7726	4793	233
19	·181 1848	·280 2519	5020	228
20	·187 7130	·280 7539	5243	223
21	·194 6774	·281 2782	5460	217
22	·202 0955	·281 8243	5673	212
23	·209 9858	·282 3915	5879	206
24	·218 3688	·282 9794	6079	200
25	·227 2664	·283 5873	6272	194
26	·236 7023	·284 2145	6460	188
27	·246 7020	·284 8604	6640	180
28	·257 2933	·285 5244	6813	173
29	·268 5060	·286 2057	6978	165
30	·280 3725	·286 9035	7136	158
31	·292 9278	·287 6170	7286	150
32	·306 2096	·288 3456	7427	141
33	·320 2589	·289 0883	7560	133
34	·335 1201	·289 8443	7684	124
35	·350 8413	·290 6127	7800	115
36	·367 4747	·291 3927	7905	106
37	·385 0770	·292 1832	8002	97
38	·403 7099	·292 9834	8089	87
39	·423 4403	·293 7923	8166	77
40	·444 3416	·294 6089	8232	67
41	·466 4933	·295 4321	8289	57
42	·489 9829	·296 2610	8335	46
43	·514 9055	·297 0945	8371	36
44	·541 3658	·297 9316	8394	23
45	·569 4783	·298 7710		

ϕ°	$r=4$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	0·071 1811	0·309 7418	·000 0105	
1	·071 3902	·309 7523	316	·000 0211
2	·072 0177	·309 7840	527	211
3	·073 0650	·309 8366	737	210
4	·074 5342	·309 9103	946	209
5	·076 4285	·310 0049	1154	208
6	·078 7517	·310 1204	1361	207
7	·081 5088	·310 2565	1567	206
8	·084 7055	·310 4132	1771	204
9	·088 3486	·310 5904	1973	202
10	·092 4458	·310 7877	2174	201
11	·097 0060	·311 0051	2372	198
12	·102 0399	·311 2423	2567	196
13	·107 5555	·311 4990	2760	193
14	·113 5680	·311 7751	2950	190
15	·120 0895	·312 0701	3137	187
16	·127 1349	·312 3838	3321	184
17	·134 7199	·312 7159	3501	180
18	·142 8621	·313 0660	3677	176
19	·151 5802	·313 4337	3849	172
20	·160 8948	·313 8186	4018	168
21	·170 8281	·314 2204	4181	164
22	·181 4042	·314 6385	4341	160
23	·192 6491	·315 0726	4495	154
24	·204 5907	·315 5222	4645	150
25	·217 2596	·315 9866	4789	144
26	·230 6885	·316 4655	4927	138
27	·244 9127	·316 9583	5062	134
28	·259 9707	·317 4644	5189	127
29	·275 9034	·317 9833	5310	121
30	·292 7555	·318 5143	5426	116
31	·310 5754	·319 0569	5535	109
32	·329 4149	·319 6104	5637	102
33	·349 3304	·320 1741	5733	96
34	·370 3832	·320 7474	5822	89
35	·392 6390	·321 3297	5904	82
36	·416 1697	·321 9201	5980	75
37	·441 0529	·322 5181	6047	68
38	·467 3733	·323 1228	6107	60
39	·495 2227	·323 7335	6160	53
40	·524 7011	·324 3495	6205	45
41	·555 9177	·324 9700	6243	38
42	·588 9916	·325 5943	6272	30
43	·624 0530	·326 2216	6295	22
44	·661 2446	·326 8510	6307	12
45	·700 7225	·327 4817		

$\phi°$	$r=5$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	0·028 0289	0·329 0589	·000 0084	
1	·028 3019	·329 0673	257	·000 0173
2	·029 1221	·329 0930	428	171
3	·030 4908	·329 1357	598	171
4	·032 4110	·329 1956	768	170
5	·034 8865	·329 2723	937	169
6	·037 9224	·329 3661	1105	168
7	·041 5250	·329 4765	1272	167
8	·045 7016	·329 6037	1437	165
9	·050 4609	·329 7474	1601	164
10	·055 8130	·329 9075	1763	162
11	·061 7690	·330 0838	1923	160
12	·068 3415	·330 2761	2081	158
13	·075 5446	·330 4842	2237	156
14	·083 3937	·330 7079	2390	153
15	·091 9061	·330 9469	2541	151
16	·101 1002	·331 2010	2689	148
17	·110 9967	·331 4700	2833	144
18	·121 6176	·331 7532	2975	142
19	·132 9872	·332 0508	3114	138
20	·145 1317	·332 3621	3249	135
21	·158 0795	·332 6870	3380	131
22	·171 8614	·333 0250	3507	127
23	·186 5105	·333 3757	3630	123
24	·202 0627	·333 7387	3750	119
25	·218 5568	·334 1137	3864	115
26	·236 0346	·334 5001	3975	110
27	·254 5413	·334 8976	4081	106
28	·274 1255	·335 3057	4182	101
29	·294 8399	·335 7239	4277	96
30	·316 7413	·336 1516	4368	91
31	·339 8909	·336 5884	4455	87
32	·364 3553	·337 0339	4535	80
33	·390 2059	·337 4874	4610	75
34	·417 5203	·337 9485	4680	70
35	·446 3827	·338 4164	4744	64
36	·476 8841	·338 8908	4802	58
37	·509 1232	·339 3709	4854	52
38	·543 2072	·339 8563	4900	46
39	·579 2529	·340 3463	4940	40
40	·617 3872	·340 8404	4975	34
41	·657 7483	·341 3378	5003	28
42	·700 4872	·341 8381	5024	22
43	·745 7688	·342 3405	5040	16
44	·793 7739	·342 8446	5049	9
45	·844 6999	·343 3495		

ϕ°	$r = 6$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·991 9999	0·341 4849	·000 0072	
1	·992 3379	·341 4921	216	·000 0144
2	·993 3526	·341 5137	359	144
3	·995 0459	·341 5496	503	143
4	·997 4213	·341 5999	645	143
5	0·000 4836	·341 6644	787	142
6	·004 2390	·341 7432	928	141
7	·008 6950	·341 8360	1068	140
8	·013 8607	·341 9428	1207	139
9	·019 7468	·342 0635	1345	137
10	·026 3653	·342 1980	1481	136
11	·033 7300	·342 3461	1615	134
12	·041 8562	·342 5075	1747	133
13	·050 7609	·342 6823	1878	131
14	·060 4633	·342 8701	2006	128
15	·070 9839	·343 0707	2133	127
16	·082 3457	·343 2839	2256	123
17	·094 5734	·343 5095	2377	121
18	·107 6941	·343 7472	2496	119
19	·121 7375	·343 9968	2611	115
20	·136 7352	·344 2579	2723	112
21	·152 7219	·344 5302	2833	109
22	·169 7350	·344 8135	2939	106
23	·187 8149	·345 1074	3041	103
24	·207 0053	·345 4115	3141	99
25	·227 3532	·345 7256	3236	95
26	·248 9095	·346 0492	3328	92
27	·271 7291	·346 3819	3415	88
28	·295 8713	·346 7235	3499	84
29	·321 3998	·347 0734	3577	78
30	·348 3836	·347 4311	3653	76
31	·376 8974	·347 7965	3724	71
32	·407 0214	·348 1689	3791	66
33	·438 8428	·348 5480	3852	62
34	·472 4556	·348 9332	3910	57
35	·507 9618	·349 3242	3962	52
36	·545 4718	·349 7204	4009	47
37	·585 1052	·350 1213	4052	43
38	·626 9922	·350 5265	4090	38
39	·671 2739	·350 9354	4122	33
40	·718 1040	·351 3477	4150	28
41	·767 6502	·351 7627	4172	22
42	·820 0951	·352 1799	4190	17
43	·875 6383	·352 5989	4202	12
44	·934 4983	·353 0191	4209	7
45	·996 9145	·353 4399		

ϕ°	$r = 7$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·961 0819	0·350 1576	·000 0062	
1	·961 4851	·350 1638	186	·000 0124
2	·962 6953	·350 1824	310	124
3	·964 7151	·350 2134	433	123
4	·967 5483	·350 2567	556	123
5	·971 2008	·350 3123	678	122
6	·975 6796	·350 3801	800	122
7	·980 9940	·350 4601	921	121
8	·987 1544	·350 5522	1040	120
9	·994 1735	·350 6562	1158	118
10	0·002 0658	·350 7720	1275	117
11	·010 8465	·350 8995	1391	116
12	·020 5347	·351 0386	1505	114
13	·031 1503	·351 1891	1617	112
14	·042 7157	·351 3508	1727	110
15	·055 2551	·351 5235	1836	109
16	·068 7956	·351 7071	1942	106
17	·083 3665	·351 9012	2046	104
18	·098 9997	·352 1058	2148	102
19	·115 7298	·352 3206	2247	99
20	·133 5946	·352 5452	2343	97
21	·152 6347	·352 7795	2437	94
22	·172 8941	·353 0232	2528	91
23	·194 4206	·353 2760	2615	88
24	·217 2653	·353 5375	2700	85
25	·241 4839	·353 8075	2782	82
26	·267 1362	·354 0857	2860	79
27	·294 2868	·354 3717	2935	75
28	·323 0053	·354 6652	3007	72
29	·353 3670	·354 9659	3074	67
30	·385 4529	·355 2732	3138	64
31	·419 3506	·355 5871	3199	60
32	·455 1549	·355 9070	3255	56
33	·492 9680	·356 2324	3308	53
34	·532 9005	·356 5632	3356	49
35	·575 0721	·356 8988	3400	44
36	·619 6127	·357 2388	3441	40
37	·666 6629	·357 5829	3477	36
38	·716 3753	·357 9306	3509	32
39	·768 9159	·358 2814	3536	28
40	·824 4653	·358 6350	3559	23
41	·883 2199	·358 9910	3578	19
42	·945 3944	·359 3488	3592	14
43	1·011 2229	·359 7080	3602	10
44	·080 9618	·360 0682	3608	6
45	·154 8920	·360 4290		

ϕ°	$r=8$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·934 0080	0·356 5570	·000 0054	
1	·934 4765	·356 5624	163	·000 0109
2	·935 8831	·356 5788	272	109
3	·938 2304	·356 6059	380	108
4	·941 5232	·356 6440	488	108
5	·945 7679	·356 6928	596	107
6	·950 9729	·356 7524	702	107
7	·957 1486	·356 8226	808	106
8	·964 3073	·356 9034	913	105
9	·972 4634	·356 9947	1017	104
10	·981 6333	·357 0964	1120	103
11	·991 8357	·357 2083	1221	101
12	0·003 0914	·357 3304	1321	100
13	·015 4237	·357 4625	1419	98
14	·028 8583	·357 6044	1516	97
15	·043 4233	·357 7560	1611	95
16	·059 1498	·357 9170	1704	93
17	·076 0714	·358 0874	1795	91
18	·094 2250	·358 2669	1884	89
19	·113 6505	·358 4553	1971	87
20	·134 3912	·358 6524	2055	84
21	·156 4939	·358 8579	2137	82
22	·180 0093	·359 0716	2217	80
23	·204 9923	·359 2933	2293	77
24	·231 5019	·359 5226	2368	74
25	·259 6019	·359 7594	2439	71
26	·289 3613	·360 0033	2507	68
27	·320 8543	·360 2540	2572	65
28	·354 1610	·360 5112	2635	62
29	·389 3678	·360 7747	2694	59
30	·426 5682	·361 0441	2750	56
31	·465 8626	·361 3191	2802	52
32	·507 3601	·361 5993	2851	49
33	·551 1780	·361 8844	2897	46
34	·597 4436	·362 1741	2939	42
35	·646 2914	·362 4681	2978	39
36	·697 8795	·362 7659	3013	35
37	·752 3605	·363 0671	3044	31
38	·809 9127	·363 3715	3072	28
39	·870 7267	·363 6787	3096	24
40	·935 0097	·363 9883	3116	20
41	1·002 9876	·364 2998	3132	16
42	·074 9063	·364 6130	3144	12
43	·151 0352	·364 9274	3153	9
44	·231 6680	·365 2427	3157	5
45	·317 1271	·365 5584		

ϕ°	$r = 9$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	1·909 9294	0·361 4744	·000 0049	
1	·910 4635	·361 4793	146	·000 0097
2	·912 0669	·361 4938	242	97
3	·914 7427	·361 5180	339	97
4	·918 4961	·361 5520	435	96
5	·923 3346	·361 5955	531	96
6	·929 2675	·361 6485	626	95
7	·936 3067	·361 7111	720	94
8	·944 4661	·361 7831	813	94
9	·953 7619	·361 8644	906	92
10	·964 2128	·361 9550	997	92
11	·975 8398	·362 0547	1088	90
12	·988 6667	·362 1635	1177	89
13	0·002 7197	·362 2812	1264	88
14	·018 0278	·362 4075	1350	86
15	·034 6230	·362 5426	1435	84
16	·052 5403	·362 6860	1518	83
17	·071 8179	·362 8378	1599	81
18	·092 4974	·362 9976	1678	79
19	·114 6239	·363 1654	1755	77
20	·138 2465	·363 3409	1830	75
21	·163 4180	·363 5239	1903	73
22	·190 1960	·363 7142	1973	71
23	·218 6422	·363 9115	2042	68
24	·248 8237	·364 1157	2107	66
25	·280 8124	·364 3264	2171	63
26	·314 6864	·364 5435	2231	61
27	·350 5295	·364 7666	2290	58
28	·388 4323	·364 9955	2345	55
29	·428 4925	·365 2300	2397	52
30	·470 8156	·365 4697	2447	50
31	·515 5153	·365 7144	2493	47
32	·562 7146	·365 9636	2537	44
33	·612 5463	·366 2173	2577	40
34	·665 1541	·366 4750	2615	37
35	·720 6932	·366 7365	2649	34
36	·779 3322	·367 0013	2680	31
37	·841 2534	·367 2693	2707	28
38	·906 6549	·367 5400	2731	24
39	·975 7519	·367 8131	2752	21
40	1·048 7784	·368 0884	2770	18
41	·125 9892	·368 3654	2784	14
42	·207 6624	·368 6438	2795	11
43	·294 1013	·368 9233	2803	7
44	·385 6379	·369 2036	2806	4
45	·482 6360	·369 4842		

$\phi°$	$r=10$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·888 2505	0·365 3717	·000 0044	
1	·888 8502	·365 3761	131	·000 0087
2	·890 6508	·365 3892	219	87
3	·893 6556	·365 4111	306	87
4	·897 8705	·365 4416	392	87
5	·903 3037	·365 4808	479	86
6	·909 9658	·365 5287	564	86
7	·917 8700	·365 5851	649	85
8	·927 0317	·365 6500	733	84
9	·937 4692	·365 7233	817	83
10	·949 2033	·365 8050	899	82
11	·962 2575	·365 8949	981	82
12	·976 6581	·365 9929	1061	80
13	·992 4345	·366 0990	1139	79
14	0·009 6193	·366 2129	1217	78
15	·028 2479	·366 3346	1293	76
16	·048 3595	·366 4639	1368	75
17	·069 9966	·366 6007	1441	73
18	·093 2058	·366 7447	1512	72
19	·118 0374	·366 8960	1581	69
20	·144 5461	·367 0541	1649	68
21	·172 7910	·367 2190	1714	66
22	·202 8360	·367 3904	1778	64
23	·234 7504	·367 5682	1839	61
24	·268 6087	·367 7522	1899	59
25	·304 4913	·367 9420	1956	57
26	·342 4851	·368 1376	2010	55
27	·382 6838	·368 3386	2062	52
28	·425 1882	·368 5448	2112	50
29	·470 1076	·368 7559	2159	47
30	·517 5593	·368 9718	2203	44
31	·567 6703	·369 1922	2245	42
32	·620 5776	·369 4167	2284	39
33	·676 4293	·369 6451	2321	36
34	·735 3855	·369 8772	2354	33
35	·797 6194	·370 1126	2385	31
36	·863 3188	·370 3510	2412	28
37	·932 6869	·370 5923	2437	25
38	1·005 9444	·370 8360	2459	22
39	·083 3313	·371 0819	2478	19
40	·165 1080	·371 3297	2494	16
41	·251 5588	·371 5790	2506	13
42	·342 9931	·371 8296	2516	10
43	·439 7491	·372 0813	2522	6
44	·542 1966	·372 3335	2526	4
45	·650 7407	·372 5861		

$\phi°$	$r=11$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·868 5367	0·368 5367	·000 0040	
1	·869 2023	·368 5407	·000 0120	·000 0080
2	·871 2002	·368 5527	199	79
3	·874 5345	·368 5725	278	79
4	·879 2114	·368 6004	357	79
5	·885 2402	·368 6361	435	78
6	·892 6324	·368 6796	514	78
7	·901 4027	·368 7310	591	77
8	·911 5681	·368 7900	668	77
9	·923 1487	·368 8568	743	76
10	·936 1674	·268 9311	818	75
11	·950 6505	·369 0129	892	74
12	·966 6268	·369 1022	965	73
13	·984 1288	·369 1987	1037	72
14	0·003 1923	·369 3024	1108	71
15	·023 8567	·369 4132	1177	69
16	·046 1651	·369 5308	1245	68
17	·070 1646	·369 6553	1311	66
18	·095 9063	·369 7864	1376	65
19	·123 4460	·369 9240	1439	63
20	·152 8439	·370 0679	1500	62
21	·184 1654	·370 2179	1560	60
22	·217 4809	·370 3739	1618	58
23	·252 8669	·370 5357	1673	56
24	·290 4057	·370 7030	1727	54
25	·330 1857	·370 8757	1779	52
26	·372 3033	·371 0536	1829	50
27	·416 8615	·371 2365	1876	47
28	·463 9718	·371 4241	1921	45
29	·513 7544	·371 6162	1964	43
30	·566 3390	·371 8125	2004	40
31	·621 8657	·372 0129	2042	38
32	·680 4854	·372 2171	2078	36
33	·742 3617	·372 4249	2110	33
34	·807 6710	·372 6359	2141	30
35	·876 6045	·372 8500	2169	28
36	·949 3690	·373 0669	2194	25
37	1·026 1888	·373 2862	2216	23
38	·107 3073	·373 5078	2236	20
39	·192 9888	·373 7314	2253	17
40	·283 5209	·373 9567	2267	14
41	·379 2165	·374 1834	2279	12
42	·480 4171	·374 4113	2287	9
43	·587 4953	·374 6400	2293	6
44	·700 8587	·374 8693	2296	3
45	·820 9540	·375 0990		

ϕ°	$r=12$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·850 4619	0·371 1582	·000 0036	
1	·851 1933	·371 1619	110	·000 0073
2	·853 3889	·371 1729	183	73
3	·857 0528	·371 1912	255	73
4	·862 1923	·371 2166	328	72
5	·868 8171	·371 2494	400	72
6	·876 9402	·371 2893	471	71
7	·886 5774	·371 3364	542	71
8	·897 7474	·371 3907	613	70
9	·910 4722	·371 4519	682	69
10	·924 7770	·371 5201	751	69
11	·940 6901	·371 5952	819	68
12	·958 2436	·371 6771	886	67
13	·977 4727	·371 7656	951	66
14	·998 4167	·371 8608	1016	65
15	0·021 1187	·371 9624	1080	64
16	·045 6258	·372 0703	1142	62
17	·071 9896	·372 1845	1203	61
18	·100 2660	·372 3048	1262	59
19	·130 5159	·372 4310	1320	58
20	·162 8054	·372 5630	1376	56
21	·197 2059	·372 7006	1431	55
22	·233 7945	·372 8437	1484	53
23	·272 6547	·372 9921	1535	51
24	·313 8765	·373 1456	1584	49
25	·357 5571	·373 3040	1632	47
26	·403 8013	·373 4672	1677	45
27	·452 7221	·373 6349	1720	43
28	·504 4412	·373 8069	1762	41
29	·559 0903	·373 9831	1801	39
30	·616 8111	·374 1631	1838	37
31	·677 7567	·374 3469	1873	35
32	·742 0923	·374 5341	1905	33
33	·809 9965	·374 7246	1935	30
34	·881 6625	·374 9182	1963	28
35	·957 2989	·375 1145	1988	25
36	1·037 1322	·375 3133	2011	23
37	·121 4073	·375 5144	2032	21
38	·210 3905	·375 7176	2050	18
39	·304 3704	·375 9226	2065	16
40	·403 6615	·376 1291	2078	13
41	·508 6058	·376 3370	2089	11
42	·619 5764	·376 5458	2097	8
43	·736 9806	·376 7555	2102	5
44	·861 2638	·376 9657	2105	3
45	·992 9140	·377 1762		

ϕ°	$r = 13$			
	$\log F(r, \nu)$	$\log H(r, \nu)$	$\Delta \log H(r, \nu)$	$\Delta^2 \log H(r, \nu)$
0	$\bar{1}$·833 7746	0·373 3653	·000 0034	
1	·834 5719	·373 3686	101	·000 0068
2	·836 9652	·373 3787	169	67
3	·840 9592	·373 3956	236	67
4	·846 5615	·373 4192	303	67
5	·853 7829	·373 4494	369	67
6	·862 6374	·373 4864	435	66
7	·873 1421	·373 5299	501	66
8	·885 3174	·373 5800	566	65
9	·899 1873	·373 6365	630	65
10	·914 7789	·373 6995	694	64
11	·932 1233	·373 7689	756	63
12	·951 2549	·373 8445	818	62
13	·972 2124	·373 9263	879	61
14	·995 0382	·374 0142	938	60
15	0·019 7792	·374 1081	997	59
16	·046 4865	·374 2078	1055	58
17	·075 2161	·374 3132	1111	56
18	·106 0288	·374 4243	1166	55
19	·138 9908	·374 5409	1219	53
20	·174 1737	·374 6628	1271	52
21	·211 6551	·374 7899	1322	51
22	·251 5187	·374 9221	1370	49
23	·293 8552	·375 0591	1417	47
24	·338 7623	·375 2008	1464	46
25	·386 3455	·375 3472	1506	43
26	·436 7186	·375 4978	1549	42
27	·490 0042	·375 6527	1589	40
28	·546 3346	·375 8115	1627	38
29	·605 8526	·375 9742	1663	36
30	·668 7120	·376 1405	1697	34
31	·735 0790	·376 3102	1729	32
32	·805 1331	·376 4831	1759	30
33	·879 0680	·376 6589	1787	28
34	·957 0932	·376 8376	1812	26
35	1·039 4354	·377 0188	1836	23
36	·126 3402	·377 2024	1857	21
37	·218 0735	·377 3881	1876	19
38	·314 9240	·377 5757	1893	17
39	·417 2053	·377 7649	1907	14
40	·525 2583	·377 9556	1919	12
41	·639 4542	·378 1475	1928	10
42	·760 1977	·378 3403	1936	7
43	·887 9308	·378 5338	1941	5
44	2·023 1367	·378 7279	1943	2
45	·166 3448	·378 9222		

ϕ°	$r = 14$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·818 2772	0·375 2489		
1	·819 1404	·375 2520	·000 0031	·000 0063
2	·821 7316	·375 2614	94	63
3	·826 0558	·375 2771	157	62
4	·832 1212	·375 2990	219	62
5	·839 9395	·375 3271	281	62
6	·849 5258	·375 3614	343	61
7	·860 8985	·375 4019	404	61
8	·874 0798	·375 4484	465	60
9	·889 0954	·375 5010	526	60
10	·905 9746	·375 5595	585	59
11	·924 7510	·375 6239	644	58
12	·945 4618	·375 6942	703	57
13	·968 1485	·375 7702	760	56
14	·992 8571	·375 8518	816	55
15	0·019 6382	·375 9390	872	54
16	·048 5469	·376 0317	926	53
17	·079 6435	·376 1297	980	52
18	·112 9939	·376 2329	1032	51
19	·148 6693	·376 3412	1083	50
20	·186 7470	·376 4544	1133	48
21	·227 3107	·376 5725	1181	47
22	·270 4509	·376 6952	1228	45
23	·316 2653	·376 8225	1273	44
24	·364 8594	·376 9542	1317	42
25	·416 3469	·377 0901	1359	40
26	·470 8506	·377 2301	1399	39
27	·528 5029	·377 3739	1439	37
28	·589 4465	·377 5215	1476	35
29	·653 8352	·377 6726	1511	33
30	·721 8353	·377 8270	1544	32
31	·793 6258	·377 9846	1576	30
32	·869 4003	·378 1452	1606	28
33	·949 3679	·378 3085	1634	26
34	1·033 7545	·378 4745	1659	24
35	·122 8047	·378 6428	1683	22
36	·216 7831	·378 8133	1705	19
37	·315 9768	·378 9857	1724	18
38	·420 6970	·379 1599	1742	15
39	·531 2818	·379 3356	1757	13
40	·648 0989	·379 5127	1771	11
41	·771 5487	·379 6909	1782	9
42	·902 0674	·379 8699	1791	7
43	2·040 1318	·380 0497	1797	5
44	·186 2627	·380 2299	1802	2
45	·341 0309	·380 4103	1804	

$\phi°$	$r = 15$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·803 8114	0·376 8754	·000 0029	
1	·804 7405	·376 8783	88	·000 0059
2	·807 5297	·376 8871	146	58
3	·812 1842	·376 9018	205	58
4	·818 7130	·376 9222	262	58
5	·827 1285	·376 9485	321	58
6	·837 4469	·376 9805	378	57
7	·849 6881	·377 0183	435	57
8	·863 8758	·377 0617	491	56
9	·880 0376	·377 1108	547	56
10	·898 2051	·377 1655	602	55
11	·918 4141	·377 2256	656	54
12	·940 7047	·377 2912	710	54
13	·965 1215	·377 3622	762	53
14	·991 7138	·377 4384	814	52
15	0·020 5357	·377 5199	865	51
16	·051 6467	·377 6064	915	50
17	·085 1115	·377 6979	964	49
18	·121 0005	·377 7942	1011	48
19	·159 3904	·377 8953	1057	46
20	·200 3641	·378 0011	1102	45
21	·244 0113	·378 1113	1146	44
22	·290 4293	·378 2259	1189	43
23	·339 7229	·378 3448	1229	41
24	·392 0053	·378 4677	1269	39
25	·447 3985	·378 5946	1307	38
26	·506 0343	·378 7252	1343	36
27	·568 0547	·378 8595	1377	34
28	·633 6129	·378 9973	1411	33
29	·702 8740	·379 1383	1442	31
30	·776 0162	·379 2825	1471	30
31	·853 2318	·379 4296	1499	28
32	·934 7285	·379 5795	1525	26
33	1·020 7304	·379 7320	1549	24
34	·111 4801	·379 8869	1571	22
35	·207 2399	·380 0440	1591	20
36	·308 2938	·380 2031	1610	18
37	·414 9495	·380 3641	1626	17
38	·527 5412	·380 5267	1640	14
39	·646 4313	·380 6907	1653	12
40	·772 0144	·380 8560	1663	11
41	·904 7199	·381 0223	1671	8
42	2·045 0157	·381 1894	1678	6
43	·193 4131	·381 3572	1682	4
44	·350 4709	·381 5254	1684	2
45	·516 8011	·381 6938		

$\phi°$	$r = 16$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·790 2485	0·378 2941	·000 0028	
1	·791 2436	·378 2969	82	·000 0055
2	·794 2308	·378 3051	137	55
3	·799 2158	·378 3188	192	55
4	·806 2081	·378 3380	246	54
5	·815 2211	·378 3626	300	54
6	·826 2719	·378 3927	354	54
7	·839 3819	·378 4281	408	53
8	·854 5764	·378 4688	460	53
9	·871 8848	·378 5149	513	52
10	·891 3410	·378 5661	564	52
11	·912 9831	·378 6226	615	51
12	·936 8541	·378 6841	666	50
13	·963 0016	·378 7507	715	49
14	·991 4782	·378 8222	764	49
15	·022 3418	·378 8985	811	48
16	·055 6559	·378 9796	858	47
17	·091 4895	·379 0654	904	46
18	·129 9181	·379 1558	948	45
19	·171 0234	·379 2506	992	43
20	·214 8939	·379 3498	1034	42
21	·261 6258	·379 4532	1075	41
22	·311 3226	·379 5606	1114	40
23	·364 0964	·379 6721	1153	38
24	·420 0681	·379 7874	1190	37
25	·479 3681	·379 9063	1225	35
26	·542 1372	·380 0289	1259	34
27	·608 5269	·380 1548	1292	33
28	·678 7007	·380 2839	1323	31
29	·752 8356	·380 4162	1352	29
30	·831 1213	·380 5514	1380	28
31	·913 7633	·380 6893	1405	26
32	1·000 9834	·380 8299	1430	24
33	·093 0211	·380 9729	1452	23
34	·190 1352	·381 1181	1473	21
35	·292 6060	·381 2654	1492	19
36	·400 7368	·381 4146	1509	17
37	·514 8561	·381 5655	1525	15
38	·635 3206	·381 7180	1538	13
39	·762 5175	·381 8718	1549	12
40	·896 8681	·382 0267	1559	10
41	2·038 8307	·382 1826	1567	8
42	·188 9051	·382 3393	1573	6
43	·347 6370	·382 4966	1577	4
44	·515 6232	·382 6543	1579	2
45	·693 5170	·382 8122		

$\phi°$	$r = 17$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	1·777 4825	0·379 5425	·000 0026	
1	·778 5436	·379 5450	78	·000 0052
2	·781 7289	·379 5528	129	52
3	·787 0445	·379 5657	181	51
4	·794 5004	·379 5838	232	51
5	·804 1110	·379 6070	283	51
6	·815 8945	·379 6352	333	51
7	·829 8736	·379 6686	384	50
8	·846 0751	·379 7070	433	50
9	·864 5306	·379 7503	483	49
10	·885 2758	·379 7986	531	49
11	·908 3516	·379 8517	579	48
12	·933 8035	·379 9096	627	47
13	·961 6821	·379 9723	673	47
14	·992 0436	·380 0396	719	46
15	0·024 9495	·380 1115	764	45
16	·060 4672	·380 1878	808	44
17	·098 6704	·380 2686	851	43
18	·139 6392	·380 3537	893	42
19	·183 4606	·380 4430	933	41
20	·230 2288	·380 5363	973	40
21	·280 0460	·380 6336	1012	39
22	·333 0225	·380 7348	1049	37
23	·389 2774	·380 8397	1085	36
24	·448 9393	·380 9482	1120	35
25	·512 1471	·381 0602	1153	33
26	·579 0504	·381 1756	1185	32
27	·649 8104	·381 2941	1216	31
28	·724 6013	·381 4157	1245	29
29	·803 6106	·381 5402	1273	28
30	·887 0408	·381 6674	1299	26
31	·975 1103	·381 7973	1323	24
32	1·068 0549	·381 9296	1346	23
33	·166 1294	·382 0642	1367	21
34	·269 6092	·382 2009	1387	20
35	·378 7922	·382 3395	1404	18
36	·494 0009	·382 4800	1420	16
37	·615 5849	·382 6220	1435	14
38	·743 9235	·382 7655	1448	13
39	·879 4285	·382 9102	1458	11
40	2·022 5477	·383 0561	1468	9
41	·173 7686	·383 2028	1475	7
42	·333 6229	·383 3503	1480	6
43	·502 6906	·383 4984	1484	4
44	·681 6063	·383 6468	1486	2
45	·871 0649	·383 7953		

φ°	$r = 18$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·765 4249	0·380 6494	·000 0024	
1	·766 5520	·380 6518	73	·000 0049
2	·769 9355	·380 6591	122	49
3	·775 5818	·380 6713	171	49
4	·783 5015	·380 6884	219	48
5	·793 7099	·380 7103	267	48
6	·806 2262	·380 7370	315	48
7	·821 0746	·380 7685	362	47
8	·838 2835	·380 8048	409	47
9	·857 8863	·380 8457	456	47
10	·879 9209	·380 8913	502	46
11	·904 4307	·380 9415	547	45
12	·931 4638	·380 9962	592	45
13	·961 0741	·381 0554	636	44
14	·993 3209	·381 1190	679	43
15	0·028 2696	·381 1869	722	42
16	·065 9915	·381 2591	763	42
17	·106 5648	·381 3354	804	41
18	·150 0744	·381 4157	843	40
19	·196 6125	·381 5001	882	39
20	·246 2790	·381 5882	919	38
21	·299 1823	·381 6802	956	36
22	·355 4391	·381 7757	991	35
23	·415 1758	·381 8749	1025	34
24	·478 5288	·381 9774	1058	33
25	·545 6451	·382 0832	1089	31
26	·616 6833	·382 1921	1120	30
27	·691 8145	·382 3041	1148	29
28	·771 2230	·382 4189	1176	27
29	·855 1078	·382 5365	1202	26
30	·943 6834	·382 6567	1227	25
31	1·037 1813	·382 7794	1249	23
32	·135 8513	·382 9043	1271	22
33	·239 9636	·383 0314	1291	20
34	·349 8099	·383 1605	1310	19
35	·465 7060	·383 2915	1326	17
36	·587 9937	·383 4241	1342	15
37	·717 0435	·383 5583	1355	14
38	·853 2571	·383 6938	1367	12
39	·997 0711	·383 8305	1377	10
40	2·148 9600	·383 9683	1386	9
41	·309 4403	·384 1069	1393	7
42	·479 0754	·384 2462	1398	5
43	·658 4799	·384 3860	1402	4
44	·848 3263	·384 5262	1403	2
45	3·049 3507	·384 6665		

ϕ°	$r=19$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·754 0014	0·381 6376	·000 0023	
1	·755 1945	·381 6399	70	·000 0046
2	·758 7762	·381 6469	116	46
3	·764 7532	·381 6584	162	46
4	·773 1369	·381 6746	208	46
5	·783 9431	·381 6954	253	46
6	·797 1925	·381 7207	299	45
7	·812 9104	·381 7505	343	45
8	·831 1269	·381 7849	388	45
9	·851 8772	·381 8237	432	44
10	·875 2015	·381 8669	476	44
11	·901 1455	·381 9144	519	43
12	·929 7603	·381 9663	561	42
13	·961 1026	·382 0224	603	42
14	·995 2351	·382 0826	643	41
15	0·032 2269	·382 1470	684	40
16	·072 1535	·382 2154	723	39
17	·115 0974	·382 2877	761	38
18	·161 1483	·382 3638	799	38
19	·210 4036	·382 4437	836	37
20	·262 9690	·382 5273	871	36
21	·318 9588	·382 6144	906	35
22	·378 4966	·382 7049	939	33
23	·441 7157	·382 7988	971	32
24	·508 7603	·382 8960	1002	31
25	·579 7858	·382 9962	1032	30
26	·654 9597	·383 0994	1061	29
27	·734 4627	·383 2055	1088	27
28	·818 4896	·383 3143	1114	26
29	·907 2506	·383 4257	1139	25
30	1·000 9723	·383 5396	1162	23
31	·099 8993	·383 6558	1184	22
32	·204 2956	·383 7742	1204	20
33	·314 4464	·383 8946	1223	19
34	·430 6601	·384 0170	1241	17
35	·553 2702	·384 1411	1257	16
36	·682 6377	·384 2667	1271	14
37	·819 1539	·384 3938	1284	13
38	·963 2435	·384 5222	1295	11
39	2·115 3673	·384 6518	1305	10
40	·276 0267	·384 7823	1313	8
41	·445 7673	·384 9136	1320	7
42	·625 1841	·385 0455	1324	5
43	·814 9263	·385 1780	1328	3
44	3·015 7041	·385 3108	1330	2
45	·228 2952	·385 4437		

ϕ°	$r = 20$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·743 1485	0·382 5253	·000 0022	
1	·744 4077	·382 5275	66	·000 0044
2	·748 1876	·382 5341	110	44
3	·754 4955	·382 5451	154	44
4	·763 3431	·382 5605	197	44
5	·774 7474	·382 5802	241	43
6	·788 7299	·382 6042	284	43
7	·805 3174	·382 6326	327	43
8	·824 5417	·382 6652	369	42
9	·846 4398	·382 7021	411	42
10	·871 0541	·382 7432	452	41
11	·898 4326	·382 7883	493	41
12	·928 6293	·382 8376	533	40
13	·961 7039	·382 8909	573	40
14	·997 7224	·382 9482	611	39
15	0·036 7574	·383 0093	650	39
16	·078 8894	·383 0743	687	37
17	·124 2043	·383 1430	724	37
18	·172 7969	·383 2153	759	36
19	·224 7699	·383 2912	794	35
20	·280 2346	·383 3706	828	34
21	·339 3115	·383 4534	860	33
22	·402 1306	·383 5394	892	32
23	·468 8327	·383 6286	923	31
24	·539 5695	·383 7209	952	30
25	·614 5047	·383 8162	981	28
26	·693 8148	·383 9142	1008	27
27	·777 6902	·384 0150	1034	26
28	·866 3362	·384 1184	1059	25
29	·959 9740	·384 2243	1082	23
30	1·058 8424	·384 3325	1104	22
31	·163 1992	·384 4429	1125	21
32	·273 3224	·384 5554	1144	19
33	·389 5124	·384 6698	1162	18
34	·512 0941	·384 7860	1179	17
35	·641 4188	·384 9039	1194	15
36	·777 8668	·385 0233	1208	14
37	·921 8503	·385 1440	1220	12
38	2·073 8165	·385 2660	1231	11
39	·234 2509	·385 3891	1240	9
40	·403 6815	·385 5130	1247	8
41	·582 6831	·385 6378	1254	6
42	·771 8822	·385 7632	1258	5
43	·971 9629	·385 8890	1261	3
44	3·183 6730	·386 0151	1263	2
45	·407 8314	·386 1414		

$\phi°$	$r=21$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·732 8121	0·383 3271	·000 0021	
1	·734 1352	·383 3292	63	·000 0042
2	·738 1155	·383 3354	105	42
3	·744 7542	·383 3459	146	42
4	·754 0660	·383 3606	188	41
5	·766 0683	·383 3793	229	41
6	·780 7641	·383 4022	270	41
7	·798 2414	·383 4293	311	41
8	·818 4736	·383 4604	351	40
9	·841 5196	.383 4955	391	40
10	·867 4241	·383 5346	430	39
11	·896 2374	.383 5776	469	39
12	·928 0162	·383 6245	508	38
13	·962 8233	·383 6753	545	38
14	0·000 7283	·383 7299	582	37
15	·041 8074	·383 7881	619	36
16	·086 1444	·383 8500	654	36
17	·133 8306	·383 9154	689	35
18	·184 9653	·383 9843	723	34
19	·239 6563	·384 0566	756	33
20	·298 0208	·384 1322	788	32
21	·360 1851	·384 2111	820	31
22	·426 2861	·384 2930	850	30
23	·496 4716	·384 3780	879	29
24	·570 9011	·384 4659	907	28
25	·649 7464	·384 5566	934	27
26	·733 1933	·384 6500	960	26
27	·821 4416	·384 7460	985	25
28	·914 7070	·384 8445	1008	23
29	1·013 2222	·384 9453	1031	22
30	·117 2380	·385 0484	1052	21
31	·227 0250	·385 1535	1071	20
32	·342 8756	·385 2607	1090	18
33	·465 1055	·385 3696	1107	17
34	·594 0558	385 4803	1123	16
35	·730 0957	·385 5926	1137	14
36	·873 6248	·385 7063	1150	13
37	2·025 0761	·385 8213	1162	12
38	·184 9195	·385 9375	1172	10
39	·353 6651	·386 0547	1181	9
40	·531 8676	·386 1728	1188	7
41	·720 1308	·386 2916	1194	6
42	·919 1130	·386 4110	1198	4
43	3·129 5327	·386 5308	1201	3
44	·352 1756	·386 6510	1203	2
45	·587 9021	·386 7712		

ϕ°	$r=22$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·722 9451	0·384 0548	·000 0020	
1	·724 3364	·384 0568	60	·000 0040
2	·728 5130	·384 0628	100	40
3	·735 4826	·384 0728	140	40
4	·745 2584	·384 0867	179	40
5	·757 8590	·384 1047	219	39
6	·773 3082	·384 1266	258	39
7	·791 6354	·384 1523	297	39
8	·812 8757	·384 1820	335	38
9	·837 0698	·384 2155	373	38
10	·864 2646	·384 2529	411	38
11	·894 5129	·384 2940	448	37
12	·927 8740	·384 3388	485	37
13	·964 4139	·384 3872	521	36
14	0·004 2054	·384 4393	556	35
15	·047 3287	·384 4949	591	35
16	·093 8713	·384 5540	625	34
17	·143 9291	·384 6164	658	33
18	·197 6061	·384 6822	690	32
19	·255 0156	·384 7513	722	31
20	·316 2801	·384 8235	753	31
21	·381 5322	·384 8987	782	30
22	·450 9155	·384 9770	811	29
23	·524 5848	·385 0581	839	28
24	·602 7073	·385 1420	866	27
25	·685 4632	·385 2286	892	26
26	·773 0472	·385 3178	916	25
27	·865 6689	·385 4094	940	24
28	·963 5543	·385 5034	962	22
29	1·066 9472	·385 5996	984	21
30	·176 1108	·385 6980	1004	20
31	·291 3286	·385 7984	1023	19
32	·412 9072	·385 9007	1040	18
33	·541 1773	·386 0047	1057	16
34	·676 4967	·386 1104	1072	15
35	·819 2523	·386 2175	1085	14
36	·969 8630	·386 3261	1098	12
37	2·128 7827	·386 4359	1109	11
38	·296 5039	·386 5468	1119	10
39	·473 5612	·386 6586	1127	8
40	·660 5361	·386 7713	1134	7
41	·858 0615	·386 8848	1140	6
42	3·066 8272	·386 9987	1144	4
43	·287 5865	·387 1131	1147	3
44	·521 1629	·387 2278	1148	1
45	·768 4580	·387 3426		

ϕ°	$r = 23$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·713 5069	0·384 7182	·000 0019	
1	·714 9643	·384 7202	57	·000 0038
2	·719 3391	·384 7259	96	38
3	·726 6397	·384 7355	134	38
4	·736 8798	·384 7488	172	38
5	·750 0786	·384 7660	209	38
6	·766 2613	·384 7869	247	37
7	·785 4585	·384 8116	284	37
8	·807 7070	·384 8400	321	37
9	·833 0493	·384 8721	357	36
10	·861 5346	·384 9078	393	36
11	·893 2180	·384 9471	429	36
12	·928 1617	·384 9899	464	35
13	·966 4346	·385 0363	498	34
14	0·008 1129	·385 0861	532	34
15	·053 2804	·385 1393	565	33
16	·102 0289	·385 1958	598	33
17	·154 4586	·385 2556	629	32
18	·210 6783	·385 3185	660	31
19	·270 8064	·385 3845	691	30
20	·334 9713	·385 4536	720	29
21	·403 3116	·385 5256	748	28
22	·475 9774	·385 6004	776	28
23	·553 1308	·385 6780	803	27
24	·634 9466	·385 7583	828	26
25	·721 6136	·385 8411	853	25
26	·813 3351	·385 9264	877	24
27	·910 3304	·386 0141	899	23
28	1·012 8362	·386 1040	921	22
29	·121 1074	·386 1961	941	20
30	·235 4191	·386 2902	960	19
31	·356 0681	·386 3862	978	18
32	·483 3750	·386 4840	995	17
33	·617 6859	·386 5836	1011	16
34	·759 3748	·386 6846	1025	14
35	·908 8466	·386 7871	1038	13
36	2·066 5394	·386 8910	1050	12
37	·232 9279	·386 9960	1061	11
38	·408 5272	·387 1021	1070	10
39	·593 8968	·387 2091	1078	8
40	·789 6446	·387 3169	1085	7
41	·996 4325	·387 4254	1090	5
42	3·214 9823	·387 5344	1094	4
43	·446 0817	·387 6438	1097	3
44	·690 5919	·387 7535	1098	1
45	·949 4561	·387 8633		

ϕ°	$r=24$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·704 4618	0·385 3256	·000 0018	
1	·705 9852	·385 3275	55	·000 0037
2	·710 5584	·385 3330	92	37
3	·718 1899	·385 3421	128	36
4	·728 8942	·385 3549	164	36
5	·742 6914	·385 3714	201	36
6	·759 6077	·385 3915	236	36
7	·779 6750	·385 4151	272	36
8	·802 9317	·385 4423	307	35
9	·829 4225	·385 4730	342	35
10	·859 1983	·385 5073	377	34
11	·892 3170	·385 5450	411	34
12	·928 8434	·385 5860	444	34
13	·968 8495	·385 6305	477	33
14	0·012 4148	·385 6782	510	32
15	·059 6268	·385 7292	542	32
16	·110 5814	·385 7834	573	31
17	·165 3831	·385 8406	603	30
18	·224 1458	·385 9009	633	30
19	·286 9928	·385 9642	662	29
20	·354 0583	·386 0304	690	28
21	·425 4870	·386 0994	717	27
22	·501 4356	·386 1711	744	26
23	·582 0734	·386 2455	769	26
24	·667 5830	·386 3225	794	25
25	·758 1612	·386 4018	818	24
26	·854 0205	·386 4836	840	23
27	·955 3899	·386 5676	862	22
28	1·062 5163	·386 6538	882	21
29	·175 6661	·386 7420	902	19
30	·295 1263	·386 8322	920	18
31	·421 2069	·386 9242	938	17
32	·554 2426	·387 0180	954	16
33	·694 5945	·387 1134	969	15
34	·842 6534	·387 2102	982	14
35	·998 8417	·387 3085	995	13
36	2·163 6169	·387 4080	1006	11
37	·337 4747	·387 5086	1017	10
38	·520 9526	·387 6103	1026	9
39	·714 6347	·387 7128	1033	8
40	·919 1558	·387 8162	1040	6
41	3·135 2068	·387 9201	1045	5
42	·363 5411	·388 0246	1048	3
43	·604 9809	·388 1295	1051	3
44	·860 4254	·888 2346	1052	1
45	4·130 8591	·388 3398		

ϕ°	$r=25$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·695 7781	0·385 8838	·000 0018	
1	·697 3659	·385 8855	53	·000 0035
2	·702 1393	·385 8908	88	35
3	·710 1019	·385 8996	123	35
4	·721 2704	·385 9119	158	35
5	·735 6660	·385 9277	193	35
6	·753 3158	·385 9470	227	35
7	·774 2534	·385 9697	261	34
8	·798 5185	·385 9958	295	34
9	·826 1578	·386 0253	329	34
10	·857 2243	·386 0582	362	33
11	·891 7784	·386 0943	394	33
12	·929 8876	·386 1338	427	32
13	·971 6270	·386 1764	458	32
14	0·017 0795	·386 2223	489	31
15	·066 3362	·386 2712	520	31
16	·119 4971	·386 3232	550	30
17	·176 6711	·386 3782	579	29
18	·237 9768	·386 4361	608	29
19	·303 5430	·386 4969	635	28
20	·373 5093	·386 5604	662	27
21	·448 0267	·386 6267	689	26
22	·527 2584	·386 6955	714	25
23	·611 3809	·386 7669	739	25
24	·700 5843	·386 8408	762	24
25	·795 0741	·386 9170	785	23
26	·895 0715	·386 9955	807	22
27	1·000 8153	·387 0762	827	21
28	·112 5627	·387 1589	847	20
29	·230 5913	·387 2436	866	19
30	·355 2004	·387 3302	883	18
31	·486 7129	·387 4185	900	17
32	·625 4776	·387 5085	916	16
33	·771 8709	·387 6001	930	14
34	·926 3001	·387 6931	943	13
35	2·089 2053	·387 7874	955	12
36	·261 0633	·387 8829	966	11
37	·442 3906	·387 9795	976	10
38	·633 7476	·388 0771	985	9
39	·835 7426	·388 1756	992	7
40	3·049 0373	·388 2748	998	6
41	·274 3517	·388 3746	1003	5
42	·512 4708	·388 4749	1007	4
43	·764 2515	·388 5756	1009	2
44	4·030 6307	·388 6765	1010	1
45	·312 6342	·388 7775		

$\phi°$	$r=26$			
	og F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·687 4284	0·386 3984	·000 0017	
1	·689 0840	·386 4001	51	·000 0034
2	·694 0540	·386 4052	85	34
3	·702 3476	·386 4136	118	34
4	·713 9805	·386 4254	152	34
5	·728 9746	·386 4406	185	33
6	·747 3581	·386 4591	218	33
7	·769 1658	·386 4810	251	33
8	·794 4395	·386 5061	284	33
9	·823 2272	·386 5345	316	32
10	·855 5847	·386 5661	348	32
11	·891 5743	·386 6009	379	31
12	·931 2665	·386 6388	411	31
13	·974 7393	·386 6798	440	30
14	0·022 0791	·386 7239	471	30
15	·073 3806	·386 7710	500	29
16	·128 7480	·386 8210	529	29
17	·188 2945	·386 8738	557	28
18	·252 1435	·386 9295	584	27
19	·320 4290	·386 9880	611	27
20	·393 2963	·387 0491	637	26
21	·470 9025	·387 1128	662	25
22	·553 4176	·387 1790	687	24
23	·641 0250	·387 2477	710	24
24	·733 9226	·387 3187	733	23
25	·832 3242	·387 3920	755	22
26	·936 4600	·387 4674	776	21
27	1·046 5783	·387 5450	796	20
28	·162 9470	·387 6246	815	19
29	·285 8547	·387 7060	833	18
30	·415 6129	·387 7893	850	17
31	·552 5576	·387 8742	865	16
32	·697 0516	·387 9608	880	15
33	·849 4867	·388 0488	894	14
34	2·010 2864	·388 1382	907	13
35	·179 9088	·388 2289	919	12
36	·358 8499	·388 3208	929	11
37	·547 6471	·388 4137	938	9
38	·746 8833	·388 5075	947	8
39	·957 1916	·388 6022	954	7
40	3·179 2602	·388 6975	960	6
41	·413 8384	·388 7935	964	5
42	·661 7426	·388 8900	968	4
43	·923 8647	·388 9868	970	2
44	4·201 1786	·389 0838	972	1
45	·494 7524	·389 1810		

ϕ°	$r = 27$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·679 3877	0·386 8744	·000 0016	
1	·681 1094	·386 8760	49	·000 0033
2	·686 2778	·386 8809	81	33
3	·694 9025	·386 8891	114	32
4	·706 9998	·386 9005	146	32
5	·722 5923	·386 9151	178	32
6	·741 7096	·386 9329	210	32
7	·764 3877	·386 9539	242	32
8	·790 6698	·386 9781	273	31
9	·820 6063	·387 0055	304	31
10	·854 2546	·387 0359	335	31
11	·891 6799	·387 0694	365	30
12	·932 9552	·387 1059	395	30
13	·978 1615	·387 1454	424	29
14	0·027 3887	·387 1879	453	29
15	·080 7353	·387 2332	482	28
16	·138 3092	·387 2814	509	28
17	·200 2283	·387 3323	536	27
18	·266 6208	·387 3859	563	26
19	·337 6258	·387 4422	588	26
20	·413 3944	·387 5010	613	25
21	·494 0896	·387 5624	638	24
22	·579 8882	·387 6261	661	24
23	·670 9806	·387 6923	684	23
24	·767 5727	·387 7607	706	22
25	·869 8863	·387 8312	727	21
26	·978 1616	·387 9039	747	20
27	1·092 6538	·387 9786	766	19
28	·213 6439	·388 0552	784	18
29	·341 4310	·388 1337	802	17
30	·476 3386	·388 2138	818	16
31	·618 7157	·388 2956	833	15
32	·768 9393	·388 3790	848	14
33	·927 4164	·388 4638	861	13
34	2·094 5869	·388 5499	873	12
35	·270 9268	·388 6372	885	11
36	·456 9512	·388 7257	895	10
37	·653 2186	·388 8151	904	9
38	·860 3344	·388 9055	912	8
39	3·078 9562	·388 9967	918	7
40	·309 7991	·389 0885	924	6
41	·553 6412	·389 1809	929	5
42	·811 3309	·389 2738	932	3
43	4·083 7948	·389 3670	934	2
44	·372 0436	·389 4604	936	1
45	·677 1878	·389 5540		

ϕ°	$r = 28$			
	$\log F(r, \nu)$	$\log H(r, \nu)$	$\Delta \log H(r, \nu)$	$\Delta^2 \log H(r, \nu)$
0	$\bar{1}$·671 6341	0·387 3160		
			·000 0016	
1	·673 4219	·387 3176		·000 0031
			47	
2	·678 7887	·387 3223		31
			79	
3	·687 7445	·387 3301		31
			110	
4	·700 3062	·387 3411		31
			141	
5	·716 4973	·387 3552		31
			172	
6	·736 3483	·387 3724		31
			203	
7	·759 8968	·387 3927		30
			233	
8	·787 1876	·387 4160		30
			264	
9	·818 2728	·387 4424		30
			293	
10	·853 2121	·387 4717		30
			323	
11	·892 0731	·387 5041		29
			352	
12	·934 9315	·387 5393		29
			381	
13	·981 8715	·387 5774		28
			409	
14	0·032 9863	·387 6183		28
			437	
15	·088 3780	·387 6620		27
			464	
16	·148 1586	·387 7084		27
			491	
17	·212 4505	·387 7576		26
			517	
18	·281 3865	·387 8093		25
			543	
19	·355 1112	·387 8635		25
			567	
20	·433 7811	·387 9203		24
			592	
21	·517 5657	·387 9794		23
			615	
22	·606 6479	·388 0409		23
			638	
23	·701 2256	·388 1047		22
			660	
24	·801 5122	·388 1706		21
			681	
25	·907 7380	·388 2387		20
			701	
26	1·020 1512	·388 3088		19
			720	
27	·139 0194	·388 3808		18
			739	
28	·264 6312	·388 4547		18
			756	
29	·397 2979	·388 5303		17
			773	
30	·537 3550	·388 6077		16
			789	
31	·685 1648	·388 6865		15
			804	
32	·841 1182	·388 7669		14
			818	
33	2·005 6375	·388 8487		13
			830	
34	·179 1790	·388 9317		12
			842	
35	·362 2366	·389 0159		11
			853	
36	·555 3447	·389 1012		10
			863	
37	·759 0825	·389 1875		9
			872	
38	·974 0781	·389 2746		7
			879	
39	3·201 0137	·389 3625		7
			886	
40	·440 6310	·389 4511		5
			891	
41	·693 7374	·389 5402		4
			896	
42	·961 2127	·389 6298		3
			899	
43	4·244 0178	·389 7197		2
			901	
44	·543 2028	·389 8098		1
			902	
45	·859 9176	·389 9000		

ϕ°	$r=29$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·664 1478	0·387 7268	·000 0015	
1	·666 0017	·387 7283	46	·000 0030
2	·671 5669	·387 7328	76	30
3	·680 8538	·387 7404	106	30
4	·693 8799	·387 7510	136	30
5	·710 6695	·387 7647	166	30
6	·731 2544	·387 7813	196	30
7	·755 6734	·387 8008	225	30
8	·783 9728	·387 8234	254	29
9	·816 2068	·387 8488	283	29
10	·852 4372	·387 8772	312	29
11	·892 7340	·387 9084	340	28
12	·937 1757	·387 9424	368	28
13	·985 8495	·387 9792	395	27
14	0·038 8519	·388 0187	422	27
15	·096 2888	·388 0609	448	26
16	·158 2763	·388 1057	474	26
17	·224 9410	·388 1531	499	25
18	·296 4208	·388 2031	524	25
19	·372 8653	·388 2555	548	24
20	·454 4367	·388 3103	571	23
21	·541 3106	·388 3674	594	23
22	·633 6767	·388 4268	616	22
23	·731 7398	·388 4883	637	21
24	·835 7212	·388 5520	657	20
25	·945 8594	·388 6177	677	20
26	1·062 4115	·388 6854	696	19
27	·185 6549	·388 7550	713	17
28	·315 8886	·388 8263	730	17
29	·453 4351	·388 8993	747	16
30	·598 6420	·388 9740	762	15
31	·751 8846	·389 0501	776	14
32	·913 5680	·389 1277	789	13
33	2·084 1297	·389 2067	802	12
34	·264 0426	·389 2868	813	11
35	·453 8181	·389 3682	824	10
36	·654 0100	·389 4505	833	9
37	·865 2184	·389 5338	841	8
38	3·088 0940	·389 6179	849	7
39	·323 3436	·389 7028	855	6
40	·571 7357	·389 7883	860	5
41	·834 1065	·389 8744	865	4
42	4·111 3678	·389 9608	868	3
43	·404 5148	·390 0476	870	2
44	·714 6355	·390 1346	871	1
45	5·042 9213	·390 2217		

φ°	r = 30			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ² log H (r, ν)
0	1·656 9109	0·388 1099	·000 0015	·000 0029
1	·658 8309	·388 1113	44	29
2	·664 5945	·388 1157	73	29
3	·674 2126	·388 1231	103	29
4	·687 7031	·388 1333	132	29
5	·705 0914	·388 1465	161	29
6	·726 4101	·388 1625	189	29
7	·751 6995	·388 1815	218	28
8	·781 0077	·388 2032	246	28
9	·814 3906	·388 2278	274	28
10	·851 9121	·388 2552	302	27
11	·893 6447	·388 2854	329	27
12	·939 6698	·388 3183	356	26
13	·990 0775	·388 3538	382	26
14	0·044 9676	·388 3920	408	25
15	·104 4498	·388 4328	433	25
16	·168 6443	·388 4762	458	24
17	·237 6820	·388 5220	483	24
18	·311 7056	·388 5703	507	23
19	·390 8701	·388 6209	530	22
20	·475 3432	·388 6739	552	22
21	·565 3065	·388 7291	574	21
22	·660 9566	·388 7865	595	20
23	·762 5053	·388 8460	616	20
24	·870 1816	·388 9076	635	19
25	·984 2323	·388 9711	654	18
26	1·104 9235	·389 0366	672	17
27	·232 5423	·389 1038	690	16
28	·367 3981	·389 1727	706	16
29	·509 8245	·389 2433	722	15
30	·660 1814	·389 3155	736	14
31	·818 8570	·389 3891	750	13
32	·986 2707	·389 4642	763	12
33	2·162 8749	·389 5405	775	11
34	·349 1593	·389 6180	786	10
35	·545 6529	·389 6966	796	9
36	·752 9288	·389 7762	805	8
37	·971 6080	·389 8567	813	7
38	3·202 3639	·389 9380	820	6
39	·445 9277	·390 0201	827	5
40	·703 0947	·390 1028	832	4
41	·974 7302	·390 1859	836	3
42	4·261 7776	·390 2695	839	2
43	·565 2668	·390 3534	841	1
44	·886 3234	·390 4375	842	
45	5·226 1804	·390 5217		

$\phi°$	$r = 31$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·649 9073	0·388 4679	·000 0014	
1	·651 8935	·388 4694	43	·000 0028
2	·657 8555	·388 4736	71	28
3	·667 8048	·388 4808	99	28
4	·681 7598	·388 4906	127	28
5	·699 7466	·388 5034	155	28
6	·721 7993	·388 5189	183	28
7	·747 9592	·388 5372	211	28
8	·778 2762	·388 5583	238	27
9	·812 8080	·388 5822	265	27
10	·851 6207	·388 6086	292	27
11	·894 7893	·388 6378	318	26
12	·942 3977	·388 6696	344	26
13	·994 5394	·388 7041	370	26
14	0·051 3173	·388 7410	395	25
15	·112 8450	·388 7805	419	25
16	·179 2464	·388 8225	444	24
17	·250 6573	·388 8668	467	23
18	·327 2249	·388 9136	490	23
19	·409 1093	·388 9626	513	22
20	·496 4842	·389 0138	534	22
21	·589 5372	·389 0673	556	21
22	·688 4714	·389 1228	576	20
23	·793 5058	·389 1804	596	20
24	·904 8771	·389 2400	615	19
25	1·022 8405	·389 3015	633	18
26	·147 6710	·389 3648	650	18
27	·279 6653	·389 4299	667	17
28	·419 1433	·389 4966	683	16
29	·566 4498	·389 5649	698	15
30	·721 9568	·389 6348	713	14
31	·886 0657	·389 7060	726	13
32	2·059 2096	·389 7786	738	13
33	·241 8567	·389 8525	750	12
34	·434 5127	·389 9275	761	11
35	·637 7246	·390 0035	770	10
36	·852 0847	·390 0806	779	9
37	3·078 2349	·390 1585	787	8
38	·316 8712	390 2372	794	7
39	·568 7494	·390 3166	800	6
40	·834 6915	·390 3966	805	5
41	4·115 5919	·390 4771	809	4
42	·412 4256	·390 5580	812	3
43	·726 2571	·390 6392	814	2
44	5·058 2499	·390 7206	815	1
45	·409 6782	·390 8021		

ϕ°	$r=32$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·643 1226	0·388 8034	·000 0014	
1	·645 1748	·388 8048	41	·000 0028
2	·651 3354	·388 8089	69	27
3	·661 6158	·388 8158	96	27
4	·676 0352	·388 8254	123	27
5	·694 6208	·388 8378	151	27
6	·717 4073	·388 8528	177	27
7	·744 4379	·388 8706	204	27
8	·775 7637	·388 8910	231	26
9	·811 4444	·388 9140	257	26
10	·851 5483	·388 9397	283	26
11	·896 1530	·388 9680	308	26
12	·945 3449	·388 9988	333	25
13	·999 2205	·389 0322	358	25
14	0·057 8864	·389 0680	383	24
15	·121 4595	·389 1062	406	24
16	·190 0681	·389 1469	430	23
17	·263 8522	·389 1899	453	23
18	·342 9638	·389 2351	475	22
19	·427 5684	·389 2826	497	22
20	·517 8452	·389 3323	518	21
21	·613 9879	·389 3840	538	20
22	·716 2063	·389 4379	558	20
23	·824 7266	·389 4937	577	19
24	·939 7929	·389 5514	596	19
25	1·061 6692	·389 6109	613	18
26	·190 6391	·389 6723	630	17
27	·327 0091	·389 7353	646	16
28	·471 1094	·389 8000	662	15
29	·623 2962	·389 8661	677	15
30	·783 9534	·389 9338	690	14
31	·953 4956	·390 0028	703	13
32	2·132 3701	·390 0732	715	12
33	·321 0601	·390 1447	727	11
34	·520 0879	·390 2174	737	10
35	·730 0183	·390 2911	746	9
36	·951 4628	·390 3657	755	9
37	3·185 0841	·390 4412	763	8
38	·431 6009	·390 5174	769	7
39	·691 7938	·390 5944	775	6
40	·966 5111	·390 6719	780	5
41	4·256 6765	·390 7498	784	4
42	·563 2967	·390 8282	787	3
43	·887 4707	·390 9069	789	2
44	5·230 3999	·390 9857	789	1
45	·593 3997	·391 0646		

$\phi°$	$r=33$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·636 5434	0·389 1183	·000 0013	
1	·638 6617	·389 1197	40	·000 0027
2	·645 0208	·389 1237	67	27
3	·655 6323	·389 1304	93	26
4	·670 5163	·389 1397	120	26
5	·689 7005	·389 1516	146	26
6	·713 2210	·389 1662	172	26
7	·741 1222	·389 1835	198	26
8	·773 4568	·389 2033	224	26
9	·810 2865	·389 2256	249	25
10	·851 6818	·389 2505	274	25
11	·897 7225	·389 2780	299	25
12	·948 4980	·389 3078	323	24
13	0·004 1077	·389 3402	347	24
14	·064 6615	·389 3749	371	24
15	·130 2802	·389 4120	394	23
16	·201 0960	·389 4514	417	23
17	·277 2533	·389 4931	439	22
18	·358 9091	·389 5370	461	22
19	·446 2340	·389 5830	482	21
20	·539 4127	·389 6312	502	20
21	·638 6453	·389 6814	522	20
22	·744 1480	·389 7336	541	19
23	·856 1542	·389 7877	560	19
24	·974 9160	·389 8437	578	18
25	1·100 7050	·389 9014	595	17
26	·233 8145	·389 9609	611	17
27	·374 5602	·390 0220	627	16
28	·523 2830	·390 0847	642	15
29	·680 3501	·390 1489	656	14
30	·846 1578	·390 2145	669	13
31	2·021 1335	·390 2815	682	13
32	·205 7387	·390 3497	693	12
33	·400 4717	·390 4190	705	11
34	·605 8714	·390 4895	715	10
35	·822 5204	·390 5610	724	9
36	3·051 0494	·390 6333	732	8
37	·292 1420	·390 7065	739	7
38	·546 5396	·390 7805	746	6
39	·815 0471	·390 8551	751	6
40	4·098 5399	·390 9302	756	5
41	·397 9704	·391 0058	760	4
42	·714 3773	·391 0818	763	3
43	5·048 3939	·391 1581	765	2
44	·402 7596	·391 2345	766	1
45	·777 3311	·391 3111		

ϕ°	$r=34$			
	log F (r, ν)	log. H (r, ν)	Δ log. H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·630 1576	0·389 4146	·000 0013	
1	·632 3421	·389 4159	39	·000 0026
2	·638 8996	·389 4198	65	26
3	·649 8424	·389 4262	91	26
4	·665 1908	·389 4353	116	26
5	·684 9738	·389 4469	142	26
6	·709 2283	·389 4611	167	25
7	·738 0001	·389 4778	192	25
8	·771 3436	·389 4970	217	25
9	·809 3225	·389 5187	242	25
10	·852 0090	·389 5429	266	24
11	·899 4858	·389 5695	290	24
12	·951 8449	·389 5985	314	24
13	0·009 1887	·389 6299	337	23
14	·071 6306	·389 6636	360	23
15	·139 2949	·389 6996	382	23
16	·212 3180	·389 7379	405	22
17	·290 8487	·389 7783	426	21
18	·375 0487	·389 8209	447	21
19	·465 0938	·389 8656	467	20
20	·561 1746	·389 9123	487	20
21	·663 4971	·389 9611	507	19
22	·772 2842	·390 0117	525	19
23	·887 7765	·390 0643	543	18
24	1·010 2336	·390 1186	561	17
25	·139 9357	·390 1746	577	17
26	·277 1848	·390 2324	593	16
27	·422 3065	·390 2917	609	15
28	·575 6518	·390 3525	623	14
29	·737 5995	·390 4148	637	14
30	·908 5576	·390 4785	650	13
31	2·088 9669	·390 5435	662	12
32	·279 3029	·390 6097	673	11
33	·480 0791	·390 6770	684	11
34	·691 8509	·390 7454	694	10
35	·915 2186	·390 8148	703	9
36	3·150 8322	·390 8850	711	8
37	·399 3963	·390 9561	718	7
38	·661 6747	·391 0278	724	6
39	·938 4971	·391 1002	729	5
40	4·230 7654	·391 1732	734	4
41	·539 4613	·391 2466	738	4
42	·865 6549	·391 3203	740	3
43	5·210 5144	·391 3943	742	2
44	·575 3166	·391 4686	743	1
45	·961 4600	·391 5429		

$\phi°$	$r = 35$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ² log H (r, ν)
0	1·623 9542	0·389 6937		
1	·626 2048	·389 6949	·000 0013	·000 0025
2	·632 9608	·389 6987	38	25
3	·644 2348	·389 7050	63	25
4	·660 0478	·389 7138	88	25
5	·680 4295	·389 7251	113	25
6	·705 4180	·389 7389	138	25
7	·735 0604	·389 7551	162	24
8	·769 4129	·389 7738	187	24
9	·808 5407	·389 7948	211	24
10	·852 5188	·389 8183	235	24
11	·901 4317	·389 8442	259	23
12	·955 3744	·389 8724	282	23
13	0·014 4525	·389 9029	305	23
14	·078 7824	·389 9356	328	22
15	·148 4925	·389 9706	350	22
16	·223 7229	·390 0078	372	21
17	·304 6270	·390 0471	393	21
18	·391 3713	·390 0884	414	20
19	·484 1369	·390 1319	434	20
20	·583 1198	·390 1773	454	19
21	·688 5323	·390 2246	473	19
22	·800 6039	·390 2738	492	18
23	·919 5823	·390 3248	510	17
24	1·045 7350	·390 3776	528	17
25	·179 3502	·390 4321	545	16
26	·320 7390	·390 4881	561	16
27	·470 2366	·390 5458	576	15
28	·628 2047	·390 6049	591	14
29	·795 0329	·390 6654	605	13
30	·971 1417	·390 7273	619	13
31	2·156 9847	·390 7904	631	12
32	·353 0516	·390 8547	643	11
33	·559 8711	·390 9201	654	10
34	·778 0150	·390 9865	664	9
35	3·008 1016	·391 0539	674	9
36	·250 8000	·391 1222	682	8
37	·506 8356	·391 1912	690	7
38	·776 9950	·391 2609	697	6
39	4·062 1324	·391 3312	703	5
40	·363 1764	·391 4021	709	4
41	·681 1377	·391 4734	713	4
42	5·017 1183	·391 5450	716	3
43	·372 3207	·391 6169	719	2
44	·748 0596	·391 6890	721	1
45	6·145 7749	·391 7612	722	

ϕ°	$r=36$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·617 9231	0·389 9572	·000 0012	
1	·620 2399	·389 9584	37	·000 0024
2	·627 1943	·389 9620	61	24
3	·638 7995	·389 9682	85	24
4	·655 0771	·389 9767	110	24
5	·676 0575	·389 9877	134	24
6	·701 7800	·390 0011	158	24
7	·732 2932	·390 0168	182	24
8	·767 6546	·390 0350	205	24
9	·807 9316	·390 0555	228	23
10	·853 2010	·390 0783	251	23
11	·903 5502	·390 1035	274	23
12	·959 0766	·390 1309	296	22
13	0·019 8889	·390 1605	318	22
14	·086 1070	·390 1924	340	22
15	·157 8628	·390 2264	361	21
16	·235 3007	·390 2625	382	21
17	·318 5782	·390 3007	402	20
18	·407 8669	·390 3409	422	20
19	·503 3529	·390 3832	441	19
20	·605 2380	·390 4273	460	19
21	·713 7407	·390 4733	478	18
22	·829 0968	·390 5212	496	18
23	·951 5615	·390 5708	513	17
24	1·081 4096	·390 6221	529	16
25	·218 9381	·390 6750	545	16
26	·364 4667	·390 7296	560	15
27	·518 3405	·390 7856	575	14
28	·680 9313	·390 8431	588	14
29	·852 6402	·390 9019	601	13
30	2·033 8997	·390 9621	614	12
31	·225 1766	·391 0234	625	12
32	·426 9744	·391 0859	636	11
33	·639 8374	·391 1495	646	10
34	·864 3536	·391 2141	655	9
35	3·101 1591	·391 2796	664	8
36	·350 9424	·391 3460	671	8
37	·614 4497	·391 4131	678	7
38	·892 4902	·391 4809	684	6
39	4·185 9427	·391 5492	689	5
40	·495 7624	·391 6181	693	4
41	·822 9894	·391 6874	697	3
42	5·168 7569	·391 7571	699	3
43	·534 3023	·391 8270	701	2
44	·920 9782	·391 8971	702	1
45	6·330 2655	·391 9673		

$\phi°$	$r=37$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 logH (r, ν)
0	$\bar{1}$·612 0550	0·390 2063	·000 0012	
1	·614 4378	·390 2074	36	·000 0024
2	·621 5908	·390 2110	60	24
3	·633 5272	·390 2170	83	24
4	·650 2694	·390 2253	107	24
5	·671 8485	·390 2360	130	23
6	·698 3051	·390 2490	154	23
7	·729 6890	·390 2643	177	23
8	·766 0594	·390 2820	200	23
9	·807 4855	·390 3020	222	23
10	·854 0464	·390 3242	245	22
11	·905 8318	·390 3486	267	22
12	·962 9420	·390 3753	288	22
13	0·025 4886	·390 4041	310	21
14	·093 5948	·390 4351	331	21
15	·167 3965	·390 4682	352	21
16	·247 0418	·390 5034	372	20
17	·332 6929	·390 5405	391	20
18	·424 5260	·390 5797	411	19
19	·522 7325	·390 6208	430	19
20	·627 5199	·390 6637	448	18
21	·739 1128	·390 7085	466	18
22	·857 7536	·390 7551	483	17
23	·983 7045	·390 8033	499	16
24	1·117 2483	·390 8532	515	16
25	·258 6900	·390 9048	530	15
26	·408 3585	·390 9578	545	15
27	·566 6085	·391 0123	559	14
28	·733 8222	·391 0682	573	13
29	·910 4119	·391 1255	585	13
30	2·096 8223	·391 1840	597	12
31	·293 5330	·391 2437	608	11
32	·501 0620	·391 3046	619	10
33	·719 9685	·391 3664	628	9
34	·950 8571	·391 4293	637	9
35	3·194 3816	·391 4930	646	8
36	·451 2499	·391 5576	653	7
37	·722 2290	·391 6229	659	6
38	4·008 1507	·391 6888	665	6
39	·309 9183	·391 7553	670	5
40	·628 5140	·391 8224	674	4
41	·965 0066	·391 8898	678	3
42	5·320 5613	·391 9576	680	3
43	·696 4499	·392 0256	682	2
44	6·094 0627	·392 0938	683	1
45	·514 9222	·392 1621		

ϕ°	$r = 38$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·606 3413	0·390 4421	·000 0012	
1	·608 7902	·390 4433	35	·000 0023
2	·616 1417	·390 4468	58	23
3	·628 4093	·390 4526	81	23
4	·645 6161	·390 4607	104	23
5	·667 7940	·390 4711	127	23
6	·694 9847	·390 4837	149	23
7	·727 2393	·390 4987	172	23
8	·764 6187	·390 5159	194	22
9	·807 1940	·390 5353	216	22
10	·855 0464	·390 5569	238	22
11	·908 2680	·390 5808	260	22
12	·966 9620	·390 6067	281	21
13	0·031 2429	·390 6348	302	21
14	·101 2374	·390 6650	322	20
15	·177 0849	·390 6972	342	20
16	·258 9378	·390 7314	362	20
17	·346 9624	·390 7676	381	19
18	·441 3400	·390 8057	400	19
19	·542 2671	·390 8457	418	18
20	·649 9569	·390 8876	436	18
21	·764 6400	·390 9312	453	17
22	·886 5655	·390 9765	470	17
23	1·016 0028	·391 0235	486	16
24	·153 2423	·391 0721	502	16
25	·298 5974	·391 1223	517	15
26	·452 4059	·391 1739	531	14
27	·615 0321	·391 2270	545	14
28	·786 8688	·391 2815	557	13
29	·968 3394	·391 3372	570	12
30	2·159 9006	·391 3942	581	12
31	·362 0454	·391 4523	592	11
32	·575 3055	·391 5115	603	10
33	·800 2556	·391 5718	612	9
34	3·037 5167	·391 6330	621	9
35	·287 7604	·391 6950	629	8
36	·551 7138	·391 7579	636	7
37	·830 1647	·391 8215	642	6
38	4·123 9677	·391 8857	648	6
39	·434 0507	·391 9505	653	5
40	·761 4223	·392 0157	657	4
41	5·107 1807	·392 0814	660	3
42	·472 5225	·392 1474	662	2
43	·858 7544	·392 2136	664	2
44	6·267 3043	·392 2800	665	1
45	·699 7361	·392 3465		

$\phi°$	*r* = 39			
	log F (*r*, *ν*)	log H (*r*, *ν*)	Δ log H (*r*, *ν*)	Δ^2 log H (*r*, *ν*)
0	$\bar{1}$·600 7740	0·390 6658	·000 0011	
1	·603 2891	·390 6669	34	·000 0023
2	·610 8391	·390 6703	56	23
3	·623 4380	·390 6760	79	23
4	·641 1093	·390 6838	101	22
5	·663 8860	·390 6940	124	22
6	·691 8107	·390 7063	146	22
7	·724 9361	·390 7209	168	22
8	·763 3246	·390 7377	189	22
9	·807 0490	·390 7566	211	22
10	·856 1930	·390 7777	232	21
11	·910 8510	·390 8009	253	21
12	·971 1287	·390 8262	274	21
13	0·037 1440	·390 8535	294	20
14	·109 0268	·390 8829	314	20
15	·186 9202	·390 9143	334	20
16	·270 9806	·390 9477	353	19
17	·361 3789	·390 9829	371	19
18	·458 3010	·391 0201	390	18
19	·561 9488	·391 0591	408	18
20	·672 5410	·391 0998	425	17
21	·790 3143	·391 1423	442	17
22	·915 5247	·391 1865	458	16
23	1·048 4484	·391 2323	474	16
24	·189 3837	·391 2796	489	15
25	·338 6522	·391 3285	503	14
26	·496 6007	·391 3788	517	14
27	·663 6033	·391 4306	530	13
28	·840 0630	·391 4836	543	13
29	2·026 4145	·391 5379	555	12
30	·223 1268	·391 5935	566	11
31	·430 7056	·391 6501	577	11
32	·649 6970	·391 7078	587	10
33	·880 6908	·391 7665	596	9
34	3·124 3244	·391 8261	605	8
35	·381 2874	·391 8866	612	8
36	·652 3259	·391 9479	619	7
37	·938 2488	·392 0098	626	6
38	4·239 9332	·392 0724	631	5
39	·558 3315	·392 1355	636	5
40	·894 4793	·392 1991	640	4
41	5·249 5035	·392 2631	643	3
42	·624 6328	·392 3274	645	2
43	6·021 2079	·392 3919	647	2
44	·440 6950	·392 4566	648	1
45	·884 6991	·392 5213		

$\phi°$	$r=40$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ² log H (r, ν)
0	$\bar{1}$·595 3459	0·390 8782	·000 0011	
1	·597 9271	·390 8793	33	·000 0022
2	·605 6756	·390 8826	55	22
3	·618 6058	·390 8881	77	22
4	·636 7416	·390 8958	99	22
5	·660 1171	·390 9057	120	22
6	·688 7760	·390 9177	142	22
7	·722 7721	·390 9319	163	21
8	·762 1697	·390 9483	185	21
9	·807 0434	·390 9667	206	21
10	·857 4789	·390 9873	226	21
11	·913 5732	·391 0099	247	20
12	·975 4348	·391 0346	267	20
13	0·043 1845	·391 0612	287	20
14	·116 9556	·391 0899	306	19
15	·196 8949	·391 1205	325	19
16	·283 1630	·391 1530	344	19
17	·375 9350	·391 1874	362	18
18	·475 4017	·391 2236	380	18
19	·581 7701	·391 2616	397	17
20	·695 2648	·391 3014	414	17
21	·816 1285	·391 3428	431	16
22	·944 6237	·391 3859	447	16
23	1·081 0339	·391 4305	462	15
24	·225 6650	·391 4767	477	15
25	·378 8470	·391 5243	491	14
26	·540 9357	·391 5734	504	14
27	·712 3146	·391 6238	517	13
28	·893 3974	·391 6756	530	12
29	2·084 6300	·391 7285	541	12
30	·286 4933	·391 7827	552	11
31	·499 5062	·391 8379	563	10
32	·724 2290	·391 8942	572	10
33	·961 2666	·391 9514	581	9
34	3·211 2729	·392 0095	590	8
35	·474 9551	·392 0685	597	8
36	·753 0789	·392 1282	604	7
37	4·046 4738	·392 1886	610	6
38	·356 0397	·392 2496	615	5
39	·682 7535	·392 3112	620	5
40	5·027 6774	·392 3732	624	4
41	·391 9676	·392 4355	627	3
42	·776 8842	·392 4982	629	2
43	6·183 8028	·392 5612	630	1
44	·614 2272	·392 6242	631	0
45	7·069 8037	·392 6874		

ϕ°	$r = 41$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·590 0501	0·391 0801	·000 0011	
1	·592 6975	·391 0812	32	·000 0021
2	·600 6445	·391 0844	54	21
3	·613 9059	·391 0898	75	21
4	·632 5064	·391 0973	96	21
5	·656 4807	·391 1069	118	21
6	·685 8737	·391 1187	139	21
7	·720 7406	·391 1325	159	21
8	·761 1472	·391 1485	180	21
9	·807 1702	·391 1665	200	20
10	·858 8973	·391 1865	221	20
11	·916 4280	·391 2086	241	20
12	·979 8734	·391 2327	260	20
13	0·049 3576	·391 2587	280	19
14	·125 0171	·391 2867	299	19
15	·207 0023	·391 3165	317	19
16	·295 4780	·391 3483	335	18
17	·390 6238	·391 3818	353	18
18	·492 6351	·391 4172	371	17
19	·601 7243	·391 4542	388	17
20	·718 1215	·391 4930	404	16
21	·842 0755	·391 5334	420	16
22	·973 8556	·391 5754	436	16
23	1·113 7524	·391 6190	451	15
24	·262 0794	·391 6640	465	14
25	·419 1750	·391 7105	479	14
26	·585 4038	·391 7584	492	13
27	·761 1593	·391 8076	505	13
28	·946 8652	·391 8581	517	12
29	2·142 9789	·391 9097	528	11
30	·349 9933	·391 9626	539	11
31	·568 4405	·392 0164	549	10
32	·798 8947	·392 0713	558	09
33	3·041 9761	·392 1272	567	9
34	·298 3551	·392 1839	575	8
35	·568 7567	·392 2414	583	8
36	·853 9658	·392 2997	589	7
37	4·154 8329	·392 3586	595	6
38	·472 2803	·392 4181	600	5
39	·807 3096	·392 4782	605	5
40	5·161 0098	·392 5386	609	4
41	·534 5660	·392 5995	612	3
42	·929 2701	·392 6607	614	2
43	6·346 5322	·392 7221	615	1
44	·787 8938	·392 7836	616	1
45	7·255 0429	·392 8452		

ϕ°	$r = 42$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·584 8804	0·391 2724	·000 0010	
1	·587 5939	·391 2734	31	·000 0021
2	·595 7394	·391 2766	52	21
3	·609 3321	·391 2818	73	21
4	·628 3972	·391 2891	94	21
5	·652 9704	·391 2985	115	21
6	·683 0975	·391 3100	135	21
7	·718 8352	·391 3235	156	20
8	·760 2510	·391 3391	176	20
9	·807 4232	·391 3567	196	20
10	·860 4419	·391 3763	216	20
11	·919 4089	·391 3978	235	19
12	·984 4383	·391 4213	254	19
13	0·055 6569	·391 4467	273	19
14	·133 2048	·391 4740	292	19
15	·217 2361	·391 5032	310	18
16	·307 9195	·391 5341	328	18
17	·405 4390	·391 5669	345	17
18	·509 9950	·391 6014	362	17
19	·621 8050	·391 6376	378	16
20	·741 1047	·391 6754	395	16
21	·868 1492	·391 7149	410	16
22	1·003 2143	·391 7559	425	15
23	·146 5976	·391 7984	440	15
24	·298 6206	·391 8424	454	14
25	·459 6298	·391 8878	467	13
26	·629 9989	·391 9345	480	13
27	·810 1308	·391 9826	493	12
28	2·000 4600	·392 0318	504	12
29	·201 4548	·392 0823	516	11
30	·413 6204	·392 1338	526	10
31	·637 5019	·392 1864	536	10
32	·873 6876	·392 2400	545	9
33	3·122 8129	·392 2945	554	9
34	·385 5647	·392 3499	562	8
35	·662 6857	·392 4060	569	7
36	·954 9802	·392 4629	575	7
37	4·263 3195	·392 5204	581	6
38	·588 6485	·392 5785	586	5
39	·931 9935	·392 6371	590	4
40	5·294 4700	·392 6962	594	4
41	·677 2923	·392 7556	597	3
42	6·081 7839	·392 8153	599	2
43	·509 3896	·392 8752	601	1
44	·961 6887	·392 9353	601	1
45	7·440 4103	·392 9954		

$\phi°$	$r = 43$			
	$\log F(r, \nu)$	$\log H(r, \nu)$	$\Delta \log H(r, \nu)$	$\Delta^2 \log H(r, \nu)$
0	$\bar{1}$·579 8310	0·391 4556	·000 0010	
1	·582 6106	·391 4566	31	·000 0021
2	·590 9546	·391 4597	51	20
3	·604 8785	·391 4648	72	20
4	·624 4083	·391 4720	92	20
5	·649 5803	·391 4812	112	20
6	·680 4416	·391 4924	132	20
7	·717 0501	·391 5056	152	20
8	·759 4750	·391 5208	172	20
9	·807 7965	·391 5380	191	19
10	·862 1068	·391 5571	210	19
11	·922 5103	·391 5781	230	19
12	·989 1236	·391 6011	248	19
13	0·062 0767	·391 6259	267	19
14	·141 5130	·391 6526	285	18
15	·227 5903	·391 6810	303	18
16	·320 4814	·391 7113	320	17
17	·420 3748	·391 7433	337	17
18	·527 4755	·391 7770	353	17
19	·642 0063	·391 8123	370	16
20	·764 2086	·391 8493	385	16
21	·894 3438	·391 8878	401	15
22	1·032 6937	·391 9279	415	15
23	·179 5637	·391 9694	430	14
24	·335 2826	·392 0124	443	14
25	·500 2054	·392 0567	457	13
26	·674 7149	·392 1024	469	13
27	·859 2234	·392 1493	481	12
28	2·054 1759	·392 1974	493	12
29	·260 0519	·392 2467	504	11
30	·477 3687	·392 2970	514	10
31	·706 6845	·392 3484	523	10
32	·948 6018	·392 4007	533	9
33	3·203 7711	·392 4540	541	8
34	·472 8957	·392 5081	548	8
35	·756 7363	·392 5629	556	7
36	4·056 1162	·392 6185	562	6
37	·371 9277	·392 6747	567	6
38	·705 1384	·392 7314	572	5
39	5·056 7991	·392 7886	577	4
40	·428 0520	·392 8463	580	3
41	·820 1404	·392 9044	583	3
42	6·234 4197	·392 9627	585	2
43	·672 3690	·393 0212	587	2
44	7·136 6055	·393 0799	587	1
45	·625 8999	·393 1386		

ϕ°	$r = 44$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·574 8962	0·391 6305	·000 0010	
1	·577 7420	·391 6315	30	·000 0020
2	·586 2845	·391 6345	50	20
3	·600 5397	·391 6395	70	20
4	·620 5341	·391 6465	90	20
5	·646 3049	·391 6554	109	20
6	·677 9004	·391 6664	129	20
7	·715 3798	·391 6793	149	20
8	·758 8138	·391 6942	168	19
9	·808 2846	·391 7109	187	19
10	·863 8866	·391 7296	206	19
11	·925 7265	·391 7502	224	19
12	·993 9238	·391 7726	243	18
13	0·068 6113	·391 7769	261	18
14	·149 9361	·391 8229	278	18
15	·238 0595	·391 8508	296	17
16	·333 1584	·391 8803	313	17
17	·435 4256	·391 9116	329	17
18	·545 0710	·391 9445	346	16
19	·662 3227	·391 9791	361	16
20	·787 4277	·392 0152	377	15
21	·920 6532	·392 0528	391	15
22	1·062 2883	·392 0920	406	14
23	·212 6450	·392 1326	420	14
24	·372 0600	·392 1746	433	13
25	·540 8966	·392 2179	446	13
26	·719 5463	·392 2625	459	12
27	·908 4315	·392 3084	470	12
28	2·108 0073	·392 3554	482	11
29	·318 7645	·392 4035	492	11
30	·541 2327	·392 4528	502	10
31	·775 9829	·392 5030	512	9
32	3·023 6317	·392 5541	520	9
33	·284 8450	·392 6062	528	8
34	·560 3426	·392 6590	536	8
35	·850 9027	·392 7126	543	7
36	4·157 3682	·392 7669	549	6
37	·480 6520	·392 8218	555	6
38	·821 7444	·392 8773	559	5
39	5·181 7208	·392 9332	564	4
40	·561 7502	·392 9896	567	4
41	·963 1049	·393 0463	570	3
42	6·387 1719	·393 1033	572	2
43	·835 4649	·393 1605	573	1
44	7·309 6389	·393 2178	574	1
45	·811 5060	·393 2752		

$\phi°$	$r = 45$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·570 0711	0·391 7975	·000 0010	
1	·572 9830	·391 7984	29	·000 0020
2	·581 7241	·391 8014	49	20
3	·596 3106	·391 8063	68	19
4	·616 7696	·391 8131	88	19
5	·643 1393	·391 8219	107	19
6	·675 4689	·391 8326	126	19
7	·713 8192	·391 8452	145	19
8	·758 2623	·391 8598	164	19
9	·808 8824	·391 8762	183	19
10	·865 7761	·391 8944	201	18
11	·929 0524	·391 9145	219	18
12	·998 8337	·391 9365	237	18
13	0·075 2558	·391 9602	255	18
14	·158 4691	·391 9857	272	17
15	·248 6386	·392 0129	289	17
16	·345 9453	·392 0418	306	17
17	·450 5863	·392 0724	322	16
18	·562 7765	·392 1046	338	16
19	·682 7492	·392 1383	353	15
20	·810 7568	·392 1737	368	15
21	·947 0729	·392 2105	383	15
22	1·091 9931	·392 2488	397	14
23	·245 8365	·392 2885	411	14
24	·408 9476	·392 3295	424	13
25	·581 6979	·392 3719	436	13
26	·764 4880	·392 4155	448	12
27	·957 7499	·392 4603	460	12
28	2·161 9490	·392 5063	471	11
29	·377 5876	·392 5534	481	10
30	·605 2071	·392 6015	491	10
31	·845 3918	·392 6506	500	9
32	3·098 7723	·392 7006	509	9
33	·366 0297	·392 7515	517	8
34	·647 9002	·392 8032	524	7
35	·945 1800	·392 8556	531	7
36	4·258 7310	·392 9087	537	6
37	·589 4872	·392 9624	542	5
38	·938 4614	·393 0166	547	5
39	5·306 7534	·393 0713	551	4
40	·695 5595	·393 1264	555	3
41	6·106 1805	·393 1818	557	3
42	·540 0352	·393 2376	559	2
43	·998 6720	·393 2935	561	1
44	·483 7836	·393 3496	561	1
45	·997 2234	·393 4057		

$\phi°$	$r=46$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·565 3509	0·391 9572	·000 0010	
1	·568 3289	·391 9581	29	·000 0019
2	·577 2685	·391 9610	48	19
3	·592 1863	·391 9658	67	19
4	·613 1100	·391 9725	86	19
5	·640 0785	·391 9811	105	19
6	·673 1423	·391 9915	124	19
7	·712 3634	·392 0039	142	19
8	·757 8157	·392 0181	161	18
9	·809 5852	·392 0342	179	18
10	·867 7706	·392 0520	197	18
11	·932 4834	·392 0717	215	18
12	0·003 8487	·392 0932	232	18
13	·082 0054	·392 1164	249	17
14	·167 1071	·392 1413	266	17
15	·259 3228	·392 1679	283	17
16	·358 8372	·392 1962	299	16
17	·465 8522	·392 2261	315	16
18	·580 5873	·392 2576	331	16
19	·703 2808	·392 2906	346	15
20	·834 1911	·392 3252	360	15
21	·973 5979	·392 3612	375	14
22	1·121 8031	·392 3987	388	14
23	·279 1333	·392 4375	402	13
24	·445 9406	·392 4776	414	13
25	·622 6047	·392 5191	427	12
26	·809 5352	·392 5618	438	12
27	2·007 1738	·392 6056	450	11
28	·215 9964	·392 6506	461	11
29	·436 5163	·392 6967	471	10
30	·669 2873	·392 7437	480	10
31	·914 9064	·392 7918	489	9
32	3·174 0186	·392 8407	498	8
33	·447 3201	·392 8905	505	8
34	·735 5636	·392 9410	513	7
35	4·039 5631	·392 9923	519	6
36	·360 1998	·393 0442	525	6
37	·698 4283	·393 0967	530	5
38	5·055 2844	·393 1498	535	5
39	·431 8925	·393 2033	539	4
40	·829 4749	·393 2572	543	3
41	6·249 3623	·393 3115	545	3
42	·693 0048	·393 3660	547	2
43	7·161 9854	·393 4207	548	1
44	·658 0347	·393 4755	549	1
45	8·183 0474	·393 5304		

$\phi°$	$r=47$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·560 7311	0·392 1100	·000 0009	
1	·563 7753	·392 1110	28	·000 0019
2	·572 9134	·392 1138	47	19
3	·588 1625	·392 1185	66	19
4	·609 5508	·392 1250	84	19
5	·637 1182	·392 1334	103	18
6	·670 9162	·392 1437	121	18
7	·711 0082	·392 1557	139	18
8	·757 4696	·392 1697	157	18
9	·810 3885	·392 1854	175	18
10	·869 8656	·392 2029	193	18
11	·936 0149	·392 2221	210	17
12	0·008 9642	·392 2431	227	17
13	·088 8555	·392 2658	244	17
14	·175 8458	·392 2902	261	17
15	·270 1076	·392 3163	277	16
16	·371 8299	·392 3440	293	16
17	·481 2188	·392 3732	308	16
18	·598 4987	·392 4041	323	15
19	·723 9132	·392 4364	338	15
20	·857 7263	·392 4702	353	14
21	1·000 2236	·392 5055	367	14
22	·151 7141	·392 5421	380	13
23	·312 5311	·392 5801	393	13
24	·483 0345	·392 6194	406	13
25	·663 6124	·392 6600	418	12
26	·854 6834	·392 7018	429	12
27	2·056 6988	·392 7447	440	11
28	·270 1448	·392 7887	451	11
29	·495 5462	·392 8338	461	10
30	·733 4685	·392 8799	470	9
31	·984 5222	·392 9269	479	9
32	3·249 3662	·392 9748	487	8
33	·528 7119	·393 0235	495	8
34	·823 3284	·393 0729	502	7
35	4·134 0476	·393 1231	508	6
36	·461 7700	·393 1740	514	6
37	·807 4710	·393 2254	519	5
38	5·172 2090	·393 2773	524	5
39	·557 1330	·393 3297	528	4
40	·963 4920	·393 3824	531	3
41	6·392 6458	·393 4355	534	3
42	·846 0761	·393 4889	536	2
43	7·325 4006	·393 5424	537	1
44	·832 3876	·393 5961	537	0
45	8·368 9732	·393 6498		

ϕ°	$r = 48$			
	$\log F(r, \nu)$	$\log H(r, \nu)$	$\Delta \log H(r, \nu)$	$\Delta^2 \log H(r, \nu)$
0	$\bar{1}$·556 2075	0·392 2565	·000 0009	·000 0018
1	·559 3178	·392 2574	28	18
2	·568 6545	·392 2601	46	18
3	·584 2348	·392 2647	64	18
4	·606 0878	·392 2711	82	18
5	·634 2541	·392 2794	100	18
6	·668 7863	·392 2894	118	18
7	·709 7492	·392 3012	136	18
8	·757 2198	·392 3149	154	17
9	·811 2881	·392 3302	171	17
10	·872 0569	·392 3474	189	17
11	·939 6427	·392 3662	206	17
12	0·014 1760	·392 3868	222	17
13	·095 8020	·392 4090	239	16
14	·184 6808	·392 4329	255	16
15	·280 9888	·392 4584	271	16
16	·384 9189	·392 4855	287	15
17	·496 6818	·392 5142	302	15
18	·616 5066	·392 5444	317	15
19	·744 6421	·392 5760	331	14
20	·881 3579	·392 6092	345	14
21	1·026 9460	·392 6437	359	13
22	·181 7216	·392 6796	372	13
23	·346 0254	·392 7168	385	12
24	·520 2250	·392 7553	397	12
25	·704 7169	·392 7950	409	11
26	·899 9284	·392 8359	420	11
27	2·106 3205	·392 8779	431	10
28	·324 3901	·392 9210	441	10
29	·554 6729	·392 9652	451	9
30	·797 7467	·393 0103	460	9
31	3·054 2350	·393 0563	469	8
32	·324 8107	·393 1032	477	8
33	·610 2007	·393 1509	485	7
34	·911 1903	·393 1993	491	6
35	4·228 6293	·393 2485	498	6
36	·563 4374	·393 2982	503	5
37	·916 6109	·393 3486	508	4
38	5·289 2309	·393 3994	513	4
39	·682 4708	·393 4507	517	3
40	6·097 6065	·393 5024	520	2
41	·536 0267	·393 5543	522	2
42	·999 2449	·393 6066	524	1
43	7·488 9134	·393 6590	526	1
44	8·006 8381	·393 7116	526	
45	·554 9966	·393 7642		

ϕ°	$r = 49$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·551 7763	0·392 3969	·000 0009	
1	·554 9527	·392 3978	27	·000 0018
2	·564 4879	·392 4005	45	18
3	·580 3995	·392 4050	63	18
4	·602 7172	·392 4113	81	18
5	·631 4824	·392 4193	98	18
6	·666 7488	·392 4291	116	18
7	·708 5826	·392 4407	133	17
8	·757 0624	·392 4541	151	17
9	·812 2801	·392 4692	168	17
10	·874 3406	·392 4859	185	17
11	·943 3629	·392 5044	201	17
12	0·019 4803	·392 5245	218	17
13	·102 8409	·392 5463	234	16
14	·193 6083	·392 5697	250	16
15	·291 9625	·392 5947	266	16
16	·398 1005	·392 6213	281	15
17	·512 2374	·392 6493	296	15
18	·634 6070	·392 6789	310	14
19	·765 4636	·392 7099	324	14
20	·905 0822	·392 7424	338	14
21	1·053 7610	·392 7762	352	13
22	·211 8218	·392 8114	365	13
23	·379 6125	·392 8478	377	12
24	·557 5084	·392 8855	389	12
25	·745 9141	·392 9244	401	12
26	·945 2662	·392 9645	412	11
27	2·156 0351	·393 0057	422	11
28	·378 7283	·393 0479	432	10
29	·613 8925	·393 0911	442	10
30	·862 1178	·393 1353	451	9
31	3·124 0408	·393 1804	459	8
32	·400 3485	·393 2263	467	8
33	·691 7826	·393 2731	474	7
34	·999 1454	·393 3205	481	7
35	4·323 3042	·393 3686	488	6
36	·665 1980	·393 4174	493	6
37	5·025 8441	·393 4667	498	5
38	·406 3461	·393 5165	502	4
39	·807 9020	·393 5667	506	4
40	6·231 8144	·393 6174	509	3
41	·679 5011	·393 6683	512	3
42	7·152 5073	·393 7195	514	2
43	·652 5197	·393 7708	515	1
44	8·181 3822	·393 8223	516	1
45	·741 1137	·393 8739		

ϕ°	$r=50$			
	log F (r, ν)	log H (r, ν)	Δ log H (r, ν)	Δ^2 log H (r, ν)
0	$\bar{1}$·547 4336	0·392 5316		
1	·550 6762	·392 5325	·000 0009	·000 0018
2	·560 4099	·392 5352	26	18
3	·576 6529	·392 5396	44	18
4	·599 4352	·932 5457	62	17
5	·628 7993	·392 5536	79	17
6	·664 7999	·392 5633	96	17
7	·707 5046	·392 5746	114	17
8	·756 9936	·392 5877	131	17
9	·813 3607	·392 6025	148	17
10	·876 7129	·392 6189	164	17
11	·947 1718	·392 6370	181	16
12	0·024 8733	·392 6568	197	16
13	·109 9685	·392 6781	213	16
14	·202 6245	·392 7010	229	16
15	·303 0249	·392 7255	245	15
16	·411 3709	·392 7516	260	15
17	·527 8818	·392 7791	275	15
18	·652 7964	·392 8080	290	14
19	·786 3739	·392 8384	304	14
20	·928 8954	·392 8702	318	14
21	1·080 6649	·392 9034	331	14
22	·242 0110	·392 9378	345	13
23	·413 2886	·392 9736	357	12
24	·594 8807	·393 0105	369	12
25	·787 2004	·393 0486	381	11
26	·990 6930	·393 0879	393	11
27	2·205 8389	·393 1282	404	10
28	·433 1556	·393 1696	414	10
29	·673 2014	·393 2120	424	9
30	·926 5783	·393 2553	433	9
31	3·193 9359	·393 2995	442	8
32	·475 9753	·393 3445	450	8
33	·773 4538	·393 3903	458	7
34	4·087 1898	·393 4368	465	7
35	·418 0685	·393 4840	472	6
36	·767 0481	·393 5318	478	5
37	5·135 1668	·393 5801	483	5
38	·523 5508	·393 6289	488	4
39	·933 4228	·393 6781	492	4
40	6·366 1119	·393 7277	496	3
41	·823 0651	·393 7776	499	2
42	7·305 8593	·393 8278	502	2
43	·816 2157	·393 8781	504	1
44	8·356 0160	·393 9286	505	1
45	·927 3206	·393 9791	505	

Report on the Progress of the Solution of the Problem of Three Bodies.
By E. T. WHITTAKER.

Introduction.

THE present Report is the fulfilment of the author's engagement to draw up a report on the planetary theory for the Association. The above title has been adopted in place of that originally chosen, as indicating more definitely the aim of the Report.

The fundamental problem of dynamical astronomy is that of determining the motion in space of any number of particles which attract each other according to the Newtonian law. The solution of the problem depends on the integration of a system of differential equations; and various methods have been given for the solution of the equations by means of infinite series of known functions. The methods are, however, in general cumbrous; the convergence of the series employed has only recently been considered with any success, and the true nature of the integrals of the problem is unknown.

The theory has hitherto been developed chiefly with the object of determining the motion of the moon and planets. While, however, the lunar and planetary theories are, both of them, attempts to solve the problem of three bodies, yet the results of the two theories are quite different in form; this is owing to the fact that the assumptions on which the approximations are based are not the same in the two cases. Thus it is known that if the masses of all but one of the particles are zero (*i.e.* do not exert any attraction on each other), these particles will circulate round the remaining particle in elliptic paths; and so a method of approximation, known as the planetary theory, has been developed, in which it is supposed that the mass of one body preponderates and the other bodies circle round it. In the lunar theory, on the other hand, it is assumed that two of the bodies circle round each other, while circling together round a preponderating third body. This gives rise to a solution of the problem by means of a different set of infinite series.

Of course, the planetary and lunar theories do not by any means exhaust the list of possible methods of approximation. For instance, it is known that a particular solution of the problem of three bodies exists, in which the three particles are always at the vertices of a moving equilateral triangle; and that, under certain conditions, this is a stable form of motion. It would therefore be possible to form a theory, analogous to the lunar and planetary theories, in which the approximation would be based on the supposition that the motion differed but little from this type; and the only reason why this theory has not been developed is, that it is not called for by the practical needs of computers of the solar system.

The results of the planetary and lunar theories may be regarded as furnishing solutions of the fundamental problem by means of infinite series, valid in each case only so long as the initial conditions are subject to certain inequalities. In addition to this, there is a considerable literature dealing with the differential equations of the problem and their transformations; and in recent years discoveries have been made relating to the nature and general properties of the solution, *e.g.* Bruns's theorem that no algebraic integrals of the problem of several attracting bodies exist, beyond the integrals of energy and momentum. In this Report it is intended to review the state of these various branches of the theory at the present time, solely in so far as they help in the mathematical discussion of the fundamental problem ; no attempt is made to consider numerical applications, or the suitability of the various developments for purposes of computation. On this account, many papers which are of the highest importance in the practical lunar and planetary theory are left unnoticed ; this is in some respects to be regretted, but it has been rendered necessary by limitations of space and time.

The Report attempts to trace the development of the subject in the last thirty years, 1868–98 ; this period opens with the time when the last volume of Delaunay's 'Lunar Theory' was newly published ; it closes with the issue of the last volume of Poincaré's 'New Methods in Celestial Mechanics.' Between the two books lies the development of the new dynamical astronomy.

The work will be distributed under the following seven headings :—

§ I.—The differential equations of the problem.
§ II.—Certain particular solutions of simple character.
§ III.—Memoirs of 1868–89 on general and particular solutions of the differential equations, and their expression by means of infinite series (excluding Gyldén's theory).
§ IV.—Memoirs of 1868–89 on the absence of terms of certain classes from the infinite series which represent the solution.
§ V.—Gyldén's theory of absolute orbits.
§ VI.—Progress in 1890–98 of the theories of §§ III. and IV
§ VII.—The impossibility of certain kinds of integrals.

§ I. *The Differential Equations of the Problem.*

Taking any fixed axes of reference, the motion of three mutually attracting bodies is determined by nine ordinary differential equations, each of the second order, or, as it is generally expressed, by a system of the eighteenth order. The known fact that the centre of gravity may be regarded as at rest is equivalent to six integrals of the system, and so the system can be reduced to the twelfth order. The further fact that the components of angular momentum about the axes are constant yields three more integrals, and the system can thus be reduced to the ninth order. The integral of energy makes possible a reduction to the eighth order ; and since the time t only enters by means of its differential dt, it can be eliminated, and the system reduced to the seventh order. A further simplification can be made, which was first pointed out explicitly by Jacobi,[1] though it is really contained in the work of Lagrange,[2] namely, that the variables can be so chosen that one of them Ω enters only by means of its differential $d\Omega$; it can therefore be eliminated (and afterwards found by a simple quadrature), and the system can be reduced to the sixth order.

Later writers have not succeeded in reducing the problem to a lower order than the sixth. It will be seen, however, that distinct advances have been made in the formulation of the equations and the theory of their

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[1] 'Sur l'élimination des nœuds dans le problème des trois corps,' *Crelle*, xxvi. pp. 115–31, 1843.

[2] 'Essai sur le problème des trois corps,' *Prix de l'Académie de Paris*, ix. 1772.

transformation, although progress has not been as marked here as in the other investigations connected with the problem of three bodies. Besides the general problem of three bodies and of n bodies, several problems of a more special character are often considered, such as the *problem of three bodies in a plane,* and the *restricted problem of three bodies.* The last-named, which has occupied a prominent place in recent researches, may be described as follows: Two bodies, S and J, revolve round their centre of gravity in circular orbits, under the influence of their mutual attraction. A third body P without mass (*i.e.* such that it is attracted by S and J, but does not disturb their motion) moves in the same plane as S and J. The restricted problem of three bodies is to determine the motion of P. This problem was first discussed by Jacobi[1] in 1836, who showed that it depends on a system of differential equations of the fourth order, one integral of which can be written down. This is now generally called the *Jacobian integral* of the restricted problem of three bodies.

The most satisfactory reduction of the differential equations of the problem of three bodies, previous to 1868, was that of Bour[2] Bour first applies a theorem due to Jacobi[3] and Bertrand,[4] in which, by making use of the integrals of motion of the centre of gravity, the problem of three bodies is made to depend on the motion of two fictitious masses m_1 and m_2, whose potential energy depends only on the lengths of the lines joining them to each other and to the origin. Bour takes as his coordinates q_1 and q_2, the distances of m_1 and m_2 respectively from the origin; q_3 and q_4, the angles made by q_1 and q_2 respectively with the intersection of the plane through the bodies and the origin with the invariable plane; p_1 and p_2, which denote $m_1\frac{dq_1}{dt}$ and $m_2\frac{dq_2}{dt}$ respectively; and p_3 and p_4, which are the components of angular momentum of m_1 and m_2 respectively, in the plane through the bodies and the origin. With these coordinates the equations become

$$\frac{dp_i}{dt}=\frac{\partial H}{\partial q_i}, \quad \frac{dq_i}{dt}=-\frac{\delta H}{\delta p_i}, \quad (i=1, 2, 3, 4)$$

where H is a certain function of the quantities p and q, and H=constant is an integral of the system.

For the rectification of an error in Bour's paper, see Mathieu's paper of 1874, referred to later in this section.

For the problem of three bodies in a plane, Bour's system becomes

$$\frac{dp_i}{dt}=\frac{\partial H}{\partial q_i}, \quad \frac{dq_i}{dt}=-\frac{\delta H}{\partial p_i}, \quad (i=1, 2, 3)$$

where p_1, p_2, q_1, q_2 are defined as before, but q_3 is now the angle between q_1 and q_2, and p_3 is the difference of the angular momenta of m_1 and m_2 round the origin.

The problem was reduced in various ways to systems equivalent to, or

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[1] *Comptes Rendus,* iii. pp. 59–61.

[2] 'Mémoire sur le problème des trois corps,' *Journal de l'École Polytechnique,* xxi. pp. 35–8, 1856.

[3] 'Sur l'élimination des nœuds dans le problème des trois corps,' *Crelle,* xxvi. pp. 115–131, 1843.

[4] Mémoire sur l'intégration des équations différentielles de la mécanique,' *Liouville,* xvii. pp. 393–436, 1852.

little differing from, Bour's system, by Brioschi[1] in 1868, and Siacchi[2] in 1871 and 1874; Vernier[3] in 1894 published what is substantially only a reproduction of Siacchi's paper of 1874. Amplifications and corrections were also made by Mathieu[4] in 1873-8.

Previously to 1868 the restricted problem of three bodies had been discussed by Scheibner[5] in 1866. His equations refer to a somewhat more general case, but for the restricted problem of three bodies they are as follows: Let n be the mean motion of the two bodies, and x, y the coordinates of the particle, referred to the centre of gravity of the bodies, the (moving) x-axis being the line joining the bodies. Also let

$$\frac{dx}{dt}+ny=\xi,\ \frac{dy}{dt}-nx=\eta,$$

then the equations of motion are

$$\frac{dx}{dt}=\frac{\delta H}{\delta\xi},\ \frac{d\xi}{dt}=-\frac{\delta H}{\delta x},\ \frac{dy}{dt}=\frac{\delta H}{\delta\eta},\ \frac{d\eta}{dt}=-\frac{\delta H}{\delta y},$$

where H is a certain function of x, y, ξ, η, and H=constant is the Jacobian integral of the system.

In 1868 Scheibner[6] reduced the general problem of three bodies to a canonical system of the eighth order without using Jacobi's transformation to the two fictitious masses. Let q_1, q_2, q_3 be the mutual distances of the three bodies, and let $p_1=\frac{\delta T}{\delta q_1}$, $p_2=\frac{\delta T}{\delta q_2}$, $p_3=\frac{\delta T}{\delta q_3}$, where T is the kinetic energy; let q_4 be the angle which the node (of the plane of the bodies, on the invariable plane) makes with one of the principal axes of inertia of the bodies at their centre of gravity; and let $p_4=k \cos i$, where k is the constant of angular momentum on the invariable plane, and i is the angle between the plane of the bodies and the invariable plane. Then the differential equations become

$$\frac{dq_i}{dt}=\frac{\delta H}{\delta p_i},\ \frac{dp_i}{at}=-\frac{\delta H}{\delta q_i},\ (i=1, 2, 3, 4)$$

where H is a certain function of the quantities p and q, and H=constant is an integral of the system.

When the motion is in one plane, the system reduces to the sixth order, as p_4 becomes a constant, and q_4, now measured from a fixed line in the plane, is determined by a simple quadrature. This reduction is more symmetrical than one given by Perchot and Ebert[7] in 1899.

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[1] 'Sur une transformation des équations différentielles du problème des trois corps,' *C. R.* lxvi. pp. 710–14.

[2] 'Intorno ad alcune trasformazioni delle equazioni differenziali del problema dei tre corpi,' *Atti di Torino*, vi. pp. 440–54; 'Sur le problème des trois corps,' *C. R.* lxxviii. pp. 110–13.

[3] 'Sur la transformation des équations canoniques du problème des trois corps,' *C. R.* cxix. pp. 451–4.

[4] 'Mémoire sur le problème des trois corps,' *C. R.* lxxvii. pp. 1071–4, lxxviii. pp. 408–10; 'Mémoire sur le problème des trois corps,' *Liouville* (3), ii. pp. 345–70; 'Sur l'application du problème des trois corps à la détermination des perturbations de Jupiter et de Saturne,' *Journal de l'École Polytechnique*, xxviii. pp. 245–69.

[5] 'Satz aus der Störungstheorie,' *Crelle*, lxv. pp. 291–2.

[6] 'Ueber das Problem der drei Körper,' *Crelle*, lxviii. pp. 390–2.

[7] 'Sur la réduction des équations du problème des trois corps dans le plan,' *Bulletin Astronomique*, xvi. p. 110–16.

In 1868 Radau published, first in a series[1] of notes in the 'Comptes Rendus,' and subsequently in a memoir[2] in the 'Annales de l'École Normale Supérieure,' his researches on the differential equations of the problem of n bodies. He finds the effect of an orthogonal substitution performed on the variables in the problem, and shows that Jacobi's substitution in the problem of three bodies is a case of this. Two other cases are worthy of mention: firstly, a transformation which is equivalent to referring the second body to the first as origin, the third body to the C.G. of the second and third, the fourth body to the C.G. of the first three, and so on, at the same time modifying the masses; and, secondly, a transformation which shows the existence of n 'canonical' points, each of which has, with reference to the motion of $(n-1)$ of the bodies, properties similar to those possessed by the C.G. for the whole system. Considering the case of three bodies, he deduces Bour's equations, and also a new canonical system of the eighth order.

A modification of the transformation of Jacobi and Radau was considered in 1889 by Andrade,[3] and in 1896–7 Poincaré[4] gave another transformation which appears to be still better suited for effecting the same reduction.

The results obtained by Allégret[5] in 1874 are substantially equivalent to some of those in Radau's papers.

Radau's researches were continued in 1869 in a number of papers,[6] of which that in Liouville's journal is the most complete; the author discusses the reduction of the order of a canonical system when one of the coordinates does not enter explicitly in the energy-function, and applies his results to the problem of three bodies, arriving at Scheibner's system.

Hesse[7] in 1872 published a fresh discussion of the problem of three bodies, somewhat on the lines of Lagrange's memoir; but it was pointed out by Serret[8] in 1873 that the equations in one of Hesse's systems were not independent, and consequently his results were invalid. Serret's paper contains also an exposition, in an improved and symmetrical form, of the essential parts of Lagrange's memoir. Other reductions of the

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[1] 'Sur un théorème de mécanique,' *C. R.* lxvi. pp. 1262–5; 'Remarques sur le problème des trois corps,' *ibid.* lxvii. pp. 171–5; 'Sur une transformation orthogonale applicable aux équations de la dynamique,' *ibid.* lxvii. pp. 316–9; 'Sur l'élimination directe du nœud dans le problème des trois corps,' *ibid.* lxvii. pp. 841–3.

[2] 'Sur une transformation des équations différentielles de la dynamique,' *Annales de l'École Norm. Sup.* v. pp. 311–75.

[3] 'Sur une réduction du problème des n corps, qui conserve $\frac{n}{2}$ ou $\frac{n-1}{2}$ distances mutuelles,' *C. R.* cviii. pp. 226–8; 'Sur les réductions du problème des n corps, qui conservent certaines distances mutuelles,' *ibid.* cviii. pp. 280–1.

[4] 'Sur une forme nouvelle des équations du problème des trois corps,' *ibid.* cxxiii. pp. 1031–5; *Acta Math.* xxi. pp. 83–97.

[5] 'Sur une transformation des équations de la mécanique céleste,' *C. R.* cxxix. pp. 656–8.

[6] 'Betrachtungen über die Flächensätze,' *Ast. Nach.* lxxiii. pp. 337–44; 'Weitere Bemerkungen über das Problem der drei Körper,' *ibid.* lxxiv. pp. 145–52; 'Sur une propriété des systèmes qui ont un plan invariable,' *C. R.* lxviii. pp. 145–9; 'Sur une transformation des coordonnées des trois corps dans laquelle figurent les moments d'inertie,' *ibid.* cxviii. pp. 1465–9; 'Ueber gewisse Eigenschaften der Differentialgleichungen der Dynamik,' *Math. Ann.* ii. pp. 167–81; 'Sur une propriété des systèmes qui ont un plan invariable,' *Liouville*, xiv. pp. 167–230.

[7] 'Ueber das Problem der drei Körper,' *Crelle*, lxxiv. pp. 97–115.

[8] 'Réflexions sur le mémoire de Lagrange intitulé "Essai sur le problème des trois corps,"' *C. R.* lxxvi. pp. 1557–65; and *Bull. des Sc. Math.* vi. p. 48.

problem of three bodies, which seem scarcely of sufficient importance to be here described in detail, are those of Weiler[1] in 1869–70, Hill[2] in 1875, Weiler[3] in 1879–80, Seydler[4] in 1884, and Duport[5] in 1898.

The problem of n bodies can be reduced from the $6n$th order to the $(6n-12)$th order, just as the problem of three bodies can be reduced from the 18th order to the 6th. This subject has been discussed in the period under review by Allégret[6] in 1875 (who fell in errors which were pointed out by Mathieu[7] in 1877), by Betti[8] in 1877, Mathieu[9] in 1877, Ball[10] in 1877, Dillner[11] in 1877 (who attempted to use quaternions, but made mistakes which were pointed out by Bruns[12] in 1880), and Dillner[13] in 1882–8.

Seydler[14] in 1885 extended the analysis of Lagrange's treatment of the problem of three bodies to the case of the problem of four bodies. The system is reduced ultimately to a system of the twelfth order and quadratures.

The general theory underlying the work of this section has been developed by Lie and Mayer. A special consideration of the problem of three bodies will be found at p. 282 of a paper[15] published by Lie in 1875.

In 1887 Bruns[16] published a paper which will be analysed later, but which contains a new reduction of the problem of three bodies.

Let q_1, q_2, q_3 be the mutual distances of the three bodies; and let $q_0 = \Sigma a_1(x_1+iy_1)/\Sigma b_1(x_1+iy_1)$, where (x_1, y_1, z_1) &c. are the coordinates of the bodies when the origin is taken at the centre of gravity, and the

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[1] 'Ueber die Elimination des Knotens in dem Problem der drei Körper, etc.,' *Ast. Nach.* lxxiv. pp. 81–96, lxxv. pp. 113–28; 'Notes sur le problème des trois corps,' *Liouville*, xiv. pp. 305–20.

[2] 'Reduction of the Problem of Three Bodies,' *The Analyst*, iii. pp. 179–85.

[3] 'Ueber die Differentialgleichungen der Bewegung in dem Problem der drei Körper,' *Ast. Nach.* xcvi. pp. 161–82; 'Das Problem der drei Körper in der neuen Störungstheorie,' *ibid.* xcvii. pp. 97–112, 129–44, 161–76, 193–208.

[4] 'Ueber einige neue Formen der Integrale des Zwei-und-Dreikörper-Problems,' *Sitzungsberichte der Ak. zu Wien*, lxxxix. pp. 851–72; 'O integrování některých rovnic vyskytrujic ich se v problemu tři těles,' *Sitzungsberichte d. Ges. der Wiss. in Prag*, 1884, pp. 16–29; 'Další příspěvky k integrováni,' etc., *ibid.* pp. 106–26.

[5] 'Sur le problème des trois corps,' *Bull. Astr.* xv. pp. 377–83.

[6] 'Mémoire sur le problème des trois corps,' *Liouville* (3), i. pp. 277–316.

[7] Mathieu, 'Sur le problème des trois corps.' *Liouville* (3), iii. pp. 216–9; Allégret, 'Note sur le problème des trois corps,' *ibid.* pp. 422–6; Mathieu, 'Réponse à la note de M. Allégret sur le problème des trois corps,' *Liouville* (3), iv. pp. 61–2.

[8] 'Sopra il moto di un sistema di un numero qualunque di punti che si attraggono o si respingono tra loro,' *Annali di matematica* (2), viii. pp. 301–11.

[9] 'Mémoire sur les équations du mouvement d'un système de corps,' *Liouville* (3), ii. pp. 5–21.

[10] 'Note on a transformation, etc.,' *Monthly Notices*, xxxvii. pp. 265–71.

[11] 'Mémoire sur le problème des n corps,' *Nova Acta R.S.S. Upsal.* vol. extra ord., 1877, 18 pp.

[12] *Jahrbuch über die Fortschritte der Mathematik*, 1877, p. 788.

[13] 'Om integration af differentialeqvationerna i n-kroppärs problemet,' *Öfversigt af K. Vet.-ak. Förhandlingar*,' 1882, No. 4, pp. 13–20, No. 8, pp. 9–29; 1886, pp. 173–84, 217–22; 1888, pp. 367–78; 'Sur l'intégration des équations différentielles du problème des *N* corps,' *Annali di matematica* (2), xi. pp. 56–64.

[14] 'Ausdehnung der Lagrange'schen Behandlung des Dreikörper-Problems auf das Vierkörper-Problem,' *Abhandlungen der k. böhm. Gesellschaft der Wissenschaften*, (7), i. No. 5, 20 pp.

[15] Begründung einer Invarianten-Theorie der Berührungs-Transformationen,' *Math. Ann.* viii. pp. 215–303.

[16] 'Ueber die Integrale des Vielkörper-Problems,' *Berichte der kgl. Sächsischen Gesellschaft der Wiss. zu Leipzig*, 1887, pp. 1–39, 55–82; *Acta Math.* xi. pp. 25–96.

invariable plane is the plane of xy, and where $a_1, a_2, a_3, b_1, b_2, b_3$ are constants subject only to the conditions

$$a_1 + a_2 + a_3 = 0, \quad b_1 + b_2 + b_3 = 0, \quad a_2 b_3 - a_3 b_2 = 1.$$

Then the problem can be reduced to the Hamiltonian system of the eighth order.

$$\frac{dq_i}{dt} = \frac{\delta \mathrm{H}}{\delta p_i}, \quad \frac{dp_i}{dt} = -\frac{\delta \mathrm{H}}{\delta q_i} \quad (i = 0, 1, 2, 3,)$$

where

$$\mathrm{H} = \sum \frac{m_2 + m_3}{2m_2 m_3} p_1^2 + \sum \frac{p_2 p_3 (q_2^2 + q_3^2 - q_1^2)'}{2m_1 q_2 q_3} + \sum \frac{1}{m_1} \{p_0(a_1 - b_1 q_0) + k b_1\}$$
$$\left\{ \frac{p_3}{q_3}(a_3 - b_3 q_0) - \frac{p_2}{q_2}(a_2 - b_2 q_0) \right\} - \sum \frac{m_2 m_3}{q_1}.$$

In this, ik is the constant of angular momentum. Bruns then reduces this to a system of the sixth order by eliminating the time and using the integral $\mathrm{H} = -h$; writing $\mathrm{H} = \mathrm{H}_1 p_0 + \mathrm{H}_2$, where H_1 and H_2 do not involve p, and putting $\mathrm{K} = -\frac{\mathrm{H}_2 + h}{\mathrm{H}_1}$, we have

$$\frac{dq_i}{dq_0} = \frac{\delta \mathrm{K}}{\delta p_i}, \quad \frac{dp_i}{dq_0} = -\frac{\delta \mathrm{K}}{\delta q_i} \quad (i = 1, 2, 3)$$

which is the required system.

It may be noted that a particularly simple case of Bruns's transformation is afforded by putting $a_1 = -1$, $a_2 = 1$, $a_3 = 0$, $b_1 = -1$, $b_2 = 0$, $b_3 = 1$; in this case q is simply the ratio of the two vectors which join the projection of m_1 to the projections of m_3 and m_2 respectively on the invariable plane. Kiaier[1] in 1891, starting from Jacobi's transformation, likewise reduced the problem to a canonical system of the sixth order.

The differential equations of the restricted problem of three bodies were discussed by Tisserand[2] in 1887 and by Poincaré[3] in 1890. Both authors reduce the problem to a canonical system of the fourth order; Tisserand takes variables defined by means of the elements of the instantaneous ellipse described by the particle round one of the bodies, while Poincaré uses the instantaneous ellipse described by the particle round the centre of gravity of the system.

§ II. *Certain Particular Solutions of Simple Character.*

Lagrange[4] in 1772 had shown that the equations of motion of the problem of three bodies can be satisfied by two particular solutions of a very simple character; in one case the three particles are always at the vertices of a moving equilateral triangle and in the other they are always on a moving straight line. We shall generally call these respectively the motions of *Lagrange's three equidistant particles* and *three collinear particles.*

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[1] 'Sur la réduction du problème des trois corps au système canonique du sixième ordre,' *Astr. Nach.* cxxvi. pp. 69–76.

[2] 'Sur la commensurabilité des moyens mouvements dans le système solaire,' *Bull. Astr.* iv. pp. 183–92.

[3] 'Sur le problème des trois corps,' *Acta Math.* xiii. pp. 1–270.

[4] 'Essai sur le problème des trois corps,' *Prix de l'Académie de Paris,* ix.

The first paper on the subject in the period under review was published by Routh[1] in 1875; he showed that the three equidistant particles are stable when the square of the sum of the masses is greater than twenty-seven times the sum of the products of the masses taken two and two together; a result which, however, had already been stated by Gascheau. The stability was considered from a somewhat more general point of view by Liapunow[2] in 1889; and Gyldén[3] in 1884 discussed solutions which differ but little from the three collinear particles.

Lagrange's results have been generalised, and corresponding theorems found for the motion of more than three bodies. An attempt made in this direction by Veltmann[4] in 1875 is open to criticism, but Hoppe[5] in 1879, and Lehmann-Filhes[6] in 1891, discovered solutions in which more than three particles are placed at the corners of a regular polygon or polyhedron, or on a straight line. Sloudsky[7] in 1892 claimed to have given some of Hoppe's results in 1878, in a paper published in Russian. In Hoppe's paper the masses of the particles are supposed to be equal, which detracts from the value of his results; in Lehmann-Filhes's paper the masses are not so restricted.

Cases in which the triangle formed by the bodies is isosceles were discussed by Fransen[8] in 1895, and Gorjatschew[9] in 1895-6.

§ III. *Memoirs of* 1868–89 *on General and Particular Solutions of the Differential Equations, and their Expression by Means of Infinite Series (excluding Gyldén's Theory).*

From the time when it was first realised that the motion of the three bodies cannot be represented in a finite form by means of known functions, interest has centred chiefly round that division of the subject to which the present section will be devoted, namely, the derivation, nature, and properties of the infinite series by means of which the problem can be solved.

The result of our observations of the heavenly bodies suggests a form into which we may try to put the analytical solution. It is found that the facts can be represented, at any rate for as far back as our records take us, by supposing that the planets move in ellipses round the sun. These ellipses are, however, not fixed, but their *elements* (the eccentricity, &c.) vary from year to year. Some of these variations, or *inequalities*, are *periodic*—that is to say, can be expressed by terms such as $a \sin (bt + c)$,

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[1] 'On Laplace's three particles, with a Supplement on the stability of steady motion,' *Proc. Lond. Math. Soc.* vi. pp. 86–97.

[2] 'On the stability of the motion in a special case of the problem of three bodies,' *Trans. Math. Soc. of Krakow* (3), ii. pp. 1–94. (Russian.)

[3] 'Om ett af Lagrange behandladt fall af tre-kroppars-problemet; *Öfversigt af K. Vet.-ak. Förhandlingar*, xli. pp. 3–11; 'Sur un cas particulier du problème des trois corps,' *Bull. Astr.* i. pp. 361–9.

[4] 'Bewegung in Kegelschnitten von mehr als zwei Körpern, welche sich nach dem Newton'schen Gesetz anziehen,' *Ast. Nach.* lxxxvi. pp. 17–30.

[5] 'Erweiterung der bekannten Speciallösung des Dreikörperproblems,' *Archiv der Math. u. Phys.* lxiv. pp. 218–23.

[6] 'Ueber zwei Fälle des Vielkörperproblems,' *Astr. Nach.* cxxvii. pp. 137–44.

[7] 'Note sur quelques cas particuliers du problème de plusieurs corps,' *Bulletin de la Soc. Imp. Natur. Moscou*, 1892, pp. 437–40.

[8] 'Ett specialfall af tre-kroppars-problemet,' *Öfversigt af K. Vet.-ak. Förhand.* lii. pp. 783–805.

[9] *Transactions of the Imp. Soc. of Nat.* Moscow, vii. viii.

where a, b, c are constants; such variations obviously do not in the long run produce any marked change in the solar system; while other variations are *secular*—that is to say, are expressed by terms such as $at + bt^2 + \ldots$; these variations of course have the effect of continually altering the orbits, leading ultimately to a completely different configuration.

The method of the classical planetary theory is to express the solution in this way: differential equations are found for the variations of the elliptic elements, and from them is found an approximate solution, which in the earlier memoirs was of the kind just described.

The question naturally arose, What would be found to be the true nature of the secular inequalities if the equations were solved rigorously instead of approximately? The first approximation can be represented by terms like ct, where c is a constant; but it is possible that this is only the first term in the expansion of (say) $\frac{c}{m}\sin mt$, where m is a very small number. If this were the case, the secular terms would really be periodic, though of a very long period. In researches relating to the stability of the solar system, and the expression of the coordinates after long intervals of time, the settlement of this question is of fundamental importance.

Although the founders of the planetary theory succeeded to some extent in their approximation in thus replacing secular terms by trigonometric terms of long period, the most important contribution to the subject previous to the period under review was the method by which Delaunay[1] discussed the motion of the moon, the essence of which may be described as follows.

Let S, J, P be the three bodies, and let the mass of P be zero; then the motion of S and J, being elliptic, may be supposed known, and to determine the motion of P we have a system of the sixth order. This can be brought to the form

$$\frac{dp_r}{dt} = \frac{\delta H}{\delta q_r}, \quad \frac{dq_r}{dt} = -\frac{\delta H}{\delta p_r}, \quad (r = 1, 2, 3)$$

where H is a function of t and of the generalised coordinates p_r, q_r. H may be called the *disturbing function*, and can be expanded as an infinite series, each term of which consists of a function of p_1, p_2, p_3, multiplied by the cosine of a linear function of q_1, q_2, q_3, t. Delaunay then fixes the attention on some particular one of these terms, and shows how to find a transformation from the variables p_r, q_r to new variables p'_r, q'_r such that the equations become

$$\frac{dp'_r}{dt} = \frac{\delta H'}{\delta q'_r}, \quad \frac{dq'_r}{dt} = -\frac{\delta H'}{\delta p'_r}, \quad (r = 1, 2, 3)$$

where H′ is a function of p'_r, q'_r, t of the same kind as H; *but H′ does not contain any term corresponding to the term in H which is under consideration.* This transformation has therefore robbed the disturbing function of one of its terms; by a fresh transformation we can deprive H′ of any other term, and so on. In this way all the important periodic terms are abolished from the disturbing function, and when the residue has become negligeable, the equations are integrated; and the coordinates are thus expressed in terms of six arbitrary constants, and the time *by means of series in which the time occurs only in the arguments of periodic terms.*

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[1] 'Théorie du mouvement de la Lune.' Paris. Vol. i. 1860; vol. ii. 1867.

In 1872 Newcomb,[1] assuming that the coordinates of the planets can be expressed by trigonometric series, as in Delaunay's theory, proved various properties of the coefficients, &c., by using the function called by Clausius the *virial*, which is the mean value of the kinetic energy of the system. This was extended by Siacchi[2] in 1873.

In 1874 Newcomb[3] proceeded to justify his assumption regarding the expression for the coordinates as functions of the time. He applies the transformation of Jacobi and Radau to the equations of $(n+1)$ bodies, and so obtains a system of the $6n$th order. It is assumed that a set of infinite series of the forms

$$p_i = \sum \mathrm{K}_{i_1, i_2, \dots i_{3n}} \begin{matrix}\cos\\ \sin\end{matrix} (i_1\lambda_1 + i_2\lambda_2 + i_3\lambda_3 + \dots + i_{3n}\lambda_{3n})$$

can be found, where p_i is one of the coordinates and $\lambda_r = l_r + b_r t$ (the quantities l being $3n$ arbitrary constants, and the quantities b and K being functions of $3n$ other arbitrary constants), such that the differential equations are approximately satisfied by these series. Newcomb, then, using the method of variation of arbitrary constants, replaces these series by others of the same form which satisfy the differential equations to a higher degree of approximation. Proceeding in this way, it appears that the problem of three bodies can be formally solved by series of this kind.

The year 1877 saw the appearance of a paper[4] which may be regarded as the beginning of the new era in Dynamical Astronomy. The author, Mr. G. W. Hill, was at the time an assistant on the staff of the American Ephemeris.

The first of the novelties in this paper is the abandonment of Kepler's ellipse. It had hitherto been usual to take, as the first approximation to the orbit of the moon, an elliptic path round the earth; the orbit, in fact, which the moon would actually describe if the sun did not exist to disturb it; the actual path of the moon was then found by calculating the perturbations caused by the sun on this elliptic motion. Hill, however, does away with the elliptic orbit altogether, and takes, as the intermediate orbit or first approximation to the moon's path, an orbit which includes all the inequalities which depend only on the ratio of the mean motions of the sun and moon, but takes account of no other inequalities. This difference between Hill and the older theorists may be otherwise stated as follows: the old astronomers first solved the problem of two bodies, and then attempted to solve the problem of the three bodies by suitably varying the solution so obtained; whereas Hill begins by solving the restricted problem of three bodies, and then attempts to solve the problem of three bodies by suitably varying this solution.

Suppose, then, that an orbit for the particle is known, which is *periodic*, *i.e.* which is such that the two bodies and the particle retake the same relative positions after the lapse of a certain interval of time. Then the coordinates of the particle can be expressed as sums of sines and cosines of multiples of a linear function of the time. We can now consider the small

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[1] 'Note sur un théorème de mécanique céleste,' *C. R.* lxxv. pp. 1750–3.

[2] 'Sur un théorème de mécanique céleste,' *C. R.* lxxvii. pp. 1288–91.

[3] 'On the General Integrals of Planetary Motion,' *Smithsonian Contribution to Knowledge*, 1874, pp. 1–31.

[4] 'On the part of the Motion of the Lunar Perigee which is a Function of the Mean Motions of the Sun and Moon,' Cambridge, Mass., Press of John Wilson & Son.

oscillations of the particle about this orbit, when the initial conditions of its motion are not exactly such as to cause it to describe the periodic orbit. These oscillations represent those inequalities in the moon's motion which depend only on the eccentricity of the lunar orbit and the ratio of the mean motions of the sun and moon; and the period of the oscillations represents the time between two successive perigees of the moon, so that the difference between this period and the period of the orbit gives that part of the motion of the lunar perigee which is a function of the mean motions of the sun and moon—whence the title of the memoir.

Let w represent the distance (measured along the normal) of the particle from the periodic orbit, at any time t during the performance of the small oscillations. Then Hill finds that w is given by an equation of the form

$$\frac{d^2w}{dt^2}+\Theta w=0$$

where Θ depends only on the relative position of the two bodies and the particle; Θ is therefore a known periodic function of t, and can be expanded in the form

$$\Theta=\Theta_0+\Theta_1 \cos 2t+\Theta_2 \cos 4t+ \ldots,$$

where Θ_0, Θ_1, Θ_2 . . . are pure constants.

(It ought to be stated here that, since all inequalities in the moon's motion which involve the sun's parallax are neglected, the distance of the two bodies from each other is supposed to be infinite, and the one of them at infinity is supposed to possess such an (infinite) mass as would correspond to a finite mean motion.)

The problem therefore is to solve the differential equation

$$\frac{d^2w}{dt^2}+\{\Theta_0+\Theta_1 \cos 2t+\Theta_2 \cos 4t+ \ldots\}w=0.$$

Equations of this type had been discussed by the founders of dynamical astronomy, D'Alembert,[1] Lagrange,[2] and Laplace,[3] and have since been discussed by a large number of mathematicians. Tisserand called the equation

$$\frac{d^2w}{dt^2}+\{\Theta_0+\Theta_1 \cos 2t\}w=0,$$

which is a particular case of the above, the *Gyldén-Lindstedt* equation; the name does not seem very appropriately chosen, but as it has now become established we shall use it here. The same equation occurs in the Potential Theory as giving rise to the functions appropriate to the Elliptic Cylinder; it is discussed from this point of view in Heine's 'Kugelfunctionen.' The more general equation above will be called either *Hill's equation* or the *generalised Gyldén-Lindstedt equation.* The theory of these equations is a matter of pure mathematics, and the papers in

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[1] *Opuscules Mathématiques*, v. p. 336.

[2] 'Solutions de différents problèmes de calcul intégral,' *Miscellanea Taurinensia*, iii. (*Œuvres*, i. p. 586.)

[3] *Œuvres*, viii. and ix.

which it has been developed will not be reviewed here; the result important for our purpose is that an integral can be found in the form

$$w = \sum_{r=-\infty}^{\infty} a_r \cos\{(c+2r)t+a\},$$

where c depends on the coefficients in the equation, and a_r and a depend on these coefficients and on two arbitrary constants of integration. For the determination of c Hill devised the following beautiful method:—

Putting $e^{it}=\zeta$, we have $\Theta = \sum\limits_{n=-\infty}^{\infty} \theta_n \zeta^{2n}$, where the quantities θ_n are constants. Hill assumes that w is of the form $w = \sum\limits_{n=-\infty}^{\infty} b_n \zeta^{c+2n}$ and substitutes this value of w in the differential equation. Since the whole coefficient of each power of ζ must now be zero, an infinite number of equations are obtained, which involve the b's linearly; on eliminating the b's a determinant with an infinite number of rows and columns (an idea first introduced by Kotteritzsch in 1870) is obtained, which involves only c and the known quantities θ_n. This determinant, equated to zero, furnishes the value of c, and consequently the motion of the lunar perigee.

The convergence of the infinite determinant was not considered by Hill; this gap in the work was filled by Poincaré[1] in 1886.

Hill's paper was reprinted,[2] with some additions, in 1886.

In 1877, Adams,[3] referring to Hill's paper, remarks that he had himself, many years previously, investigated the motion of the moon's node by a method similar to that used by Hill for the perigee, and had found the same infinite determinant.

In 1878 Hill[4] published in a more complete form the derivation of the periodic solution, which in its character of intermediate orbit had been the foundation of his previous paper. The solution is found by actually substituting, in the differential equations of the restricted problem of three bodies, expansions of the desired form with undetermined coefficients; these coefficients are then determined as functions of a parameter m, which depends on the ratio which the period of the periodic solution bears to the period of revolution of the two principal masses round each other, *i.e.* on the ratio of the mean motions of the sun and moon. By varying m, different periodic solutions are obtained; the last one of Hill's solutions (*the orbit of maximum lunation*) has cusps at the points where the elongation from the sun is a right angle.

Hill's work soon led to further developments. In 1883–4 Poincaré,[5] using a theorem due to Kronecker in the general theory of functions,

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[1] 'Sur les déterminants d'ordre infini,' *Bulletin de la Soc. Math. de France*, xiv. pp. 77–90.

[2] 'On the part of the motion of the Lunar Perigee, which is a function of the mean motions of the Sun and Moon,' *Acta Math.* viii. pp. 1–36.

[3] 'On the motion of the Moon's Node in the case when the orbits of the Sun and Moon are supposed to have no eccentricities, and when their mutual inclination is supposed to be indefinitely small,' *Monthly Notices, Roy. Ast. Soc.* vol. xxxviii. pp. 43–9.

[4] 'Researches in the Lunar Theory,' *Amer. Journ. Math.* i. pp. 5–27, 129–48, 245–61.

[5] 'Sur certaines solutions particulières du problème des trois corps,' *C. R.* xcvii. pp. 251–2; *Bull. Astr.* i. pp. 65–74.

proved the existence of an infinite number of periodic solutions in the general problem of three bodies; and in 1887 Bohlin[1] applied an idea of Hill's (*viz.* using the Jacobian integral to separate off regions of space into which the moon cannot enter) to a more general class of dynamical problems. In the same year (1887) Hill[2] discussed the different systems of variables which might be employed in solving a system somewhat more general than the restricted problem of three bodies, namely, that of a particle of zero mass, attracted by two bodies which move in Keplerian ellipses round their common centre of gravity.

Poincaré's[3] memoirs of 1881–6 on curves defined by differential equations lead to one result of importance in Dynamical Astronomy. In order that the system of n bodies may be stable, two conditions must be fulfilled: firstly, the mutual distances must always remain within certain limits; and, secondly, if the system has a definite configuration at any instant, it must be possible to find a subsequent instant at which the configuration differs from this as little as we please. It follows from the investigations of this series of memoirs that, if the first of these conditions is satisfied, the second is also.

In 1883 Lindstedt[4] resumed the consideration of the problem which had been treated by Newcomb nine years before, namely, the expression of the coordinates in the problem of three bodies as trigonometric series, whose arguments are linear functions of the time. A fuller account[5] of the work was published in 1884. The author starts from the equations of Lagrange's 'Essai sur le problème des trois corps'; the system is reduced to four different equations, each of the second order; and these are solved by successive approximation. After the rth approximation has been effected, the $(r+1)$th approximation is obtained by solving four linear non-homogeneous differential equations with constant coefficients. This can be done by known methods; but if the solution is carried out in the usual way, terms will arise in which the time t occurs as a factor (these are the 'secular terms' of the old planetary theory). Lindstedt therefore modifies the equations in accordance with a method indicated by himself in a previous paper,[6] and obtains a solution in which t occurs only in the arguments of trigonometric functions. It thus appears that the mutual distances of the three bodies can be expressed as trigonometric series of four arguments, each of which is a linear function of the time. The defects of Lindstedt's memoir in regard to convergence, &c., will be noticed in connection with other papers.

A fresh proof of Lindstedt's results was given by Tisserand[7] in 1884–5,

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[1] 'Ueber die Bedeutung des Princips der lebendigen Kraft für die Frage von der Stabilität dynamischer Systeme,' *Acta Math.* x. pp. 109–30.

[2] 'Coplanar Motion of two Planets, one having a Zero Mass,' *Annals of Math.* iii. pp. 65–73.

[3] 'Sur les courbes définies par les équations différentielles'; *Liouville* (3) vii. pp. 375–422; (3) viii. pp. 251–96; (4) i. pp. 167–244; (4) ii. pp. 151–217.

[4] 'Sur la forme des expressions des distances mutuelles dans le problème des trois corps,' *C. R.* xlvii. pp. 1276–8, 1353–5; 'Ueber die Bestimmung der gegenseitigen Entfernungen in dem Probleme der drei Körper,' *Astr. Nachr.* cvii. pp. 197–214.

[5] 'Sur la détermination des distances mutuelles dans le problème des trois corps,' *Annales de l'Ecole Norm.* (3) i. pp. 85–102.

[6] 'Beitrag zur Integration der Differentialgleichungen der Störungstheorie, *Mémoires de l'Acad. de Saint-Pétersbourg*, xxxi. No. 4.

[7] 'Note sur un théorème de M. A. Lindstedt concernant le problème des trois corps,' *C. R.* xcviii. pp. 1207–13; 'Mémoire sur le problème des trois corps,' *Annales de l'Observatoire de Paris, Mémoires*, xviii.

on the lines of Delaunay's lunar theory; Tisserand extended Lindstedt's theorem, and in 1887 Lindstedt[1] showed how this extension could be derived from his own original paper. An imperfection in Lindstedt's first paper was removed by Poincaré[2] in 1886, who, by an ingenious application of Green's theorem, proved that only one secular term appears in each of Lindstedt's approximations, and that this can always be removed.

In 1889 Poincaré[3] gave a fresh method of derivation for Lindstedt's series, by transforming the Gyldén-Lindstedt differential equation into a Hamiltonian system of the fourth order, replacing this by the corresponding Hamilton-Jacobi partial differential equation, and solving the latter by a series proceeding in ascending powers of a small parameter, the coefficients being trigonometric series of two arguments. Poincaré observes, however, that in the problem of three bodies this method will not apply if Kepler's ellipse is taken as the first approximation, and consequently another intermediary orbit must be used.

The number of independent arguments required in order to express the coordinates in the problem of n bodies, without having the time outside trigonometric functions, was shown by Harzer[4] in 1889 to be $3(n-1)$.

The question of the convergence of sums of periodic terms, such as are obtained in Lindstedt's expansions, had now become a matter of prime importance. Poincaré[5] in 1882–4 showed, firstly, that if such a series is absolutely convergent for certain values of the time, it is so for all values of the time; and, secondly, that a function cannot be represented by two different absolutely convergent series of this kind. Further, a function represented by such a series can assume indefinitely great values if the convergence is not uniform. In a further note[6] in 1885, he showed that this can happen in two ways: either the function may steadily increase, or its value may oscillate, the amplitude of the oscillations increasing indefinitely. Bruns[7] in 1884 further discussed the series of Dynamical Astronomy: as these are usually obtained by the integration of trigonometric series, it follows that the coefficients of those terms whose periods are very long will be affected by very small divisors. Bruns shows that this causes the series to fluctuate between convergence and divergence, when the constants, on which the coefficients of the time in the arguments depend, are altered in value by small amounts.

Features of special interest present themselves in the planetary theory when the periods of two planets are very nearly commensurate with each other. In this case some of the inequalities of long period rise to importance; thus, in the theory of Jupiter and Saturn an inequality with a period of 900 years has a large coefficient; the grandeur of this coefficient is due to the fact that its denominator contains a factor

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[1] 'Ueber ein Theorem des Herrn Tisserand aus der Störungstheorie,' *Acta Math.* x. pp. 381–4.

[2] 'Sur une méthode de M. Lindstedt,' *Bull. Astr.* iii. pp. 57–61.

[3] 'Sur les séries de M. Lindstedt,' *C. R.* cviii. pp. 21–4.

[4] 'Ueber die Argumente des Problems der n-Körper,' *Astr. Nach.* cxx. pp. 193–218.

[5] 'Sur les séries trigonométriques,' *C.R.* xcv. pp. 766–8, xcvii. pp. 1471–3; 'Sur la convergence des séries trigonométriques,' *Bull. Astr.* i. pp. 319–27.

[6] 'Sur les séries trigonométriques,' *C. R.* ci. p. 131.

[7] 'Bemerkungen zur Theorie der allgemeinen Störungen,' *Ast. Nach.* cix. pp. 215–22

$5n-2n'$ (where n and n' are the mean motions of Saturn and Jupiter), and this factor is very small, on account of the approximate commensurability of n and n'. In certain cases (called *librations*) the commensurability is exact ; thus a linear relation exists between the mean motions of three of Jupiter's satellites.

Tisserand[1] in 1887 applied Delaunay's method of integration to discuss the effect of approximate commensurability, showing that commensurability is not inconsistent with the stability of the system.

Bohlin[2] in 1888–9 gave a new method for treating the cases in which terms with small divisors appear likely to endanger the convergence. He considers the equation

$$\frac{d^2\zeta}{dw^2}=-\Sigma i\beta_{ij}\sin(i\zeta-jw),$$

where the coefficients β_{ij} are of the order of the disturbing masses and form an absolutely convergent series, and where the independent variable w is, in the applications to the planetary theory, a multiple of the time.

If in this equation we write $w=-x$, $\frac{d\zeta}{dw}=-p_1$, we have

$$\frac{d\zeta}{dx}=p_1,\quad \frac{dw}{dx}=-1,\quad \frac{dp_1}{dx}=-\Sigma i\beta_{ij}\sin(i\zeta-jw),$$

which we can write

$$\frac{d\zeta}{dx}=\frac{\delta\mathrm{H}}{\delta p_1},\quad \frac{w}{dx}=\frac{\delta\mathrm{H}}{\delta p_2},\quad \frac{dp_1}{dx}=-\frac{\delta\mathrm{H}}{\delta\zeta},\quad \frac{dp_2}{dx}=-\frac{\delta\mathrm{H}}{\delta w},$$

where

$$\mathrm{H}=\tfrac{1}{2}p_1{}^2-p_2-\Sigma\beta_{ij}\cos(i\zeta-jw).$$

The solution of this Hamiltonian canonical system depends in the ordinary way on the solution of the Hamilton-Jacobi partial differential equation

$$\tfrac{1}{2}\left(\frac{\delta\mathrm{V}}{\delta\zeta}\right)^2-\frac{\delta\mathrm{V}}{\delta w}=g+\Sigma\beta_{ij}\,(\cos(i\zeta-jw).$$

This is now replaced by the equation

$$\tfrac{1}{2}\left(\frac{\delta\mathrm{V}}{\delta\zeta}\right)^2-\frac{\delta\mathrm{V}}{\delta w}=\kappa^2 g+\kappa^2\Sigma\beta_{ij}\cos(i\zeta-jw),$$

in order to mark the fact that g and the β's are small (in the applications κ^2 is the mass of the disturbing body) ; and Bohlin integrates this equation by expanding V as a power-series in κ,

$$\mathrm{V}=\mathrm{V}_0+\kappa\mathrm{V}_1+\kappa^2\mathrm{V}_2+\ldots$$

It is found that the occurrence of small divisors can be avoided in the series which represent the quantities V_r, and hence the original difficulty would appear to have been removed. It is, however, possible that large

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[1] 'Sur la commensurabilité des moyens mouvements dans le système solaire,' *C. R.* civ. pp. 259–65 ; *Bull. Astr.* iv. pp. 183–92.

[2] 'Ueber eine neue Annäherungsmethode in der Störungstheorie,' *Bihang till Kgl. Svenska Vet.-ak. Handlingar*, xiv. No. 5 ; 'Zur Frage der Convergenz der Reihenentwickelungen in der Störungstheorie,' *Ast. Nach.* cxxi. pp. 17–24.

numerators may occur, and so the question of convergence is not definitely settled.

The above expansion in powers of κ is noticeably similar to that of Poincaré.

§ IV. *Memoirs of* 1868–89 *on the Absence of Terms of certain Classes from the Infinite Series which Represent the Solution.*

The distinction between the secular and periodic inequalities of the elliptic elements of a planet's orbit has already been explained. Laplace in 1773 showed that one of these elements—the *mean distance* or *semi-major axis of the orbit*—has no secular inequalities at all, when terms of higher orders than the first powers of the masses and the squares of the eccentricities and inclinations are neglected. Lagrange in 1776 proved that this result still holds when all powers of the eccentricities and inclinations are taken into account; and in 1808 Poisson showed that it is still true when terms involving squares of the masses are included in the calculations.

In the period under review, Tisserand[1] in 1875–6 simplified Poisson's proof by using the transformation of Jacobi and Radau, thus reducing the problem of three bodies to a system of the twelfth order, depending on a single perturbing function.

In 1874–5, Mathieu[2] extended the discussion so as to include terms multiplied by the cubes of the masses. He first, by using Jacobi's substitution, replaces the sun and three planets by three fictitious planets moving round a fixed centre; the orbits of these bodies are homothetic with the actual orbits, and consequently the study of the variations of the mean distances in the fictitious orbits will give the required results. The author then, by developing the disturbing function as far as terms of the third order in the masses, shows that the reciprocals of the mean distances have no secular variations of this order.

In 1877 Haretu[3] published an extract from a memoir[4] which appeared in 1883. He uses the transformation by which Tisserand had, in 1875, simplified Poisson's work, and discusses a memoir published in 1816, in which Poisson believed he had proved the non-existence of secular terms in the mean distances, of the third order in the perturbing masses, when the variations of the elements of the disturbed planet only were taken into account. Haretu shows that Poisson had overlooked a certain class of terms, and proves that secular inequalities arise from these terms, which are not ultimately cancelled; and hence that the theorem of the invariability of the mean distances holds only to terms of the second order in the disturbing masses. Haretu, however, does not give the explicit analytical expression of the third order terms in the secular inequalities.

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[1] 'Mémoire sur un point important de la théorie des perturbations planétaires,' *Mémoires de l'Académie de Toulouse* (7) vii. pp. 374–88; *Annales de l'École Norm. Sup.* (2) vii. pp. 261–74 (merely a reprint); 'Note sur l'invariabilité des grands axes des orbites des planètes,' *C. R.* lxxxii. pp. 442–5.

[2] 'Mémoire sur les inégalités séculaires des grands axes des orbites des planètes,' *C. R.* lxxix. pp. 1045–9; *Crelle,* lxxx. pp. 97–127.

[3] 'Sur l'invariabilité des grands axes des orbites planétaires,' *C. R.* lxxxv. pp. 504–6.

[4] 'Sur l'invariabilité des grands axes des orbites planétaires,' *Annales de l'Obs. de Paris, Mémoires,* xviii. (39 pp.).

In 1889, Eginitis[1] gave the analytical expression for those secular inequalities of the mean distances which are of the third order in the disturbing forces. After showing that they can arise only from a term

$$\frac{1}{n^2a^3}\left(\int\frac{\partial R''}{\partial t}dt\right)^2,$$

where $\frac{\partial R''}{\partial t}$ denotes the aggregate of terms of the first and second order, he finds $\int\frac{\partial R''}{\partial t}dt$ by substituting the ordinary development of the disturbing function, squares it, and shows that secular inequalities arise from the multiplication of terms with the same arguments. He further shows that these secular inequalities are periodic, though their period is very long.

The transition from the old planetary theory, with its secular and periodic inequalities, to the new Dynamical Astronomy, in which all terms are periodic, had its effect on theorems such as that now under consideration. Tisserand[2] in 1888 gave the new formulation of the theorem of the invariability of the mean distances, when the solution of the problem of three bodies is expressed as in Delaunay's lunar theory. He shows that the theorem does not hold when terms of the order of the fourth power of the ratio of the mean motions are taken into account, and for the general problem of three bodies confirms Haretu's result that the theorem does not hold for terms of the order of the cube of the disturbing forces.

In 1878 Adams[3] published some curious results relating to one of the expansions in the lunar theory. Let e be the eccentricity of the lunar orbit, and let γ be the sine of half the inclination of the moon's orbit to the ellipse; these quantities are supposed defined as in Delaunay's theory: let n be the moon's mean motion, $(1-c)n$ the mean motion of the lunar perigee, $(1-g)n$ the mean motion of the moon's node, a the mean distance, and r the radius vector. Then the non-periodic part of $\frac{a}{r}$ can be expanded in the form

$$A+Be^2+C\gamma^2+Ee^4+2Fe^2\gamma^2+G\gamma^4+\ldots$$

where A, B, C ... are functions of the solar eccentricity and of the ratio of the mean motions of the sun and moon; similarly the terms in c which involve e^2 and γ^2 can be denoted by $He^2+K\gamma^2$, and the similar terms in g by $Me^2+N\gamma^2$.

Then Adams's theorems are that

$$B=0,\quad C=0,\quad EK-FH=0,\quad FN-GM=0.$$

These results are all obtained by one process, which for the case of the first may be thus described: consider two moons, of which the orbit of one has no eccentricity or inclination, and the orbit of the other has no inclination. It is proved that a certain function of the coordinates of the two moons is purely periodic; and it is shown that this requires the vanishing of the quantity B.

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[1] 'Sur la stabilité du système solaire,' *C. R.* cviii. pp. 1156–9; 'Mémoires sur la stabilité du système solaire,' *Annales de l'Obs. de Paris, Mémoires*, xix.

[2] 'Sur un point de la théorie de la Lune,' *C. R.* cvi. pp. 788–93.

[3] Note on a remarkable property of the analytical expression for the constant term in the reciprocal of the moon's radius vector,' *Monthly Notices, Roy. Astro. Soc.* xxxviii. pp. 460–72.

§ V. *Gyldén's Theory of Absolute Orbits.*

In 1881 Hugo Gyldén, Director of the Observatory at Stockholm, began the publication of a new method for calculating the motions of the heavenly bodies. The method has been made of practical importance by its application, in the hands of Gyldén's pupils, to the minor planets, and is of theoretical interest from the fact that (as in Delaunay's, Newcomb's, and Lindstedt's memoirs) the time appears only in the arguments of periodic terms. In this report it seems best to give, first of all, a general account of the method, and then briefly to notice the series of memoirs in which Gyldén and his pupils have developed it.

Consider, then, a system consisting of the sun and two planets. For convenience one of these will be spoken of as the *disturbed* and the other as the *disturbing* planet. At any instant the motion of the disturbed planet is taking place in a certain (moving) plane, which passes through the sun; this we can call the *plane of its instantaneous orbit*; in this plane we take (as an axis from which to measure angles) a line which moves with the plane in such a way that the surface formed by the motion of the line always cuts the plane orthogonally. The angle between this line and the radius vector to the planet can be called the planet's *true longitude*, and denoted by v; the radius vector from the sun to the planet will be denoted by r.

The quantities r, v are given by differential equations of the form

$$\frac{d}{dt}\left(r^2\frac{dv}{dt}\right)=\mathrm{M}\frac{\partial\Omega}{\partial v},\quad r\frac{d^2r}{dt^2}-r^2\left(\frac{dv}{dt}\right)^2+\frac{\mathrm{M}}{r}=\mathrm{M}r\frac{\partial\Omega}{\partial r},$$

where Ω (which is called the *disturbing function*) is supposed to be expressed in terms of r, v, and the quantities which define the moving plane and the position of the disturbing planet, and where M is the sum of the masses of the sun and the disturbed body.

Let the perpendicular distance of the disturbed body from some fixed plane be zr. Then the third differential equation of the disturbed body's motion may be written in the form

$$\frac{d^2(zr)}{dt^2}+\mathrm{M}zr=\text{a function of the positions of the planets.}$$

Now introduce new variables ρ, η, S connected with the old variables by the relations

$$r=\frac{a(1-\eta^2)}{1+\rho},\quad r^2\frac{dv}{dt}=\frac{\{\mathrm{M}a(1-\eta^2)\}^{\frac{1}{2}}}{1+\mathrm{S}}$$

where a is a constant called the *protometer*, as yet undetermined; as there are only two conditions here to determine the three quantities ρ, η, S we can impose another condition later.

The equations for r and v now transform into

$$-\frac{1}{1+\mathrm{S}}\frac{d\mathrm{S}}{dv}=(1+\mathrm{S})^2\mathrm{Q}+\frac{1}{2}\frac{1}{1-\eta^2}\frac{d\eta^2}{dv}$$

and

$$\frac{d^2\rho}{dv^2}+\rho=-\left\{\frac{2}{1-\eta^2}\frac{d\eta^2}{dv}+(1+\mathrm{S})^2\mathrm{Q}\right\}\frac{d\rho}{dv}+2\mathrm{S}-\mathrm{S}^2-(1+\mathrm{S})^2\mathrm{P}$$

$$-\left\{\frac{1}{1-\eta^2}\frac{d^2\eta^2}{dv^2}+\frac{2}{(1-\eta^2)^2}\left(\frac{d\eta^2}{dv}\right)^2+\frac{(1+\mathrm{S})^2}{1-\eta}\mathrm{Q}\frac{d\eta^2}{dv}\right\}(1+\rho)$$

where

$$\mathrm{P}=r^2\frac{\partial\Omega}{\partial r},\quad \mathrm{Q}=\frac{r^2}{a(1-\eta^2)}\frac{\partial\Omega}{\partial v}.$$

Also, the equation in z can be written

$$\frac{d^2z}{dv^2}+z=-(1+\mathrm{S})^2\mathrm{Q}\frac{dz}{dv}+(1+\mathrm{S})_2\mathrm{Z}_1,$$

where Z_1 is a certain function of the positions of the planets.

Now let us consider the form in which Gyldén wishes to express the solution of these equations.

The differential equations will finally be solved by means of sums of periodic terms whose arguments are linear functions of v; these terms may be classified in the following way:—

Firstly, there will be terms which vanish altogether when the disturbing mass is put equal to zero; these are called *coordinated terms*, and correspond to the 'periodic inequalities' of the classical planetary theory.

Secondly, there will be terms which, when the disturbing mass is put equal to zero, do not vanish, but coalesce with the terms which represent the Keplerian elliptic motion of the disturbed planet round the sun. These terms involve the disturbing mass in their arguments, but not in their coefficients; they are called *elementary terms*, and correspond to the 'secular inequalities' of the classical planetary theory. Terms will also occur in the course of Gyldén's process which involve the disturbing mass in the denominator of their coefficients, and so would become infinite if the disturbing mass were put equal to zero; these are called *hyper-elementary*, and it is shown that they do not appear in the final result. And, lastly, we have already seen that when the periods of two planets are nearly commensurable, certain terms of long period rise to importance; these are called the *semi-elementary* or *characteristic terms* for the planet under discussion.

The quantity ρ, as already defined, will be composed of both elementary and coordinated terms. Let (ρ) denote the elementary terms, and let R denote the coordinated terms, so

$$\rho=(\rho)+\mathrm{R}.$$

It will appear that ρ is of the form

$$(\rho)=\kappa\cos\{(1-\varsigma)v-\Gamma\}+\sum_{n=1}^{\infty}\kappa_n\cos\{(1-\varsigma_n)v-\Gamma_n\},$$

where κ (called the *diastemmatic modulus*) and Γ (called the *longitude of the absolute perihelion at the origin of time*) are two of the six constants of integration of the problem, κ_n and Γ_n are functions of the constants of integration, and ς and ς_n are small constant quantities of the order of the perturbing forces.

We can now define η; let

$$\eta \cos \pi = \kappa \cos \Gamma + \Sigma \kappa_n \cos \{(\varsigma - \varsigma_n)\, v - \Gamma_n\}$$
$$\eta \sin \pi = \kappa \sin \Gamma - \Sigma \kappa_n \sin \{(\varsigma - \varsigma_n)\, v - \Gamma_n\}.$$

Thus η contains only elementary terms, and

$$(\rho) = \eta \cos \{(1 - \varsigma)v - \pi\}.$$

η is called the *diastemmatic function*, and $(1-\varsigma)v-\pi$ is called the *diastemmatic argument.*

If in the expressions for the coordinates we strike out all the coordinated terms, leaving only those which are elementary, these modified expressions for the coordinates will define a new orbit, which will be so near to the true orbit that the difference between them will be only of the same order of magnitude as the disturbing forces. This new orbit may be called the *absolute orbit.* The *radius vector in the absolute orbit* (r) is thus defined by

$$(r) = \frac{a(1-\eta^2)}{1+(\rho)}.$$

The variable z can be divided into two parts just as ρ was; thus

$$z = (z) + Z,$$

where (z) contains all the elementary terms; (z) is of the form

$$(z) = i \sin \{(1+\tau)v - \Theta\} + \sum_{n=1}^{\infty} i_n \sin \{(1+\tau_n)v - \Theta_n\}$$

where i (called the *anastemmatic modulus*) and Θ (called the *longitude of the absolute node*) are two more of the six constants of integration of the problem, and τ, i_n, τ_n, Θ_n are constants depending on them. If this be written in the form

$$(z) = \mathrm{J} \sin \{(1+\tau)v - \Omega\}.$$

J is called the *anastemmatic function*, and $(1+\tau)v-\Omega$ is called the *anastemmatic argument.*

Gyldén (who, however, is not in this particular followed by his pupil Harzer) further introduces a quantity ζ called the *reduced time*, which is defined by the equation

$$\frac{d\zeta}{dv} = \frac{a^{\frac{3}{2}}}{\mathrm{M}^{\frac{1}{2}}} \frac{(1-\eta^2)^{\frac{3}{2}}}{\{1+(\rho)\}^2},$$

and a quantity called the *time reduction*, $\frac{a^{\frac{3}{2}}}{\mathrm{M}^{\frac{1}{2}}}\mathrm{W}$, defined by

$$t = \zeta + \frac{a^{\frac{3}{2}}}{\mathrm{M}^{\frac{1}{2}}}\mathrm{W}.$$

W therefore satisfies the differential equation

$$\frac{d\mathrm{W}}{dv} = \frac{(1-\eta^2)}{\{1+(\rho)\}^2} \left[\frac{1+\mathrm{S}}{\left\{1+\frac{\mathrm{R}}{1+(\rho)}\right\}^2} - 1 \right];$$

the integration of this will clearly introduce another arbitrary constant, which will be denoted by Λ, and will be called the *absolute longitude*, or *mean longitude for* $t=0$.

The six arbitrary constants which have now been defined are the *elements* which fix the absolute orbit of the disturbed body, namely, Λ (the absolute longitude), Γ (the longitude of the absolute perihelion), Θ (the longitude of the absolute node), a (the protometer), κ (the diastemmatic modulus), and i (the anastemmatic modulus).

Having now described the form in which the solution is to be obtained, we can resume the consideration of the differential equations.

First, we have to expand in a suitable way the disturbing function Ω and the quantities P and Q. This is effected by means of infinite series, each term of which consists of a product of powers of the various small quantities such as η, multiplied by a trigonometrical function of the longitude.

Next, we have to substitute these expansions in the differential equations for ρ, ς, and W, and integrate these equations.

The equations for ρ and S are respectively of the forms

$$\frac{d^2\rho}{dv^2}+(1-\beta)\rho=\Sigma a_n \cos(\lambda_n v-\beta_n),$$

$$\frac{dS}{dv}=\Sigma b_n \cos(\lambda_n v-\beta_n),$$

where the quantities λ_n are constants, but the quantities a_n, b_n, β_n contain the unknown variables. These equations are solved by processes of successive approximation; only those terms are initially retained which have a considerable effect, and in this way the elementary part (ρ) is determined. A feature of Gyldén's treatment of equations such as that given above for ρ is the use of the *horistic function*, which is a modification of the term containing the first power of the dependent variable, and is designed to ensure the convergence of the approximations.

We may regard the arbitrary constants κ and Γ as arising from the integration of the equation in ρ, i and Θ as arising from that in z, a as arising from that in S, and Λ as arising from that in W.

The principal papers in which Gyldén's theory has been developed will now be briefly noticed. In 1881 Gyldén published three short papers [1] in French and German, and three long memoirs in Swedish.[2] The derivation of the differential equations of the first Swedish memoir was simplified by Backlund [3] and Callandreau.[4]

Further notes and criticisms on the early part of the theory of intermediate orbits were given in 1882 by Thiele [5] and Radau.[6] The

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[1] 'Sur la théorie du mouvement des corps célestes,' *C. R.* xcii. pp. 1262–5; 'Sur l'intégration d'une équation différentielle linéaire du deuxième ordre dont dépend l'évection,' *C. R.* xciii. pp. 127–31; 'Ueber die Theorie der Bewegungen der Himmelskörper,' *Ast. Nach.* c. p. 97.

[2] 'Undersökningar af theorien för himlakropparnas rörelser,' *Bihang till K. Sv. Vet.-ak. Handlingar*, vi. and vii. I wish gratefully to record my obligations to Mr. W. F. Sedgwick, late Scholar of Trinity College, Cambridge, who has kindly placed at my disposal a manuscript English translation of the *Undersökningar*, with many corrections of his own.

[3] 'Ableitung von Professor Gyldén's Differentialgleichungen für die intermediäre Bewegung,' *Ast. Nach.* ci. pp. 19–22; Professor Gyldén's 'Neue Untersuchungen über die Theorie der Bewegung der Himmelskörper,' *Copernicus*, ii.

[4] 'Sur la théorie du mouvement des corps célestes,' *C. R.* xciii. pp. 779–81.

[5] 'Ueber Professor Gyldén's intermediäre Bahnen,' *Ast. Nach.* cii. pp. 65–70.

[6] 'Sur un point de la théorie des perturbations,' *C. R.* xcv. pp. 117–20.

notion of the absolute orbit and the definitions of elementary and coordinated terms are introduced in the second part of the 'Undersökningar.' Gyldén wrote another paper[1] on this in 1882, and in the same year discussed further[2] one of the differential equations of his theory of intermediate orbits.

A long series of papers dealing with the processes for integrating differential equations of the second order by successive approximation, and with the convergence of the developments, was published[3] by Gyldén in 1882–96. On this see also Harzer.[4]

In 1885 Gyldén[5] and Shdanow[6] applied the theory of intermediate orbits, which had been given in the 'Undersökningar,' to the case of the moon's motion. The problem is made to depend on the solution of the Gyldén-Lindstedt equation, and the results yield an approximation to the motion of the perigee. Andoyer[7] also applied Gyldén's theory to the moon in 1887; and Tisserand[8] in 1888 discussed the Gyldén-Lindstedt equation, and applied his results to Andoyer's equations.

Harzer[9] in 1886 applied Gyldén's ideas to the determination of the motion of those of the minor planets (*e.g.* Hecuba) whose mean motion is approximately twice as great as that of Jupiter. On account of this approach to commensurability, some of the characteristic terms become very important. Harzer modifies Gyldén's original procedure in two respects: firstly, in using the true longitude throughout as the independent variable; and, secondly, in abandoning the use of the 'reduced time.'

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[1] 'Ueber die absoluten Elemente der Planeten-Bahnen,' *Ast. Nach.* ciii. pp. 49–58.

[2] 'Sur l'équation différentielle qui donne immédiatement la solution du problème des trois corps jusqu'aux quantités de deuxième ordre inclusivement,' *C. R.* xcv. pp. 55–8.

[3] 'Eine Annäherungsmethode im Probleme der drei Körper,' *Acta Math.* i. pp. 77–92; 'Untersuchungen über die Convergenz der Reihen, welche zur Darstellung der Coordinaten der Planeten angewendet werden,' *ibid.* ix. pp. 185–294; 'Nouvelles recherches sur les séries employées dans les théories des planètes,' *ibid.* xv. pp. 65–189; xvii. pp. 1–168; 'Ueber die Convergenz einer in der Störungstheorie vorkommenden Reihe,' *Ast. Nach.* cxix. pp. 321–30; 'Bemerkungen über die Convergenz der nach der Potenzen der störenden Kräfte geordneten Annäherungen im Störungsproblem,' *ibid.* cxxi. pp. 80–94; 'Sur une équation différentielle du second ordre, non linéaire et à coefficients doublement périodiques,' *C. R.* cxxii. pp. 160–5; 'Remarques ultérieures relativement à ma dernière communication à M. Hermite,' *ibid.* cxxii. pp. 585–8; 'Om bestämningen af ojemnheter med mycket lång period i theorien för planeters och satelliters rörelser,' *Öfversigt af Kongl. Vet.-ak. För.* lii. pp. 419–32; 'En transformation af den differentialekvation, som bestämmer ojemnheterna med mycket långa periorder i en planets longitud,' *ibid.* lii. pp. 503–6; 'Olika methoder att bestämma de horistika termerna i den differentialekvation, som förmedlar hädledningen af ojemnheterna i en planets longitud,' *ibid.* liii. pp. 421–30.

[4] 'Ueber eine Differentialgleichung der Störungstheorie,' *Ast. Nach.* cxix. pp. 273–94.

[5] 'Sur l'orbite intermédiaire de la Lune,' *C. R.* ci. pp. 223–6; 'Die intermediäre Bahn des Mondes,' *Acta Math.* vii. pp. 125–72.

[6] *Recherches sur le mouvement de la Lune autour de la Terre d'après la Théorie de M. Gyldén*, Stockholm, 1885.

[7] 'Contribution à la théorie des orbites intermédiaires,' *Annales de la Fac. des Sc. de Toulouse,* i.

[8] 'Sur une équation différentielle du second ordre qui joue un rôle important dans la mécanique céleste,' *ibid.* ii.

[9] 'Untersuchungen über einen speciellen Fall des Problems der drei Körper,' *Mémoires de Saint-Pétersbourg*, xxxiv. No. 12; 'Quelques remarques sur un cas spécial du problème des trois corps,' *Astronomiska Iakttagelser och Undersökningar anstälda på Stockholms Observatorium,* iii. No. 4.

Some criticisms on Harzer's paper (and also on Brendel's paper of 1889) were made by Charlier[1] in 1890; and Harzer himself made some corrections in 1891.[2] Brendel[3] in 1887 derived Harzer's equations as a special case of Gyldén's system.

After this several applications of Gyldén's theories to definite cases were published. Wellmann[4] in 1888 discussed the intermediate orbit of Thetis, and Brendel[5] in 1889 found the absolute orbit of planets of the Hestia type, whose mean motion is approximately triple that of Jupiter.

Some developments useful in the theory were given in 1889 by Masal,[6] and improvements in the integration of the equations were introduced by Wolf[7] in 1890.

Backlund[8] in 1892 discussed by Gyldén's methods the motion of the group of small planets whose mean motion is approximately twice that of Jupiter; in distinction to Gyldén and Harzer he takes the time as the independent variable. The same subject was treated by an improved analysis in a number of papers[9] published in 1897–8.

Researches in connection with the properties of series such as those occurring in Gyldén's work were published by Gyldén[10] and Backlund[11] in 1889, and by Olsson[12] in 1890 and 1891.

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[1] *Vierteljahrsschrift der Astron. Gesells.* xxv. p. 175.

[2] 'Berichtigung zur Abhandlung "Untersuchungen über einen speciellen Fall des Problems der drei Körper,"' *Ast. Nach.* cxxvi. p. 399.

[3] 'Ueber einige in neuerer Zeit angewandte Formen für Differentialgleichungen im Problem der drei Körper,' *ibid.* cxvi. pp. 161–6.

[4] 'Die intermediäre Bahn des Planeten ⑰ Thetis nach Herrn Gyldéns Theorie,' *Archiv der Math. u. Physik* (2) vi. pp. 353–91.

[5] 'Om Användningen af den absoluta Störungsteorien på en Grupp af små planeterna, med numerisk Tillämpning på Planeten ㊻ Hestia,' *Astr. Iakttagelser och Under. anst. på Stockholms Obs.* iv. No. 3; 'Sur les perturbations de la planète ㊻ Hestia, d'après la théorie de M. Gyldén,' *C. R.* cviii. pp. 49–51; *Ueber die Anwendung der Gyldén'schen absoluten Störungstheorie auf die Breitenstörungen einer gewissen Klasse kleiner Planeten*, Inaugural-Dissertation, Göttingen, 1890.

[6] 'Formeln und Tafeln zur Berechnung der absoluten Störungen der Planeten,' *Kgl. Svenska Vet-ak. Handlingar*, xxiii. No. 7.

[7] *Sur les termes élémentaires dans l'expression du rayon vecteur*, Habilitationsschrift, Stockholm, 1890.

[8] 'Ueber die Bewegung einer gewissen Gruppe der kleinen Planeten,' *Mémoires de l'Acad. de Saint-Pétersbourg* (7) xxxviii. No. 11.

[9] 'Ueber die Integration der Differentialgleichung des Radius vector einer gewissen Gruppe der kleinen Planeten,' *Bulletin de l'Acad. de Saint-Pétersbourg* (5) vi. pp. 311–19; 'Sur la détermination des termes à longues périodes dans l'expression de la longitude des petites planètes du type de Hécube,' *Bull. Astr.* xiv. pp. 321–5; 'Deuxième méthode pour la détermination des termes à longues périodes dans l'expression de la longitude des petites planètes du type de Hécube,' *ibid.* xv. pp. 5–9; 'Formeln zur Berechnung angenäherten Bahnen der kleinen Planeten vom Hecuba-Typus, nebst ihrer Anwendung auf den Planeten (184) Dejopeja,' *Astr. Nach.* cxlv. pp. 241–8; 'Ueber die Bewegung der kleinen Planeten des Hecuba-Typus,' *Mémoires de l'Acad. de Saint-Pétersbourg* (8) i.

[10] 'Sur les termes élémentaires dans les coordonnées d'une planète,' *C. R.* cviii. pp. 79–82, 116–9; 'Sur la représentation analytique des perturbations des planètes,' *ibid.* cix. pp. 395–6.

[11] 'Ueber die Kleiner Divisoren bei den elementären Gliedern in der Theorie der Planetenbewegungen,' *Astr. Nach.* cxxii. pp. 273–302.

[12] 'Bemerkungen über die Integrationsmethoden der Zeitreduction in der

Gyldén in 1893 published the first volume of a work[1] which was intended to furnish, in three volumes, a complete exposition of his theory of absolute orbits. His death occurred in 1896 before the second volume was ready, but it is expected that Dr. Backlund, who has charge of Gyldén's manuscript, will as far as possible carry out the original design.

Backlund[2] in 1896 described a method, founded on Gyldén's work, for integrating the differential equation which determines the radius vector in the case of minor planets whose mean motion is nearly twice that of Jupiter. Brendel[3] in the same year discussed the relation of Gyldén's series to the gaps in the distribution of the minor planets; in 1897 Brendel[4] announced that he had found an improved process of integration, and in 1898 the same author published the theoretical part[5] of a memoir in which the motions of the minor planets are discussed by a modified form of Gyldén's process; the second part, which is not yet published, is to deal with definite applications to the solar system.

§ VI. *Progress in* 1890–8 *of the Theories of* §§ *III. and IV.*

A new impetus was given to Dynamical Astronomy in 1890 by the publication of a memoir[6] by Poincaré.

The first feature is the introduction of *integral invariants.* We can regard a system of ordinary differential equations

$$\frac{dx_1}{dt}=X_1, \ldots \frac{dx_n}{dt}=X_n$$

as defining the motion of a point whose coordinates are $(x_1, x_2, \ldots x_n)$ in space of n dimensions. If now we consider a group of such points which occupy a ν-dimensional region ζ_0 at the beginning of the motion, they will at any subsequent time t occupy a region ζ. A ν-ple integral taken over ζ is called an *integral invariant* if it has the same value at all times t. Thus, in the motion of an incompressible fluid, the volume of the fluid which was contained initially in any given region is an integral invariant.

Poincaré gives a number of integral invariants which exist in particular cases, and then proceeds to apply his results to the question of the *stability* of the motion in the problem of three bodies. There are, he remarks, two senses in which the word 'stability' may be taken. It may be taken to mean that variations in the mean distances of the bodies are always restrained within finite limits—Hill and Bohlin have proved that under

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Gyldén'schen Theorie,' *Archiv f. Math. og Natur.* Christiania, xiv. pp. 1–10 (1890); 'Ueber die Convergenz der Annäherungen in der Gyldén'schen Störungstheorie,' *ibid.* pp. 232–9; 'Untersuchung über eine Gruppe von langperiodisch elementären Gliedern in der Zeitreduction,' *Bihang till k. Sv. Vet-ak. Handlingar*, xvii. No. 4.

[1] *Traité analytique des orbites absolues des huit planètes principales,* tome 1, 'Théorie générale des orbites absolues,' Stockholm.

[2] 'Sur l'intégration de l'équation différentielle du rayon vecteur d'un certain groupe des petites planètes,' *C. R.* cxxii. pp. 1103–7.

[3] 'Ueber die Lücken im System der Kleiner Planeten und über ein Integrationsverfahren im Probleme der drei Körper,' *Ast. Nach.* cxl. pp. 145–60.

[4] 'Ueber stabile und instabile Bewegungen in unserem Planetensystem,' *Jahresbericht der Deutscher Math. Verein*, vi. pp. 123.

[5] 'Theorie der kleinen Planeten,' erster Theil, *Abhandlungen der Kön. Ges. der Wiss. zu Göttingen*, Neue Folge, i. No. 2.

[6] 'Sur le problème des trois corps et les équations de la dynamique,' *Acta Math.* xiii. pp. 1–220.

certain conditions the motion in the restricted problem of three bodies is, in this sense, stable,—or stability[1] may be taken (as by Poisson) to mean that the system is to pass infinitely often through positions as near as we please to the initial position; the intervening oscillations may be of any magnitude.

The existence of asymptotic solutions (which will be explained later) shows that an infinite number of particular solutions of the restricted problem of three bodies exist, which are not stable in Poisson's sense of the word. But M. Poincaré now proves that there are also an infinite number which are stable, and, further, that the former are the exception and the latter are the rule, in the same sense as commensurable numbers are the exception and incommensurable numbers are the rule. In other words, the probability that the initial circumstances may be such as to give rise to an unstable solution is zero.

The proof of this is made to depend on the following theorem; when the point $(x_1, x_2, \ldots x_n, y_1, y_2, \ldots y_n)$ moves so that its coordinates are always finite, and the integral invariant

$$\int dx_1 \ldots dx_p,\quad dy_1 \ldots dy_n$$

exists, then for every region r_0 in space, however small this region may be, there exist trajectories which pass through r_0 an infinite number of times; and, in fact, those points of r_0 which do not give rise to such trajectories form a volume which is infinitely small compared with r_0.

It is thus shown that, when the constant of relative energy in the restricted problem of three bodies lies between certain limits, *the motion is stable* not only in the sense of Hill and Bohlin, but in the sense of Poisson; the number of exceptional cases to which this law does not apply being infinitely small in comparison with the number of orthodox cases. The result is, however, not extended to the general problem of three bodies.

The author next passes to the theory of *periodic solutions.*

Consider a system of differential equations

$$\frac{dx_i}{dt}=\mathrm{X} \quad (i=1, 2, \ldots n),$$

where the X's are functions of $x_1, x_2, \ldots x_n$, and a parameter μ; $\mathrm{X}_1, \mathrm{X}_2, \ldots \mathrm{X}_n$ may also involve t, but if so they are supposed to be periodic functions of t with a period 2π.

A *periodic solution* of these equations of period T is of the form

$$x_i=\phi_i(t), \quad (i=1, 2, \ldots n)$$

where the functions ϕ are such that $\phi_i(t+\mathrm{T})=\phi_i(t)$. (If x_i is an angular variable, this may become $\phi_i(t+\mathrm{T})=\phi_i(t)+2n\pi$, where n is an integer.)

The meaning of this for our purpose is, of course, that the relative motion of the moving bodies repeats itself at regular intervals T of time.

Suppose that, for the value 0 of the parameter μ, these equations admit of a periodic solution,

$$x_i=\phi_i(t), \quad (i=1, 2, \ldots n)$$

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[1] A discussion of general definitions of stability is given in the second volume of Klein and Sommerfeld's *Theorie des Kreisels.*

the period being, for example, 2π. The question is now propounded, whether the system admits of periodic solutions differing but little from this, when μ has values which, though very small, are different from zero. M. Poincaré finds the answer. *By choosing, as initial values of the coordinates, certain functions of μ, it is in general possible to obtain such periodic solutions.*

It is further shown that as μ varies, *periodic solutions disappear in pairs* in the same way as the real roots of algebraic equations. This happens when a certain functional determinant is zero.

Poincaré next proceeds to define the *characteristic exponents* of a periodic solution.

Suppose that a periodic solution, as above, has been found. Consider a motion differing but little from this, and defined by

$$x_i = \phi_i(t) + \xi_i, \quad (i=1, 2, \ldots n),$$

where the quantities ξ are supposed to be so small that their squares and products can be neglected.

Then to determine the ξ's we have

$$\frac{d\xi_i}{dt} = \sum_\kappa \xi_\kappa \frac{\delta X_i}{\delta x_\kappa}, \quad (i=1, 2, \ldots n).$$

As these are linear differential equations of a definite type, with periodic coefficients, ξ_i will be a sum of n quantities, each of the form $e^{a_\kappa t} S_{i\kappa}$, where the quantities $S_{i\kappa}$ are periodic functions of t with the same period as $\phi_i(t)$, and the n constants a_κ are the roots of a certain algebraical equation.

The constants a are called the *characteristic exponents* of the periodic solution. If they are purely imaginary the ξ's will remain small, and the periodic solution is stable; if not, the solution is unstable.

If two of the characteristic exponents are equal, the form of the solution is altered, as the terms of the form te^{at} now appear.

When the original equations have the Hamiltonian canonical form, the characteristic exponents can be arranged in pairs, the exponents in each pair being numerically equal, but of contrary signs. The n values of a^2 are called the *coefficients of stability* of the periodic solution considered; if they are all real, negative, and distinct there is stability. When the Hamiltonian function does not involve t, one of the n coefficients of stability is zero, so two of the characteristic exponents are zero.

The author now shows that the functional determinant already mentioned vanishes only when one of the characteristic exponents of the original periodic solution is zero; the theorem already given can thus be put in the more precise form.

If a set of equations, which depend on a parameter μ, admit of a periodic solution when $\mu=0$, for which no one of the characteristic exponents is zero, then they also admit of a periodic solution for small values of μ.

Poincaré then turns to the periodic solutions of the differential equations of dynamics. For greater definiteness, the system is supposed to have three degrees of freedom; the equations are taken in the form—

$$\frac{dx_i}{dt} = \frac{\delta F}{\delta y_i}, \quad \frac{dy_i}{dt} = -\frac{\delta F}{\delta x_i}, \quad (i=1, 2, 3)$$

and F is supposed to be a uniform function of the x's and y's independent of t, and to be periodic in the y's of period 2π. F is further supposed to depend on an arbitrary parameter μ, and to be expansible in the form

$$F=F_0+\mu F+\mu^2F_2+\mu^3F_3+\ldots$$

where F_0 does not involve the quantities y.

When $\mu=0$, the equations can be integrated; x_1, x_2, x_3 are in this case constant, and

$$y_i=n_it+w_i, \text{ where } n_i=-\frac{\delta F_0}{\delta x_i},$$

the quantities w_i being arbitrary constants of integration. The solution will be periodic if n_1, n_2, n_3 are commensurable with each other; the period T will then be the least common multiple of the quantities

$$\frac{2\pi}{n_1}, \quad \frac{2\pi}{n_2}, \quad \frac{2\pi}{n_3}$$

In general, it will be possible to choose x_1 x_2, x_3 so that n_1, n_2, n_3 may have any prescribed values—at least in some domain; so that there are ∞^3 periodic solutions, when μ is zero.

The author next proceeds to investigate whether periodic solutions of period T exist, when μ is not zero. By a process of reasoning similar to that used before, it is shown that, corresponding to any periodic solution which exists when $\mu=0$, and whose constants satisfy certain conditions, *there exists in general a solution of period* T when μ has small values different from zero. The quantities x_i and y_i-n_it can be expressed as series of ascending powers of μ, the coefficients in which are circular functions of $\frac{2\pi t}{T}$; and a method of forming these expansions is given.

The results are applied to the restricted problem of three bodies; a difficulty arises, which in this case is solved by a simple artifice, but which is not so easily disposed of in the general problem of three bodies.

Still considering the dynamical system with three degrees of freedom, Poincaré considers a solution

$$x_i=\phi_i(t)+\xi_i, \quad y_i=\psi_i(t)+\eta_i,$$

differing but little from a periodic solution, and writes

$$\xi_i=e^{\alpha t}S_i, \quad \eta_i=e^{\ t}T_i,$$

where S_i and T_i are periodic functions of t.

When the periodic solution corresponds to $\mu=0$, the six exponents α are all zero; when μ is not zero it is shown that the quantities α, S_i, and T_i are *expansible in ascending powers* (not of μ, but) *of* $\sqrt{\mu}$. It is shown that to every set of values of n_1 and n_2 there correspond at least one stable and one unstable periodic solution; and that there are exactly as many stable solutions as unstable when μ is sufficiently small.

The next idea to be introduced is that of *asymptotic solutions.* Returning to the general system

$$\frac{dx_i}{dt}=X_i, \quad (i=1, 2, \ldots n)$$

let

$$x_i=x_i^0$$

define a known periodic solution.

Put
$$x_i = x_i^0 + \xi_i.$$

The system now becomes a set of n equations to determine the ξ's ; if these are solved on the supposition that squares and products of the ξ's can be neglected, the solution is of the form

$$\xi_i = A_1 e^{\alpha_1 t} \phi_{1i} + A_2 e^{\alpha_2 t} \phi_{2i} + \dots + A_n e^{\alpha_n t} \phi_{ni},$$

where the A's are constants of integration, the α's are the characteristic exponents, and the ϕ's are periodic functions of t. In order to solve the equations when products of the ξ's are not neglected, assume

$$\xi_i = \eta_1 \phi_{1i} + \eta_2 \phi_{2i} + \dots + \eta_n \phi_{ni}.$$

The equations determining the η's can now be written down ; it is proved that they can be solved by assuming each of the quantities η to be a series of ascending powers of $A_1 e^{\alpha_1 t}$, $A_2 e^{\alpha_2 t}$, ... $A_n e^{\alpha_n t}$; the A's being constants of integration, and the coefficients being periodic functions of t.

In general, some of the quantities α will have their real parts negative. The other α's can be got rid of in the expression for ξ by taking the corresponding A's to be zero. Then, when t increases indefinitely, ξ_i will diminish indefinitely ; in other words, the solutions thus obtained approximate more and more closely to the original periodic solution as the time increases ; they are called *asymptotic solutions.*

Similarly, another class of solutions can be obtained which differ widely from the periodic solution when $t = +\infty$, but approximate to it for $t = -\infty$. These form a second kind of asymptotic solutions.

In the case $n=2$, the solution can be represented by the locus of a point whose coordinates are

$$e^{x_1} \cos t, \quad e^{x_1} \sin t, \quad x_2.$$

If the solution is periodic, this locus is a closed curve in space, and the solutions asymptotic to it are represented by curves asymptotic to this curve. The aggregate of these asymptotic curves is called an *asymptotic surface* ; there will of course be two asymptotic surfaces corresponding to $t = \infty$ and $t = -\infty$ respectively, and each of them passes through the periodic curve.

M. Poincaré then discusses the case in which the original equations

$$\frac{dx_i}{dt} = X_i \quad (i = 1, 2, \dots n)$$

contain a parameter μ. It is shown that, when the X's and the characteristic exponents α of the periodic solution are expansible in powers of μ, the coordinates of a point describing an asymptotic solution can also be expressed as series of ascending powers of μ.

The theory of asymptotic solutions is then specially developed for the differential equations of dynamics. The system is taken in the form

$$\frac{dx_i}{dt} = \frac{\delta F}{\delta y_i}, \quad \frac{dy_i}{dt} = -\frac{\delta F}{\delta x_i}, \quad (i = 1, 2, \dots n)$$

where F is expansible in powers of μ.

It has already been shown that the characteristic exponents α are developable in powers of $\sqrt{\mu}$, and are all zero when $\mu = 0$. It is now proved that series can be found which proceed in ascending powers of the quantities $\sqrt{\mu}$, $A_i e^{\alpha_i t}$, $e^{t\sqrt{-1}}$, and $e^{-t\sqrt{-1}}$, and satisfy formally the differential equations which must be satisfied by the coordinates in an asymptotic solution ; but that these series are not convergent.

The series in question belong, in fact, to that important class of developments which are now called *Asymptotic Expansions* ; of which the best-known examples are Stirling's series for the Γ-function,

$$\Gamma(z)=\sqrt{2\pi}\, z^{z-\frac{1}{2}}e^{-z}+\ldots,$$

and the so-called 'semiconvergent' expansions for the Bessel functions and Riemann's ζ-function. An example given by M. Poincaré is the function

$$F(w,\mu)=\sum_n \frac{w^n}{1+n\mu}$$

This series converges uniformly when μ is positive and $|w|<w_0$, where w_0 is a positive quantity less than unity. If $F(w,\mu)$ is developed in ascending powers of μ, it becomes

$$\sum_{n,p} w^n(-n)^p\mu^p.$$

This series does not converge, but is an asymptotic expansion ; that is to say, if ϕ_p denote the sum of those terms for which the index of μ is not greater than p, the quantity

$$\frac{F(w,\mu)-\phi_p}{\mu^p}$$

tends to zero as μ takes a sequence of positive values tending to zero. The series thus represents the function $F(w,\mu)$ for small values of μ in the same way as Stirling's series represents the Γ-function for large values of z. The series found in this section are of the same character, regarded as functions of $\sqrt{\mu}$ for small values of μ.

Passing in the second part of the memoir to the special discussion of a dynamical system with two degrees of freedom, the author studies the asymptotic surfaces, which have already been defined. An infinite number of *doubly asymptotic solutions* is shown to exist ; these belong at the same time to both of the classes of asymptotic solutions, *i.e.* they are approximately periodic when $t=-\infty$ and $t=\infty$, but are not periodic in the meantime.

Poincaré next discusses *periodic solutions of the second kind.* Suppose that a set of periodic solutions of the kind already discussed is known, the expressions for the coordinates being expansible in ascending powers of μ. Let μ_0 be a definite value of μ. In certain cases there exists a set of periodic solutions, in which the expressions for the coordinates are expansible in ascending powers of $(\mu-\mu_0)^{\frac{1}{2}}$. These are called *periodic solutions of the second kind.* Their period is approximately a multiple of the period of the solution from which we started. When $\mu>\mu_0$ there are two of these solutions of the second kind corresponding to each value of μ ; when $\mu=\mu_0$ they coalesce into a single solution of the first kind, namely, the member for $\mu=\mu_0$ of the set of solutions from which we started ; when $\mu<\mu_0$ they are imaginary.

Poincaré now goes on to discuss the question of the convergency of Lindstedt's series. He takes the differential equations in the form

$$\frac{dx_1}{dt}=\frac{\delta F}{\delta y_1},\quad \frac{dx_2}{dt}=\frac{\delta F}{\delta y_2},\quad \frac{dy_1}{dt}=-\frac{\delta F}{\delta x_1},\quad \frac{dy_2}{dt}=-\frac{\delta F}{\delta x_2}$$

where

$$F=F_0+\mu F_1$$

and F_0 is a function of x_1 and x_2 only. The x's and y's are regarded as functions of w_1 and w_2, where

$$w_1=\lambda_1 t+\varpi_1,\quad w_2=\lambda_2 t+\varpi_2,$$

and where

$$\left.\begin{aligned} x_i&=\sum_{\kappa=0}^{q}\mu^\kappa x_i^\kappa \\ y_i&=w_i+\sum_{\kappa=1}^{q}\mu^\kappa y_i^\kappa \\ \lambda_i&=\sum_{\kappa=0}^{q}\mu^\kappa \lambda_i^\kappa \end{aligned}\right\}\quad (i=1,\ 2)$$

The author sketches Lindstedt's result, that the constants λ_i^κ can be so determined that these expressions for x_i and y_i (in which x_i^κ and y_i^κ are periodic functions of w_1 and w_2) may formally satisfy the above differential equations, with an error of the order μ^{q+1}.

The series are first assumed to be uniformly convergent; and it is shown that if this assumption were true, all the characteristic exponents of the periodic solutions (which arise when λ_1 is commensurable with λ_2) would be zero. Since this is not the case, the assumption must be false; and thus the result is obtained, that Lindstedt's series do not converge uniformly for all values of the arbitrary constants of integration which they contain.

The author next discusses the nature of the integrals of the differential equations, other than those integrals which are already known.

The system

$$\frac{dx_i}{dt}=\frac{\delta F}{\delta y_i},\quad \frac{dy_i}{dt}=-\frac{\delta F}{\delta x_i}\quad (i=1,\ 2)$$

has an integral

$$F(x_1,\ x_2,\ y_1,\ y_2)=\text{constant}.$$

Suppose, if possible, that another integral exists of the form

$$\phi(x_1,\ x_2,\ y_1,\ y_2)=\text{constant},$$

where ϕ is a uniform analytic function of μ, x_1, x_2, y_1, y_2, and is periodic in y_1 and y_2, of period 2π. It is proved that in this case the equations

$$\frac{\frac{\delta F}{\delta x_1}}{\frac{\delta\phi}{\delta x_1}}=\frac{\frac{\delta F}{\delta x_2}}{\frac{\delta\phi}{\delta x_2}}=\frac{\frac{\delta F}{\delta y_1}}{\frac{\delta\phi}{\delta y_1}}=\frac{\frac{\delta F}{\delta y_2}}{\frac{\delta\phi}{\delta y_2}}$$

must be satisfied at all points of all periodic solutions. It is then further shown that these equations must be satisfied identically; thus ϕ is a function of F, and so the two integrals ϕ and F are not distinct.

Hence the result. The system possesses no integral (other than the integral F), which is a uniform analytic function of x_1, x_2, y_1, y_2, μ for all values of y_1 and y_2, for small values of μ, and for values of x_1 and x_2 contained within certain limits, and which is periodic in y_1 and y_2.

This forms an important complement to Bruns's result, which will be reviewed in the next section of this report.

The last section of Poincaré's memoir is occupied with the extension of the results, which have been obtained for systems with two degrees of freedom, to more general systems, *i.e.* to the problem of n bodies.

Poincaré's paper gave a fresh stimulus to the investigation of periodic solutions. In 1890 v. Haerdtl[1] calculated numerically two cases of the restricted problem of three bodies. Charlier[2] in 1892 discussed the same cases by means of expansions proceeding in ascending powers of the time, and the same author[3] in 1893 found a set of periodic solutions of the problem of three bodies in a plane, whose expansion involves four arbitrary constants; the mutual distances of the bodies are given as series of ascending powers of a quantity

$$\{a^2 + a'^2 - 2a' \cos(\lambda t + \epsilon)\}^{\frac{1}{2}},$$

the coefficients in the series being constants.

Callandreau[4] in 1891 discussed the equations which lead by successive approximations to solutions differing but little from periodic solutions.

Lord Kelvin[5] in 1892 traced by graphic methods a looped orbit, which may be regarded as a continuation of the set of periodic solutions which Hill believed to be terminated by the moon of maximum lunation.

Coculesco[6] in 1892 proved the stability (in both Hill's and Poisson's senses) of the motion in one of the cases treated by v. Haerdtl. The motion of the same system, under fresh conditions of projection, was investigated in 1894 by Burrau[7]; in the second paper he considers those purely libratory motions in which the zero particle does not, in the relative movement, circulate round either of the other bodies, and finds that the series of solutions is terminated by an *orbit of ejection*, in which the zero particle starts from a collision with one of the other bodies. These libratory orbits were further discussed in 1895 by Thiele,[8] and (by use of Poincaré's theory) by Perchot[9] and Mascart.

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[1] 'Skizzen zu einen speciellen Fall des Problems der drei Körper,' *Abhand. der K. Bayer. Ak. in München*, xvii. pp. 589–644.

[2] 'Studier öfver tre-kroppar-problemet,' *Bihang till K. Sv. Vet.-ak. Handlingar*, xviii. No. 6.

[3] *Ibid.* xix. No. 2.

[4] 'Sur quelques applications des théories concernant les solutions particulières périodiques du problème des trois corps et l'intégration des équations différentielles linéaires à coefficients périodiques,' *Bull. Astr.* viii. pp. 49–67.

[5] 'On Graphic Solution of Dynamical Problems,' *Brit. Assoc. Report*, 1892, pp. 648–52; *Phil. Mag.* xxxiv. p. 447.

[6] 'Sur la stabilité du mouvement dans un cas particulier du problème des trois corps,' *C. R.* cxiv. pp. 1339–41.

[7] 'Recherches numériques concernant des solutions périodiques d'un cas spécial du problème des trois corps,' *A. N.* cxxxv. pp. 233–40, cxxxvi. pp. 161–74.

[8] *Ibid.* cxxxviii. pp. 1–10.

[9] 'Sur une classe de solutions périodiques dans un cas particulier du problème des trois corps,' *C. R.* cxx. pp. 906–9; *Bull. Ast.* xii. pp. 329–52.

Poincaré's method for the direct calculation of periodic solutions of dynamical systems was modified in 1895 by Kobb,[1] so as to be applicable to the problem of three bodies.

Darwin in 1896 published a preliminary notice[2] of a paper[3] which appeared in 1897, and in which a large number of periodic solutions are calculated numerically. The case considered is the restricted problem of three bodies; two of the bodies, S and J, revolve round each other in circular orbits, and the mass of the third body P is zero. Darwin finds six families of periodic orbits; in one (Planet A), P describes a closed path round S, as in Hill's periodic orbit; in two others (oscillating Satellites *a* and *b*) P oscillates about a position on the line joining S and J, as in the libratory motions of Burrau, Thiele, and Perchot and Mascart; and in the remaining three (Satellites A, B, C), P describes a closed path round J. In the numerical work, the mass of S is supposed to be ten times the mass of J. When different values are assumed for the constant of energy, the orbits of these families change their form, pass from stability to instability and *vice versâ*, and even go out of existence altogether.

Another class of periodic solutions of the restricted problem of three bodies was found in 1898 by Schwarzschild.[4]

An application of Poincaré's theories in a different direction was made in 1893 by Perchot.[5] In the first part of his memoir the coefficients of the principal periodic inequalities of the longitudes of the lunar node and perigee are calculated; the author takes the equations in Delaunay's form, and applies the theory of periodic solutions. In the second part, the secular variations of the eccentricities and inclinations are discussed, with the aid of Poincaré's theory of stability.

The theories of periodic solutions, characteristic exponents, asymptotic solutions, and the non-existence of uniform integrals were somewhat more completely discussed in 1892 by Poincaré[6] himself in the first volume of his treatise on the new developments of dynamical astronomy. The second volume, which was published in 1893, and contains a good deal of matter which had not appeared in the memoir of 1891, opens with a chapter on asymptotic expansions; after this the author discusses, by Jacobi's method, Lindstedt's theory of the solution of the equations of dynamics by means of sums of periodic terms, using his own proof of its applicability, as given originally in *C. R.* cviii. Newcomb's method is shown to be fundamentally equivalent to Lindstedt's. Lindstedt's theory is then applied, firstly, to prove a result obtained by Poincaré[7] in 'C. R.' cxiv. regarding the expression of the secular inequalities in the planetary

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[1] 'Sur le calcul direct des solutions périodiques dans le problème des trois corps,' *Öfversigt af K. Sv. Vet.-ak. Förh.* lii. pp. 215-22.

[2] 'On Periodic Orbits,' *Brit. Assoc. Report*, 1896, pp. 708–9.

[3] 'Periodic Orbits,' *Acta Math.* xxi. pp. 99–242; *Math. Annalen*, li. pp. 523–83.

[4] 'Ueber eine Classe periodischer Lösungen des Dreikörperproblems,' *Astr. Nach.* cxlvii. pp. 17–24; 'Ueber weitere Classe periodischer Lösungen des Dreikörperproblems,' *ibid.* pp. 289–98.

[5] 'Sur les mouvements des nœuds et du périgée de la lune, et sur les variations séculaires des excentricités et des inclinaisons,' *Annales de l'Ec. Norm. Sup.* (5) x. suppl. pp. 3–94.

[6] *Les Méthodes Nouvelles de la Mécanique Céleste*, Paris, Gauthier-Villars, vol. i. 1892, vol. ii. 1893, vol. iii. 1898.

[7] 'Sur l'application de la méthode de M. Lindstedt au problème des trois corps,' *C. R* cxiv pp. 1305–9.

theory as sums of periodic terms, and, secondly, to effect the general expansions in the problem of three bodies; as explained in the paper referred to, there is a difficulty here, since in Kepler's ellipse the node and perihelion are fixed, and thus there is a linear relation between the mean motions of the arguments used. This difficulty is surmounted, and another is considered in the following chapter, arising from the fact that if the eccentricities are very small (supposing that e is used as one of the variables, and not $e \cos \varpi$ and $e \sin \varpi$), some of the developments break down. It is shown that this difficulty can be avoided by taking as starting-point a periodic solution instead of Kepler's ellipse.

The author then proceeds to discuss the convergency of Lindstedt's expansions; his results in this connection were disputed by Hill,[1] and led to some controversy.

After some interesting remarks on the theorem of the secular invariability of the mean distances, Poincaré proceeds to show how the coefficients in Lindstedt's series can be calculated directly, without the complicated transformations which were introduced in the proof of their existence; and then a new way of forming Lindstedt's series is explained, in which half of the original equations of motion are replaced by the equation of energy and certain equations involving an auxiliary function S. Two equalities which can be used in the verification of these processes were given in 1895.[2]

The first half of the book may be said to centre round a theorem, which may be stated as follows:—

Let the equations of dynamical astronomy be given in the form

$$(1) \qquad \frac{dx_i}{dt}=\frac{\delta F}{\delta y_i}, \quad \frac{dy_i}{dt}=-\frac{\delta F}{\delta x_i}, \quad (i=1, 2, \ldots n).$$

The function F is periodic in the quantities y, and may depend on the x's in any manner. Moreover, certain of the terms are small in comparison with others, and the order of magnitude of the different terms may be put in evidence by introducing a small quantity μ, and developing F in ascending powers of μ, in the form

$$F=F_0+\mu F_1+\mu^2 F_2+\ldots \qquad .$$

F_0 does not involve the quantities y.

Then it is proved that the equations (1) can be formally satisfied by series of the form

$$(2) \qquad \begin{cases} x_i=x_i^{(0)}+\mu x_i^{(1)}+\mu^2 x_i^{(2)}+\ldots \\ y_i=w_i \quad +\mu y_i^{(1)}+\mu^2 y_i^{(2)}+\ldots \end{cases} \quad (i=1, 2, \ldots n)$$

where the quantities $x_i^{(\kappa)}$ and $y_i^{(\kappa)}$ are periodic functions of the quantities

$$w_i=n_i t+\varpi_i\,; \quad (i=1, 2, \ldots n) \qquad ;$$

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[1] Hill (1895), 'On the Convergence of the Series used in the subject of Perturbations,' *Bull. Amer. Math. Soc.* ii. pp. 93–7. Poincaré (1896), 'Sur la divergence des séries de la Mécanique Céleste,' *C.R.* cxxii. pp. 497–9. Hill (1896), 'Remarks on the Progress of Celestial Mechanics since the middle of the century,' *Bull. Amer. Math. Soc.* ii. pp. 125–36. Poincaré (1896), 'Sur la divergence des séries trigonométriques, *C. R.* cxxii, pp. 557–9.

[2] 'Sur un procédé de vérification, applicable au calcul des séries de la Mécanique Céleste,' *C. R.* cxx. pp. 57–9.

the quantities ϖ_i are constants of integration; the quantities n_i are constants (called the *mean motions*) which can be developed as power-series in μ. The quantities $x_i^{(\kappa)}$ and $y_i^{(\kappa)}$ can themselves be developed in series of the form

$$(3) \qquad x_i^{(\kappa)}(\text{or } y_i^{(\kappa)})=\Sigma A \cos (m_1 w_1+m_2 w_2+\ \ldots\ +m_n w_n+h).$$

Suppose for simplicity that $n=2$. If the ratio of the mean motions is commensurable, one of the terms of the series (3) becomes infinite; leaving this case, it is shown (pp. 96, 97) that incommensurable values of the ratio of the mean motions can be sorted into two categories—those for which the series converges and those for which the series diverges—and in every interval, however small, there are values of the first category, and also values of the second category; in particular, the series converges for incommensurable values whose square is commensurable. The convergence is in no case uniform. By an artifice, however, the series (3) can be regarded as composed of only a finite number of terms, and so the series (2) can be formed.

What may be regarded as the second half of the book begins, in the sixteenth chapter, with an introduction to Gyldén's theory; the Gyldén-Lindstedt equation is treated by the methods of chapter ix. and by those of Gyldén, Bruns, Hill, and Lindstedt; and then the author proceeds to the more difficult of Gyldén's differential equations. The last three chapters of the volume are devoted to an exposition of Bohlin's method, and to an extension in which some of the limitations of Bohlin's work are removed.

The theorem regarding the expression of the coordinates as trigonometric series was still further improved[1] by Poincaré in 1897. It is shown that the coordinates in the problem of three bodies can be expressed by series proceeding in ascending powers of a small parameter μ of the order of the two small masses, and of several constants ρ of the order of the eccentricities and inclinations. These series are periodic functions of five arguments:

$$w_1=n_1 t+\varpi_1, \quad w_2=n_2 t+\varpi_2, \quad \omega_1=\nu_1 t+\varepsilon_1, \quad \omega_2=\nu_2 t+\varepsilon_2, \quad \omega_3=\nu_3 t+\varepsilon_3.$$

Here ϖ_1, ϖ_2, ε_1, ε_2, ε_3 are constants of integration; n_1, n_2, ν_1, ν_2, ν_3 are functions of μ, the quantities ρ, and two other constants z_1 and z_2, and can be expanded as power-series in μ and the quantities ρ^2; the coefficients in the series depend on z_1 and z_2. The quantities n_1 and n_2 may be called the mean motions of the planets; z_1^2 and z_2^2 may be called their mean distances; ϖ_1 and ϖ_2 correspond to their longitudes at the epoch, the quantities ρ to the eccentricities and inclinations, the quantities ω to the longitudes of the perihelia and nodes. The development of n_1 and n_2 in powers of μ commences with terms of order 0, while the development of ν_1, ν_2, ν_3 commences with terms of order one, so the w's vary quickly and the ω's vary slowly. Terms whose arguments are compounded of the ω's only may, by analogy with the older theories, be called secular terms. Poisson's theorem on the invariability of the mean distances, in its new interpretation, is proved in the course of the paper. The mutual distances of the bodies depend only on the differences of the above five arguments.

The third (and last) volume of Poincaré's book was published in

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[1] 'Sur l'intégration des équations du problème de trois corps', *Bull. Astr.* xiv. pp. 261–70.

1898–9. The first half of it is devoted to the theory of Invariant Integrals, which is given here in a more developed form than in the memoir of 1890; while the second half is concerned chiefly with the theory of periodic solutions of the second kind. Since the publication of the 1890 memoir, periodic solutions had been connected by the author[1] with the theory of least action. In the first of the two notes referred to it is shown that the existence of periodic solutions of different kinds can be inferred from the principle of least action, when the law of attraction is some inverse power of the distance higher than the square; in the second note, a classification of unstable periodic solutions is made, which depends on the principle of least action; and it is shown that when the constants of the motion are varied, a periodic solution cannot pass from one kind of instability to the other. In this volume, the theory of least action is further applied.

After developing the theory of periodic solutions of the second kind, Poincaré shows that some of the results of Darwin's paper of 1897 are in accordance with his own theorems, and criticises others; and terminates the book by a study of doubly-asymptotic solutions.

Since 1892 Brown[2] has published several memoirs dealing with the lunar theory on the plan projected by Hill. The first paper extends Hill's paper of 1878 by including in the work the inequalities which involve the sun's parallax; in other words, Hill found periodic solutions of the motion of a particle in a plane under the influence of two bodies which revolve round each other in circular orbits, and whose distance apart is infinite, while Brown supposes this distance to be finite. In the second paper the inequalities dependent on the moon's eccentricity are included, *i.e.* the general solution of Hill's problem, which of course is not periodic, is found. The investigations of the third paper relate to the more general problem of the moon's motion, and include a deduction and extension of the theorems of Adams's memoir of 1878. (See § IV.) Brown is at present preparing a complete numerical lunar theory.

In 1895 Hill[3] calculated numerically the periodic solution, which may be taken as the base of the lunar theory, and in 1896 Liapounow[4] discussed Hill's series, and proved their convergence in the case of the actual motion of the moon.

Andoyer[5] in 1890 gave another method for finding the solution of the differential equations of Dynamical Astronomy by means of series of periodic terms. He obtains the series directly by assuming that they are of the required form but with undetermined coefficients, and finds these coefficients by successive approximation. It is shown that the mean distances of the planets contain no long-period terms of orders zero or one, which corresponds to the theorem of the invariability of the mean distances.

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[1] 'Sur les solutions périodiques et le principe de moindre action,' *C. R.* cxxiii. pp. 915–8 (1896); 'Les solutions périodiques et le principe de moindre action,' *ibid.* cxxiv. pp. 713–6 (1897).

[2] 'On the part of the Parallactic Inequalities in the Moon's motion which is a function of the mean motions of the Sun and Moon,' *Amer. Jour. Math.* xiv. pp. 141–60 (1892); 'The Elliptic Inequalities in the Lunar Theory,' *ibid.* xv. pp. 244–63, 321–38 (1893); 'Investigations in the Lunar Theory,' *ibid.* xvii. pp. 318–58 (1895).

[3] 'The Periodic Solution as a first approximation in the Lunar Theory,' *Ast. Jour.* xv. pp. 137–43.

[4] *Transactions of the Physical Section of the Imp. Soc. of Nat. &c. Moscow*, viii.

[5] 'Sur les formules générales de la Mécanique Céleste,' *Annales de la Fac. de Toulouse*, iv. K. 35 pp.

The same author[1] in 1896 showed that a theorem analogous to the invariability of the mean distances can be obtained for a general class of dynamical systems.

The solution of canonical systems of equations by series was discussed in 1891–2 by Wand[2]; suggestions for directing the approximations in the problem of n bodies were published in 1891 by Laska,[3] and in 1897 by Kövesligethy,[4] and (for solving the differential equation for the mean distance) in 1893 by Gyldén.[5] The first part of a paper[6] published by Newcomb in 1895 contains a solution of the problem of three bodies based on continued approximation. Hill[7] in 1893 and 1897 showed how, by dividing the potential function otherwise than in the old theories, an intermediate orbit may be obtained which is free from the disadvantages of Kepler's ellipse; and Krassnow[8] in 1898–9 obtained an intermediate orbit for the moon, making the suppositions of the restricted problem of three bodies, by integrating a Hamilton-Jacobi partial differential equation, in which small quantities of the third order are neglected.

Painlevé[9] in 1896 showed that the problem of three bodies can be integrated by means of series of polynomials, convergent for all values of t, except when the initial conditions are such that two of the bodies collide after a finite interval of time. The same author[10] in 1897 showed that the conditions which must be satisfied in order that, after a finite interval of time, two of the bodies may collide, cannot be algebraical conditions.

Brown[11] in 1897 discussed the properties of the general solution in trigonometric series of the problem of three bodies, by supposing it to have been derived by integrating the Hamilton-Jacobi equation. Several properties of the constants of the solution are deduced, including those previously given by Newcomb. In a second paper,[12] the same method is applied to the Lunar Theory, and Adams's theorems on the constant part of

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[1] 'Sur l'extension que l'on peut donner au théorème de Poisson, relatif à l'invariabilité des grands axes,' *C. R.* cxxiii. pp. 790–3.

[2] 'Ueber die Integration der Differentialgleichungen, welche die Bewegungen eines Systems von Punkten bestimmen,' *Ast. Nach.* cxxvi. pp. 129–38, cxxvii. pp. 353–60, cxxx. pp. 377–90.

[3] 'Zur Berechnung der absoluten Störungen,' *Sitzungsberichte der k. Böhm. Ges. der Wiss.*, Prague, 1891, pp. 147–53.

[4] 'Störungen im Vielkörpersystem,' *Mathem. u. Natur. Berichte aus Ungarn*, xiii. pp. 380–412.

[5] 'Ueber die Ungleichheiten der grossen Axen der Planetenbahnen,' *Ast. Nach.* cxxxiii. pp. 185–90.

[6] 'Action of the Planets on the Moon,' *American Ephemeris Papers*, v. Part III.

[7] 'On Intermediate Orbits,' *Annals of Maths.* viii. pp. 1–20 (1893). 'On Intermediary Orbits in the Lunar Theory,' *Astron. Journ.* xviii. pp. 81–7 (1897).

[8] 'Zur Theorie der intermediären Bahnen des Mondes,' *Ast. Nach.* cxlvi. pp. 7–10; 'Weitere Mittheilung betreffend die Theorie der intermediären Bahnen des Mondes,' *ibid.* cxlvi. pp. 337–40; 'Zur Integration der Jacobi'sche Differentialgleichung für die Mondbewegung,' *ibid.* cxlviii. pp. 37–42.

[9] 'Sur les singularités des équations de la Dynamique et sur le problème des trois corps,' *C. R.* cxxiii. pp. 871–3.

[10] 'Sur les cas du problème des trois corps (et des n corps) où deux des corps se choquent au bout d'un temps fini,' *C. R.* cxxv. pp. 1078–81.

[11] 'On the application of Jacobi's Dynamical Method to the General Problem of Three Bodies,' *Proc. Lond. Math. Soc.* xxviii. pp. 130–42. There is a slight error in result (x.), p. 141 of the paper.

[12] 'On certain properties of the Mean Motions and the Secular Accelerations of the principal arguments used in the Lunar Theory,' *Proc. Lond. Math. Soc.* xxviii. pp. 143–55.

the lunar parallax, in the generalised form previously given by the author, are shown to be simple deductions from a single equation.

Researches relating to the convergence of the trigonometric series of dynamical astronomy were published in 1896 by Charlier[1] and in 1898 by Poincaré.[2] The former, by expanding in descending powers of m the coefficient of the mth term in such a series, arrived at the conclusion that the convergence can be augmented by dividing the function expressed into two parts, one of which depends on the first terms in these expansions of the coefficients. In Poincaré's paper the author first connects the series of the older theories, in which the time occurs explicitly, with the new expansions, and then observes that the slow convergence of the latter is to some extent compensated for by the fact that the terms can be grouped together in such a way that, although the individual terms of a group may be large, yet their sum is small. The latter part of the paper is devoted to showing how the expansions which represent periodic and asymptotic solutions can be derived from the general expansions.

§ VII. *The Impossibility of Certain Kinds of Integrals.*

Poincaré's theorem on the non-existence of uniform integrals of the problem of three bodies, other than those already known, has already been reviewed in § VI. Before the publication of Poincaré's memoir, however, an important theorem on the non-existence of algebraic integrals had been obtained by Bruns.[3]

In Bruns's paper, the differential equations of the problem are first taken, in their unreduced form, as a system of the $6n$th order; they can be written

$$\frac{dx_r}{dt}=y_r, \quad \frac{dy_r}{dt}=f_r(x_1, x_2, \ldots x_{3n}, \varsigma), \quad (r=1, 2, \ldots 3_n)$$

where ς denotes the sum of all the mutual distances of the bodies; the reason for introducing ς is that the quantities f are rational functions of $x_1, x_2, \ldots x_{3n}, \varsigma$, whereas they would be irrational functions of $x_1, x_2,—x_{3n}$ alone. ς is a function of the x's, given as a root of an algebraical equation.

Bruns supposes that this system of equations possesses an integral of the form $\phi(x_1, x_2, \ldots x_{3n}, y_1, y_2, \ldots y_{3n})$, where $\frac{d\phi}{dt}=0$ and where ϕ is an algebraic function of its arguments. ϕ must therefore be a root of an algebraic equation whose coefficients are rational functions of the quantities x, y, and which we may take to be irreducible. On differentiating this, it appears that either the coefficients of the algebraic equation in ϕ are themselves integrals, or else ϕ satisfies an equation of lower degree, whose coefficients are rational in the quantities x, y, ς. In this way it is proved that all integrals which are algebraic functions of the quantities x and y are algebraic combinations of other integrals which are themselves rational functions of the quantities x, y, and ς. We need

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[1] 'Ueber die trigonometrischen Entwickelungen in der Störungstheorie,' *Ast. Nach.* cxli. pp. 273–8.

[2] 'Sur la façon de grouper les termes des séries trigonométriques qu'on rencontre en mécanique céleste,' *Bull. Astr.* xv. p. 289–310.

[3] 'Ueber die Integrale des Vielkörper-Problems,' *Berichte der Kgl. Sächsischen Ges. der Wiss. zu Leipzig*, 1887, pp. 1–39, 55–82; *Acta Math.* xi. pp. 25–96.

therefore only consider this latter class of integrals. It is shown that integrals of this class can be compounded of another kind of integrals, called by Bruns *homogeneous*. When a homogeneous integral is resolved into factors which are rational integral functions of the quantities y, it appears that each of these factors either is itself an integral or can be made into an integral by associating certain factors with it; and so, finally, every integral of the problem of n bodies which is algebraic in the variables x, y, and is independent of t, can be compounded algebraically from integrals of a very special class, which are rational integral functions of the quantities y, and rational functions of the quantities x and ς, and which are, moreover, homogeneous. It is further shown that if ϕ denote an integral of this last class, and ϕ_0 denote the terms in it which are of highest order in the quantities y, then φ_0 involves the x's rationally and integrally, and only by means of the expressions $(y_1 x_r - y_r x_1)$, and ϕ_0 does not involve ς.

Now let A, B, C be the three components of angular momentum of the system, let L′, M′, N′ be the three components of linear momentum, let L, M, N be the coordinates of the centre of gravity, and let

$$A' = MN' - NM', \quad B' = LN' - L'N, \quad C' = LM' - L'M;$$

all these quantities are supposed to be expressed in terms of the quantities x and y, so that any one of them equated to a constant represents one of the known integrals of the system of differential equations. Then it is shown that ϕ_0 involves the variables x only in the combinations A, B, C, A′, B′, C′, and is a rational integral function of A, B, C, A′, B′, C′, and the y's; and then ϕ_0 is proved to be a rational integral function of A, B, C, A′, B′, C′, L′, M′, N , T, say

$$\phi_0 = f(A, B, C, A', B', C', L', M', N', T).$$

Now let $-U$ be the potential energy of the system, so $T-U$ is an integral. Then the quantity

$$J = f(A, B, C, A', B', C', L', M', N', T-U)$$

is also an integral, since it is compounded solely of integrals; and when it is arranged according to powers of the variables y it coincides with the integral ϕ in the terms of highest degree. The difference

$$\phi' = \phi - J$$

is therefore an integral of the same kind as ϕ, except that its degree in the variables y is at least one unit lower than the degree of ϕ in these variables. Thus any integral ϕ can be made to depend on the known integrals and an integral of lower degree in the y's: proceeding in this way, ϕ can be made to depend on the known integrals and an integral of the same kind as ϕ, but of zero degree in the y's; but such an integral would be a constant. Thus Bruns arrives at the theorem: *In the problem of* n *bodies, the only integrals which involve the coordinates and velocities algebraically, and which do not involve the time explicitly, are compounded of the integrals of the centre of gravity, of angular momentum, and of energy.*

Bruns then proceeds to the reduction of the differential equations of the problem of three bodies which has already been given in § 1 of this report, and shows that the system of the 6th order at which he arrives has no algebraic integrals, and that it is not possible by any algebraic transformation which leaves the canonical form of the equations unaltered to obtain any further separation of the variables analogous to the elimination of the nodes.

In the second part of the paper (pp. 67–96), the author first, by an easy extension of the previous result, shows that no integrals exist which involve the time and the variables algebraically, except the known integrals, and then finds the *integral-equations* of the reduced system of equations for the problem of three bodies, *i.e.* functions of the variables whose derivatives with respect to the time vanish when the functions themselves vanish ; and shows that the only integral-equation is the one whose vanishing expresses the condition that the motion takes place in one plane.

The author then discusses the question, whether any integrals of the reduced system exist in the form of integrals of algebraic total differentials, *i.e.* the generalised Abelian integrals which have since been studied by Picard. This also is shown to be impossible ; and, lastly, this result can be extended to the problem of *n* bodies, since, if such an integral existed for the problem of *n* bodies, a corresponding integral for the problem of three bodies could be derived by equating all but three of the masses to zero.

A defect in Bruns's proof (pp. 37 *sqq.* of Bruns's paper) was pointed out and remedied by Poincaré[1] in 1896.

Gravé[2] in 1896 showed that the differential equations of the problem of three bodies, in the form given by Bertrand, possess no integrals independent of the law of attraction other than those already known ; and Painlevé[3] in 1897–8 extended Bruns's result, by showing that every integral of the problem of *n* bodies which involves the velocities algebraically (whether the coordinates are involved algebraically or not) is an algebraic combination of the known integrals of energy and momentum

On Solar Radiation.—Report of the Committee, consisting of Dr. G. JOHNSTONE STONEY (*Chairman*), Professor H. McLEOD (*Secretary*), Sir G. G. STOKES, Professor A. SCHUSTER, Sir H. E. ROSCOE, Captain W. de W. ABNEY, Dr. C. CHREE, Professor G. F. FITZGERALD, Professor H. L. CALLENDAR, Mr. G. J. SYMONS, Mr. W. E. WILSON, and Professor A. A. RAMBAUT, *appointed to consider the best Methods of Recording the Direct Intensity of Solar Radiation.*

THE Balfour Stewart actinometer is now in the hands of Professor Callendar, who proposes to employ it in connection with one of his bolometric methods.

The Committee therefore asks for reappointment.

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[1] 'Sur la méthode de Bruns,' *C. R.* cxxiii. pp. 1224–8.

[2] 'Sur le problème des trois corps,' *Nouvelles Annales* (3) xv. pp. 537–47.

[3] 'Sur les intégrales premières de la Dynamique et sur le problème des *n* corps, *C. R.* cxxiv. pp. 173–6, 1897 ; 'Mémoire sur les intégrales premières du problème des *n* corps,' *Bull. Astr.* xv. pp. 81–113, 1898.

Electrolysis and Electro-chemistry.—Report of the Committee, consisting of Mr. W. A. SHAW (*Chairman*), Mr. E. H. GRIFFITHS, Rev. T. C. FITZPATRICK, Mr. S. SKINNER, *and* Mr. W. C. D. WHETHAM (*Secretary*), *appointed to report on the Present State of our Knowledge in Electrolysis and Electro-chemistry.*

The conductivity of a number of salts in very dilute aqueous solution at the freezing point of water has been determined by Mr. Whetham, while Mr. Griffiths has concurrently made observations of the freezing point for corresponding solutions. The observations of conductivity extend to solutions of sulphuric acid, potassium chloride, sodium chloride, barium chloride, copper sulphate, potassium permanganate, potassium bichromate, and potassium ferricyanide. The range of dilution is, speaking generally, from below the hundred-thousandth to about the twentieth part of a gram equivalent per thousand grams of solution.

The water used was specially distilled three times, and finally from a platinum still, and collected in platinum vessels. Its approximate conductivity was about $1{\cdot}1 \times 10^{-15}$ at 18° C. in C.G.S. units. The best water obtained by Kohlrausch by distillation in vacuo had a conductivity of $0{\cdot}2 \times 10^{-15}$ in the same units at the same temperature.

The results obtained this year, while confirming those described at the last meeting of the Association for solutions of moderate concentrations, show differences when great dilutions are reached, but the constancy of the present measurements shows that the water now used is good enough to enable trustworthy values to be obtained even at the lowest limits of dilution above mentioned.

Mr. Griffiths has remodelled his apparatus for determination of freezing points, and is now able to carry the measurements of temperature to a higher degree of accuracy than hitherto.

As soon as the observations are completed it is intended to publish the results of both investigations together.

No further progress has been made with the rest of the Report.

Tables of Certain Mathematical Functions.—Report of the Committee, consisting of Lord KELVIN (*Chairman*), Lieutenant-Colonel ALLAN CUNNINGHAM, *R.E.* (*Secretary*), Dr. J. W. L. GLAISHER, Professor A. G. GREENHILL, Professor W. M. HICKS, Major P. A. MACMAHON, and Professor A. LODGE, *appointed 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.*

THE Tables (Binary Canon) were reported *complete* last year. The Committee only wait for a grant to proceed with the printing, estimated at 120*l.* for 100 copies, or 135*l.* for 200 copies; a portion of which would be hereafter repaid by the sale of copies of the Tables.

Seismological Investigations.—Fourth Report of the Committee, consisting of Professor J. W. JUDD (*Chairman*), Mr. JOHN MILNE (*Secretary*), Lord KELVIN, Professor T. G. BONNEY, Sir F. J. BRAMWELL, Mr. C. V. BOYS, Professor G. H. DARWIN, Mr. HORACE DARWIN, Major L. DARWIN, Professor J. A. EWING, Professor C. G. KNOTT, Professor R. MELDOLA, Mr. R. D. OLDHAM, Professor J. PERRY, Professor J. H. POYNTING, Mr. CLEMENT REID, Mr. G. J. SYMONS, *and* Prof. H. H. TURNER. *Drawn up by the Secretary.*

CONTENTS.

I. *On Seismological Stations already established.*

INSTRUMENTS of the same type have been forwarded to the following twenty-three stations :—Shide, Kew, Toronto, Victoria, B.C., San Fernando (Spain), Madras, Bombay, Calcutta, Batavia, Mauritius, Cape Town, Arequipa, Strathmore College (Philadelphia), Tokio, Cordova (Argentina), New Zealand (two instruments), Cairo, Paisley, Mexico, Beyrout, Honolulu, and the last to Trinidad.

It is expected that shortly instruments will be installed in Ireland, New South Wales, and Victoria, and your Secretary has had correspondence about the establishment of seismographs in other countries.

The following Report contains registers from the first eleven of the above-mentioned stations, and reports from several of the remainder are expected to arrive shortly.

The principal analysis of these registers has been made in reference to the one from Shide, but as many earthquakes have been recorded which did not reach that station, but were common to groups of observatories in other parts of the world, it is evident that if similar analyses are made in reference to other localities, our knowledge respecting the distribution of seismic disturbances will be largely increased. Should any of the observers who have forwarded copies of their observations to Shide consider it advisable to undertake this work, it is hoped that this report will be of assistance in carrying out the same.

The Committee thank the Directors of observatories in Italy, Germany, and Russia for copies of records corresponding to those obtained in Shide. For the purpose of seeing the installation in the Isle of Wight and discussing records, Shide has been visited by Colonel Gore, R.E., of the Trigonometrical Survey of India, Mr. R. D. Oldham, of the Geological Survey of that country, Dr. Figee, in charge of the instrument in Batavia, Mr. T. F. Claxton, Director of the Observatory in Mauritius, Dr. F.

Ōmori, in charge of Seismological Observatories in Japan, Mr. T. Heath, of the Royal Observatory, Edinburgh, and by many others directly or indirectly interested in the work of this Committee.

II. *Notes respecting Observing Stations and Registers obtained from the same.*

1. *England: Isle of Wight, Newport, Shide. Observer*, Mr. J. Milne.

The continuity of records obtained from this station has largely been dependent upon the interest shown in the work by Shinobu Hirota, Mr. Milne's assistant.

At rare intervals, usually in consequence of some irregularity in the band of bromide paper, the clock driving the same has been stopped. Failures due to this cause have been extremely few. The greater number of failures arise from 'air tremors,' which during the winter months, in frosty weather, and at night are frequent. Slight continuous movements of the boom produced by these air currents have no doubt eclipsed many small earthquakes, and have certainly hidden the commencement of larger disturbances. These difficulties, which occur from time to time, and interfere with observations for at least one month out of twelve, are not likely to be overcome until the instrument is moved to a larger and better ventilated room.

A pair of horizontal pendulums recording on smoked paper have given records of the periods of earth vibrations.

The Shide Register.

The following register is compiled from the photographic records of a Milne Horizontal Pendulum, and refers to E.W. displacements. The time used is Greenwich Mean Civil Time. Midnight=24 or 0 hours.

Amp.=Amplitude, or half the complete range of motion. It is expressed in millimetres. 1 mm.=0″·5 of arc. Records of ·5 mm. or less refer to a mere thickening of the line, and indicate half its width.

D=Duration expressed in hours, minutes and seconds.

P.T.'s=Preliminary Tremors, the duration of which is from the first movement to the maximum motion.

L.W.'s=Large waves, and refers to the maximum motion.

Doubtful means that it is not certain that the record refers to earthquake motion.

The instrument stands on a brick pier founded on the upended beds of hard chalk.

No.	Date	Time of Commencement	Remarks
		1898.	
		H. M. S.	
170	Feb. 27	11 7 44	Amp. ·25mm. D 4m.
171	Mar. 3	15 37 34	Doubtful.
172	" 4	16 53 35	"
173	" 4	21 13 46	Amp. ·25mm. D 6m.
174	" 5	16 35 12	Doubtful.
175	" 17	16 44 22	"
176	" 19	4 45 29	Amp. ·25mm. D 2m.
177	" 21	22 51 50	Thirteen small group up to 1h. 30m. on 22nd. Max. about 0h. 30m.
178	" 23	20 48 6	Amp. ·25mm. D 2m.

THE SHIDE REGISTER—*continued.*

No.	Date	Time of Commencement	Remarks
		H. M. S.	
179	Mar. 28	17 44 28	Amp. ·5mm. D 4m.
	„ 28	18 11 55	„ „ „ 3m.
	„ 28	18 21 5	„ „ „ „
	„ 28	23 44 5	„ ·25mm. „ „
180	„ 29	0 5 11	„ „ „ 7m.
	„ 29	13 33 0	This is the first of at least 28 distinct disturbances, with durations of from 2 to 6 minutes. Those marked with an asterisk commenced gently, and the others abruptly. The largest of the series is that at 15h. 56m. 12s., which has an amplitude of 1mm., and a duration of 7m. Other marked members in the series are at 15h. 29m. 30s., 17h. 23m. 2s., and 18h. 54m. 33s. Many of these are of doubtful character.
	„ 29	15 29 30*	
	„ 29	15 46 36	
	„ 29	15 49 48	
	„ 29	15 56 12*	
	„ 29	16 13 16	
	„ 29	16 39 18	
	„ 29	16 53 32	
	„ 29	17 3 42	
	„ 29	17 13 52	
	„ 29	17 15 54	
	„ 29	17 23 2*	
	„ 29	17 27 6	
	„ 29	17 58 37	
	„ 29	18 12 51	
	„ 29	18 27 6	
	„ 29	18 54 33*	
	„ 29	19 35 14	
	„ 29	19 38 17	
	„ 29	20 12 51	
	„ 29	20 27 6	
	„ 29	20 30 9	
	„ 29	21 56 35	
	„ 29	22 1 40	
	„ 29	22 8 47	
	„ 29	22 43 22	
	„ 29	22 51 30	
	„ 29	23 0 39	
181	„ 30	12 7 0	Amp. 1mm. D 6m.
182	„ 31	8 21 1	Maxima at 5·7, and 11m. later. Amp. 1mm. D 24m.
183	„ 31	11 24 56	Doubtful. Amp. ·5mm. D 10m.
184	„ 31	13 15 42	The first of a series of 22 very slight shocks, ending at 5 P.M. Greatest amp. 1mm.
	„ 31	13 45 12	
	„ 31	13 59 26	
	„ 31	14 15 42	
185	April 3	7 38 35	Amp. ·5mm. D 10m.
186	„ 4	11 42 11	„ ·25mm. „ 5m.
	„ 4	12 24 53	„ ·5mm. „ „
	„ 4	12 39 8	„ ·25mm. „ „
187	„ 5	14 30 0	From 13·30 to 15·30. About 12 small disturbances; each commences suddenly. The one at 14·30 has 2 max. each ·5mm. D 8m.
188	„ 6	12 37 17	Ten min. later a max. amp. 2mm. Small P.T.'s 6m. D 35m.
189	„ 15	7 47 55	Six min. later a max. amp. 2mm., 7m. still later another, max. 1·5mm. D 54m. Small P.T.'s 4m.
190	„ 15	22 15 31	Amp. ·5mm. D 3m.
191	„ 18	17 51 31	„ „ „ „

THE SHIDE REGISTER—*continued.*

No.	Date	Time of Commencement.			Remarks
		H.	M.	S.	
192	April 23	9	8	49	Five min. later a max. amp. 1mm. Small P.T.'s 3m. D 16m.
193	„ 23	23	58	55	Thirty-six min. later a max. amp. 6mm. Small P.T.'s 25m. D about 2h. Commencement earlier than noted.
194	„ 25	17	55	27	Doubtful.
195	„ 25	11	14	17	Amp. ·25mm. D 5m. Six or eight similar disturbances between these two.
	„ 25	12	25	10	„ „ „ „
196	„ 29	16	39	4	Continuous to 17h. 37m. 34s., with at least 7 max. each 1mm.
197	May 1	10	33	0	Doubtful.
198	„ 7	4	9	55	Seven other small shocks up to 5.30. Amp. ·25 to ·5mm. D 2 to 5. All doubtful.
199	„ 7	6	4	6	Thirty-five min. later a max. amp. 1·75mm. Motion rises and falls every 5 to 9m. for 2h.
200	„ 20	23	29	5	Amp. 1mm. D 5m.
201	„ 22	17	28	15	Amp. 1mm. and D for each about 5m.
	„ 22	18	31	15	
	„ 22	19	20	15	
202	„ 22	22	50	0	
203	„ 22	1	31	21	Amp. ·75mm. D 8m.
204	„ 30	1	16	54	„ ·25mm. „ 1m.
205	„ 30	1	30	54	„ „ „ „
206	„ 30	2	56	54	„ „ „ „
207	„ 30	4	18	55	„ ·1mm. „ 10m.
	„ 30	5	30	0	„ „ „ 5m.
208	„ 30	12	57	50	„ ·25mm. „ 2m.
209	„ 31	1	38	51	„ ·5mm. „ 3m.
210	June 3	17	14	44	„ „ „ 10m.
211	„ 19	7	8	50	„ ·25mm. „ 3m.
212	„ 20	18	52	47	„ ·5mm. „ 6m.
213	„ 21	0	46	42	Fourteen min. later amp. 2·5mm. Small P.T.'s 12m. D extends 2h.
214	„ 22	6	52	42	From a series of 10 max. each with amp. ·25 to ·5 mm. D 5m.
	„ 22	7	14	42	
	„ 22	7	39	42	
	„ 22	9	7	42	
215	„ 29	18	48	37	Forty min. later a max. amp. 8mm. Small P.T.'s 9m. D 3h. The seismogram shows a marked symmetry. Period of L.W.'s 23s.
216	July 2	4	27	24	Max. amp. ·5mm. D 4m.
217	„ 2	17	3	23	„ „ 1mm. „ 8m. Doubtful.
218	„ 3	21	42	23	Amp. ·5mm. D 5m.
219	„ 12	10	30	0	Max. amp. ·75mm. D 5m Doubtful.
220	„ 13	23	51	8	„ „ ·5mm. „ 3m.
221	„ 14	17	46	15	„ „ 1·25mm. „ 40m. Small P.T.'s 14m.
222	„ 20	16	59	26	„ „ ·75mm. „ 45m.
223	„ 21	11	35	56	„ „ ·25mm. „ 4m.
224	„ 26	23	21	14	Amp. ·25mm. D 3m.
225	Aug. 8	8	53	30	Max. amp. 1mm. D 35m.
226	„ 19	1	51	12	„ „ 25mm. „ 3m.
227	„ 20	16	4	19	Amp. ·25. D 2m.
228	„ 21	17	28	0	Max. amp. 2·5mm. D 2m.
229	„ 22	23	39	3	„ „ 4mm. „ 17m. Doubtful.
230	„ 31	20	5	2	„ „ 10mm. „ 3h. Smallest P.T.'s 5m. Max. 31m. from commencement. Shows symmetry. Period of L.W.'s 32s.

THE SHIDE REGISTER—*continued.*

No.	Date		Time of Commencement	Remarks
			H. M. S.	
231	Sept.	3	16 4 48	Max. amp. 1·25mm. D 56m.
232	,,	13	18 11 37	Slight thickenings until 20h. 7m. 35s.
	,,	13	20 7 35	
233	,,	22	12 30 54	A series of 6 max. with amps. reaching 3mm. D for each 3 to 5 m.
	,,	22	13 37 52	
234	,,	25	12 51 50	Amp. ·5mm. D 13m.
235	Oct.	11	16 58 52	Max. amp. 1·5mm. D 1h. 40m. About 19 maxima.
236	,,	11	19 26 38	Amp. ·25mm. D 2m.
237	,,	12	13 21 2	,, ,, ,, ,,
238	,,	15	4 2 44	Max. amp. ·5 mm. D 7m.
239	Nov.	17	13 20 15	,, ,, ,, ,, 35m.
240	Dec.	1	12 48 16	,, ,, ,, ,, 55m. About 11 thickenings.
241	,,	3	3 18 43	Amp. ·25 mm. D 1m.
242	,,	3	6 25 53	,, ,, ,, 5m.
243	,,	3	17 42 26	,, ,, ,, 2m.
244	,,	4	20 20 40	,, ,, ,, 2m.
				1899.
245	Jan.	6	19 11 9	Max. amp. ·25mm. D 20m.
246	,,	12	3 58 18	,, ,, ·75mm. ,, 6m.
247	,,	12	9 2 26	,, ,, ·25mm. ,, 12m.
248	,,	14	2 48 55	,, ,, 2·5mm. ,, 50m. Two shocks, the second from 3h. 25m. 30s.
249	,,	22	8 22 53	Max. amp. 1mm. D 30m.
250	,,	24	23 47 42	,, ,, 6mm. ,, 80m. Commencement and end uncertain.
251	,,	30	18 55 52	Amp. ·25mm. D 1m.
252	,,	31	11 22 47	Max. amp. 1mm. D 20m.
253	,,	31	17 32 31	,, ,, ·25mm. ,, 8m.
254	Feb.	23	13 47 23	,, ,, ·75mm. ,, 10m.
255	,,	26	13 47 29	,, ,, 1mm. ,, 12m.
256	,,	27	10 12 19	,, ,, 2mm. ,, 28m. Two shocks.
257	,,	27	15 26 40	,, ,, 1mm. ,, 5m.
258	,,	28	16 7 14	Amp. ·25mm. D 3m.
259	,,	28	19 47 38	Max. amp. ·75mm. D 15m.
260	,,	28	23 1 5	,, ,, ·25mm. ,, 6m.
261	Mar.	6	15 32 52	Amp. ·25mm. D 15m.
262	,,	6	20 52 31	,, ,, ,, 7m.
263	,,	7	1 31 1	Max. amp. 1·5 mm. D 80m. Commencement and end uncertain.
264	,,	12	9 55 10	Max. amp. 1mm. D 50m.
265	,,	17	19 44 48	Amp. ·25mm. D 4m.
266	,,	19	13 45 35	,, ,, ,, 10m.
267	,,	21	14 58 47	,, ·5mm. ,, 43m. Max. at 15h. 39m. 8s.
268	,,	23	10 45 16	,, 1·5mm. ,, 1h. 38m. Max. at 11h. 16m. 16s. Small P.T.'s 28m.
269	,,	23	14 57 41	Amp. ·75mm. D 44m. Max. at 15h. 0m. 47s. Small P.T.'s 1m. 2s.
270	,,	25	14 53 19	Amp. ·5mm. D 45m. Max. at 15h. 21m. 14s.
271	,,	25	20 39 52	Amp. ·25mm. D 3m.
272	April	3	11 1 6	,, ·5mm. ,, 12m.

The preceding part of this List is contained in the 'British Association Report' for 1898, pp. 179–276.

In its original form the above List did not contain records numbered 170, 173, 176, 177, 178, 190, 191, 198, 204, 205, 206, 208, 209, 211, 212, 218, 224, 227, 234, 236, 237, 241, 242, 243, 244, 251, 258, 261, 262, 265, 266, 267, 268, 269, 270, 271, and 272. The reason for the omission was that these records were so small that it was not considered likely that they would be recorded at other stations. I call them the subsidiary list.

Between March 18 and 21 the original list was sent to stations No. 1 to 19,[1] and also to Strassburg, Padua, Rome, Rocca di Papa, Casamicciola, Catania, Potsdam, Nicolaiew, Edinburgh and Bidstone.

On April 14 the subsidiary was forwarded to Cadiz, Bombay, Toronto, Potsdam, Rome, Rocca di Papa, Catania, Paisley and Kew.

The responses have, when necessary, been reduced to Greenwich mean civil time, and are contained in the following tables:—

2. *England: Kew Observatory. Superintendent,* Dr. CHARLES CHREE, *F.R.S.*

Kew has met with difficulties in common with Shide, but the tremors have not been so frequent or pronounced. Why certain earthquakes like Nos. 196, 207, 214, 220, 221, 225, 246, 247, &c., were not recorded, whilst the amplitudes of large earthquakes are smaller than the same at Shide and at the same time show phases of maxima movements farther separated in time than they appear to be at the latter place, is difficult to understand. The most likely explanation is that at Kew the foundations of the instruments rise from an extremely thick bed of soft tertiary materials more or less saturated with water, whilst at Shide the piers rise from the surface of upended beds of comparatively hard, dry chalk.

The Kew Register.

Such a statement as 'normal line or line, ·2 mm.; tremors, 0·4 mm.' means that the full width of the line (*not* the half width) was ·2 mm. when undisturbed, but ·4mm. when disturbed. In such a case the amplitude would be $\frac{1}{2}$ (·4 − ·2), or ·1 mm. On the other hand, when it is said either that 'max. amplitude = 0·9 mm.,' or 'amplitude = 5·5 mm.,' it is meant that the half width of the central line was 0·9 in the former and 5·5 in the latter case. The *true* amplitude would be in the former case, say, $0·9-x$, when $2x$ was the undisturbed width of the line, whatever that might be at the time.

At Kew variations in the full width of the line from ·1 to ·3 mm. are noticed.

Milne Seismograph started at Kew Observatory on April 19, 1898.

No.	Shide No.	Date	Time of Commencement H.	Time of Commencement M.	Remarks: (D = duration in minutes)
		1898.			
1	195	April 25	11	5·9	Character slight. D = 2. Faint tremors 11h. 14m. to 11h. 24m.
	—	,, 28	15	3·9	Fairly well marked. D = 12. Max. tremor 0·4 mm.

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[1] See *British Association Report*, 1898, pp. 180–182.

THE KEW REGISTER—*continued.*

No.	Shide No.	Date	Time of Commencement		Remarks: (D = duration in minutes)
			H.	M.	
3	—	April 29	8	5·7	Slight. D = 2. Normal line = ·2 mm. Max. tremor = ·5 mm.
4	199	May 7	6	4·0	Very faint tremors at intervals from 6h. 4m. to 6h. 41m. Most marked at 6h. 10·5m. and 6h. 39m.
5	—	„ 8	8	37·3	Slight. D = 2. Normal line = ·2 mm. Tremor = 0·4 mm.
6	—	„ 10	15	49·2	Slight. D = $2\frac{1}{2}$. Normal line = ·2 mm. Tremor = 0·5 mm.
7	—	„ 11	12	3·1	Slight. D = 2. Normal line = ·2 mm. Tremor = 0·4 mm.
8	—	„ 17	8	37·7	Slight. D = 2. Normal line = ·2 mm. Tremor = 0·5 mm.
9	—	„ 21	12	45·5	Very slight; little more than a broadening of the line.
10	—	„ 22	11	54·5	„ „ „
11	—	„ 22	12	43·0	„ „ „
12	—	„ 23	14	7·4	„ „ „
13	—	„ 27	2	58·6	Slight pulsations for about 35min. Max. at 3h. 15m.
		„ 27	3	7·2	
		„ 27	3	21·7	
		„ 30&31	—		Boom 'off' greater part of time.
14	—	June 1	16	18·2	Small movement. D = 3. Line = ·15 mm. Tremor = 0·4 mm.
15	210	„ 3	17	10·7	Fairly well marked. D = 8. Max. at 17h. 14·5m.
16	—	„ 13	14	22·8	Very slight. D = 5.
17	—	„ 17	18	41·7	„ „ D = $2\frac{1}{2}$.
18	211	„ 19	7	8·4	Little more than a broadening of the line.
19	213	„ 21	0	46·3	Fairly well marked movement. D = 64·8. Max. at 0·59·1, with a sudden movement. Max. amplitude = 0·9 mm. = 0″·55, followed by slowly decreasing tremors till 1h. 51·1m.
20	—	„ 21	19	2·8	Slight. D = 4m. Normal line = ·2 mm. Tremor = ·4 mm.
21	214	„ 22	6	54·4	A long series of slight tremors, the times given being for the commencement of the major movements, but there was almost constant movement till apparently 9h. 6·5m.
			7	12·2	
			7	36·5	
22	215	„ 29	18	47·2	The largest disturbance recorded here during 1898. The maximum movement was at 19h. 21·6m., with an amplitude of 5·5 mm. = 3″·36 of arc; the next largest swing occurred at 19h. 26·2m., with amplitude of 5 mm. The movements grew smaller and smaller until 20h. 4·2m., but there were numerous tremblings up to 21h. 8·6m.
23	216	July 2	4	25·4	Short, but well defined. Began suddenly, with almost no preliminary tremor. Max. was at 4h. 28·5m., with an amplitude = 0·5 mm.
24	217	„ 2	16	25·8	Very slight. D = $4\frac{1}{2}$.

THE KEW REGISTER—*continued.*

No.	Shide No.	Date	Time of Commencement		Remarks: (D = duration in minutes)
			H.	M.	
25	218	July 3	21	44·5	Very slight. D = 2.
26	—	„ 13	18	3·0	Succession of slight tremors, lasting for 15m.
27	—	„ 15	22	9·3	*Very* slight; little more than a broadening of the line.
28	223	„ 21	11	35·0	Very slight.
29	—	„ 22	14	2·5	Slight. D = 3. Line ·15 mm. Tremor = ·3 mm.
30	—	„ 25	14	36·1	Slight. D = 7. Line ·2 mm. Tremor = ·6 mm.
		Aug. 13–28	—		Action of boom doubtful. ? Grazing scale plate.
31	—	„ 30	15	39·3	*Very* slight; a mere broadening of the line.
32	230	„ 31	20	4·0	Large disturbance, lasting for 1h. 33·6m. Max. amplitude = 5·5 mm.
33	—	Sept. 3	9	0·3	*Very* slight. D = 1½. Line ·2 mm. Tremor ·4 mm.
34	231	„ 3	15	54·0	*Very* slight. End at 16h. 14m.
35	232	„ 13	18	11·3	*Very* slight.
36	—	„ 20	12	28·4	Very slight. D = 1½. Line ·2mm. Tremor ·4mm.
37	233	„ 22	12	46·5	Long periods of small swings, lasting from 12h. 46·5m. to 2h. 9·8m. Maxima at 1h. 10m., 1h. 39·4m., and 1h. 44·2m. Max. amplitude = 0″·31.
38	234	„ 25	0	50·3	Small. D = 13. Max. at 0h. 53m. Line ·3 mm. Tremor ·8 mm.
39	—	„ 28	17	40·0	? Tremor or light flare. D = 1½.
40	—	„ 29	14	48·8	*Very* slight; just a broadening of line for 3m.
41	235	Oct. 11	16	59·2	Fairly well marked period of small swings, lasting 1h. 16m. Max. at 17h. 38·7m. and 17h. 45.3m. Amplitude = 0″·33.
42	237	„ 12	13	20·6	Small. Preliminary tremors 2·5m. Max. at 13h. 23·5m., with amplitude = 0″·30.
43	238	„ 15	4	28·0	Slight. D = 3. Line ·15 mm. Tremor ·5 mm.
44	239	Nov. 17	13	37·2	Movement well marked, but swings not large. Preliminary tremors 10·8m. Max. at 13h. 46·4m. and 13h. 58·6m. Total D = 53. Max. amplitude = 0″·60.
45	240	Dec. 1	12	51·6	Very slight. D = 24.
46	241	„ 3	3	1·3	Very slight; scarcely more than a broadening of line.
		„ 3	3	7·0	„ „ „
		1899.			
47	245	Jan. 6	19	37·0	Slight. D = 15. Line ·4 mm. Tremor ·8 mm.
48	—	„ 6	19	41·5	Slight ripples lasting, say, for 28 mins., with max. at 20h. 4·2m. Line ·5 mm. Tremor 1 mm.

THE KEW REGISTER—*continued.*

No.	Shide No.	Date	Time of Commencement		Remarks: (D = duration in minutes)
			H.	M.	
49	248	Jan. 14	2	58·2	Well-marked disturbance. First max. at 3h. 26·5m., second at 3h. 28·2m. Max. amplitude 1·75 mm. = 1″·03. Total duration 1h. 11·3m. (Duration of preliminary tremors 27·2m.)
50	249	„ 22	8	22·2	Short, but well marked. Max. at 8h. 29m., with amplitude 0″·77. D = 27·5. (Preliminary tremors 5·6m.)
51	—	„ 22	19	52·6	Slight. D = 3. Line ·4 mm. Tremor ·7 mm.
52	250	„ 24–25	23	47·6	Large and distinct movement. First max. at 0h. 35·5m. on 25th, with amplitude 2″·14; second max. at 0h. 42·6m., with amplitude 2″·44. The amplitude exceeded 0″·5 till 1h. 10m., and then died down very gradually. Total D = 2h. 59·6m. (Preliminary tremors 43·4m.)
53	251	„ 30	18	45·8	Only a broadening of the normal line.
54	252	„ 31	11	21·8	A short but distinct movement, dying off very gradually. Max. at 11h. 25m. Amplitude = 0″·30. D uncertain, probably 21m.
55	253	„ 31	17	31·3	*Very* small; just a broadening of line. D from 2–4.
56	—	Feb. 1	10	27·7	„ „ „
			12	42·7	„ „ „
			13	9·0	„ „ „
57	—	„ 1	21	43·7	„ „ „
58	—	„ 2	10	42·8	„ „ „
			11	16·9	„ „ „
59	—	„ 12	12	12·0	Slight. D = 2½. Normal line ·4 mm. Tremor ·8 mm.
60	254	„ 23	13	49·5	Slight. D = 6. Normal line ·3 mm. Tremor ·6 mm.
61	255	„ 26	13	49·0	*Very* slight; just a thickening of line. D = 9 mm.
62	256	„ 27	11	27·5	Small movement. D = 25. Line ·3 mm. Trace 1·0 mm.
63	257	„ 27	15	27·2	*Very* slight. D = 3.
64	—	„ 28	7	7·2	Slight. D = 8. Line ·3 mm. Tremor ·8 mm.
65	259	„ 28	19	48·5	Slight. D = 6. Line ·3 mm. Tremor ·8 mm.
66	262	Mar. 6	20	36·7	Very slight. End at 21h. 9·2m.
67	263	„ 7	1 1 1	17·7 23·5 41·8	A short series of small movements, lasting from 1h. 17·7m. to about 2h. 11·8m. Max. at 1h. 53·4m. Line ·2 mm. Tremor ·8 mm.
68	264	„ 12	9	55·7	Faint suspicion of movement.
69	—	„ 15	12	28·9	Small. D = 2. Line ·1 mm. Trace ·5 mm.
70	—	„ 16	12	0·5	„ D = 1½. „ ·2 mm. „ ·5 mm.
71	267	„ 21	15	25·5	Trace rather ill-defined, focus not being good, but apparently lasted about 12m. Character slight.
72	—	„ 22	22	15·7	Slight. D = 4. Normal line ·2 mm. Trace ·5 mm.

THE KEW REGISTER—*continued.*

No.	Shide No.	Date	Time of Commencement	Remarks: (D=duration in minutes)
			H. M.	
73	268	Mar. 23	11 0·5	A series of small swings. Total duration 45m. First max. 11h. 20·2m., second at 11h. 22·2m. Max. amplitude = 0″·30.
74	269	,, 23	15 0 4	Small. D = 18·5. Max. at 15h. 14·7m. Line ·2 mm. Tremor ·8 mm.
75	—	,, 24	4 53 6	Slight movements on and off till 5h. 30m. Line ·4 mm. Tremor ·9 mm.
76	270	,, 25	14 54 0	Distinct movement.
77	271	,, 25	20 46 1	Merely a broadening of the line. (No further movements during March, 1899.)

3. *Canada: Toronto. Meteorological Observatory.*
Professor R. F. STUPART, *Director.*

The instrument has been moved from the small building outside the Magnetic Observatory to the inside of the same. One result is that air tremors have apparently entirely disappeared. The Observatory is situated on a bed of alluvium, perhaps 100 feet in thickness and stretching 20 miles North, East, and West with Lake Ontario on the South. Beneath the alluvium are granitic and other primitive rocks.

The purchase money for the Toronto instrument and the funds required for the installation and maintenance of the same, and also for the installation of a seismograph at Victoria, B.C., have been provided by the Dominion Government. The excellent series of results obtained from these stations, amongst other things, throw light upon changes taking place along the Eastern and Western Canadian seaboards. They have already attracted the attention of scientific men, and will undoubtedly act as an incentive for other Governments to work on similar lines.

The Toronto Register.

No.	Shide No.	Date	Commencement	Maximum	End	Amp.	Remarks
			1897.				
			H. M. S.	H. M. S.	H. M. S.	MM.	
1	133	Sept. 20	19 24 0	—	Aircurrents	—	—
2	—	,, 21	—	6 53 30	—	—	—
3	—	,, 25	15 16 16	15 17 0	15 20 16	0·5	—
4	—	Oct. 13	20 05 30	—	—	0·2	—
5	—	,, 13	22 14 0	Thickening of line.		Dur. 4 m.	
6	—	Nov. 10	14 58 0	15 2 0	15 7 0	0·7	—
7	—	,, 19	6 21 19	6 23 19	Aircurrents	—	—
8	153	Dec. 11	10 0 0	10 3 0	10 36 0	1·0	—
9	—	,, 19	14 38 0	14 38 0	—	—	—
10	156	,, 28	20 24 37	30 31 40	20 54 20	2·0	—
11	157	,, 29	11 32 29	11 35 31	12 35 0	6·9	—
			1898.				
12	—	Jan. 20	0 54 0	0 58 22	1 2 0	0·3	—
13	161	,, 25	0 13 30	0 29 0	1 3 0	6·8	—

THE TORONTO REGISTER—*continued.*

No.	Shide No.	Date		Commencement	Maximum	End	Amp.	Remarks
				H. M. S.	H. M. S.	H. M. S.	MM.	
14	—	Mar.	20	12 48 38	12 51 8	13 19 0	2·0	—
15	—	„	25	—	20 18 0	—	1·5	—
16	—	„	29	15 35 30	15 38 27	15 41 29	0·2	—
17	188	Apr.	6	12 44 40	12 54 44	13 3 12	5·0	Well marked.
18	189	„	15	Air currents	7 26 40	Air currents	2·0	Well marked.
19	—	„	21	22 42 41	23 24 7	22nd. 0 39 43	2·2	—
20	193	„	22	23 59 50	0 34 26 23rd.	23rd. 1 49 12	3·9	Very pronounced.
21	196	„	29	16 28 20	16 35 5	17 9 46	7·2	—
22	199	May	7	6 0 42	6 16 40	Air currents	5·2	Large shake.
23	—	„	27	{ 2 26 47 2 27 57 }	2 32 12	Uncertain	2·0	Moderate.
24	215	June	29	18 43 41	18 55 18	20 43 41	16.	Very large.
25	—	July	11	Small displa	cements 20	About h. and 23h.	15m.	
26	—	„	20	Uncertain	17 2 33	Uncertain	1·0	—
27	—	„	23	23 10 31	23 24 0	23 30 0	0·5	Small but decided.
28	—	„	24	19 56 54	19 59 0	Uncertain	0·5	Small.
29	—	„	25	15 31 39	15 39 0	16 40 0	1·0	Moderate, four distinct shocks.
30	—	Aug.	4	4 5 21	4 5 21	4 23 17	0·3	—
31	—	„	16	10 39 5	10 45 50	10 48 50	1·0	Three distinct shocks.
32	230	„	31	20 17 53	21 3 20	22 12 36	1·1	Series of small shocks.
33	231	Sept.	3	16 17 22	16 18 30	16 31 20	0·2	Very small.
34	232	„	13	18 21 45	19 15 44	21 11 0	2·1	Moderate.
35	—	„	25	9 45 2	9 53 32	10 1 0	0·3	Small.
36	—	„	25	18 56 37	18 57 32	19 16 50	0·7	Small.
37	235	Oct.	11	16 47 29	17 29 30	17 47 29	3·6	Large.
38	—	„	22	0 51 18	—	—	—	Very small.
39	239	Nov.	17	13 9 46	13 44 50	14 44 2	1·5	Marked.
40	—	„	27	1 24 1	—	—	—	Very small.
41	—	Dec.	5	A noticeable	thickening	of the line	at 16h.	7m.
42	—	„	11	7 33 15	—	—	—	Decided, but small.
43	—		20	8 2 55	—	—	—	Thickening of the line.
44	—	„	23	{ 5 26 55 5 40 8 }	—	—	0·1	{ Two very small ones.
45	245	Jan.	6	19 9 8	Uncertain	19 57 0	—	Succession of small shocks.
46	246	„	12	3 47 50	—	—	0·4	Very small, but decided.
47	248	„	14	2 42 18	2 57 6	4 8 51	3·2	Moderate.
48	—	„	24	12 14 59	—	—	—	Very small.
				1899.				
49	250	Jan.	24	23 50 24	0 12 10	2 27 28	9·5	Large.
50	252	„	31	11 36 0	11 37 12	12 22 42	0·2	—
51	—	Feb.	7	—	22 4 0	—	—	Minute.
52	—	„	8	19 24 14	19 34 23	19 58 14	0·5	Very small.
53	254	„	23	Air currents	14 4 0	—	0·5	Very small.

THE TORONTO REGISTER—*continued.*

No.	Shide No.	Date	Commencement	Maximum	End	Amp.	Remarks
			H. M. S.	H. M. S.	H. M. S.	MM.	
54	256?	Feb. 27	11 41 10	11 42 20	—	1·0	Very small.
55	259	„ 28	20 0 15	20 1 0	20 8 0	0·3	Very small.
56	263	Mar. 7	1 19 29	2 1 0	2 19 29	0·5	Small.
57	264	„ 12	9 52 11	9 58 7	10 52 11	3·5	Moderate.
58	266?	—	—	—	—	—	—
59	268	„ 23	10 41 52	11 6 0	11 41 52	0·6	Small.
60	269	„ 23	Thickening of line at 14h. 45m. 47s.				Duration, 20m.
61	—	„ 24	5 9 18	—	5 14 18	0·3	Very small.
62	270	„ 25	14 44 37	14 46 57	—	0·5	P.T.'s marred by air currents.
63	—	Apr. 5	8 33 38	Thickening of line uncertain.			
64	—	„ 12	17 55 0	17 59 4	19 34 3	0·6	Small.
65	—	„ 13	4 9 8	4 11 0	4 31 8	0·4	Very small.
66	—	„ 14	6 56 43	7 2 37	7 7 45	0·6	Very small.
67	—	„ 16	13 48 59	14 2 48	15 22 10	7·0	Large and continuous.
68	—	„ 17	2 2 11	3 0 0	3 0 59	0·6	Series of small shocks.
69	—	May 8	3 50 22	3 51 22	4 47 0	0·3	Very small.
70	—	„ 12	15 44 5	15 46 0	15 54 0	0·4	Small.
71	—	June 5	4 38 42	4 54 16	7 3 51	14·7	Very large.
72	—	„ 5	15 7 24	15 16 0	17 18 0	10·0	Very large.

Instrument put into basement January 19, 1899.
Double vibration of boom 15 seconds or the same as before.

4. *Canada: Victoria, B.C.* Mr. E. BAYNES REID, *Superintendent.* Mr. F. NAPIER DENISON *in charge of the Seismograph.*

The instrument is in the basement of an old brick building with stone foundation on the shore of the harbour. It is placed on a solid concrete pillar, built on bed rock not many yards distant from the water. I am not aware that troubles arising from 'air tremors,' or other causes, have interfered with the regular working of the instrument.

The Victoria Register.

No	Shide No.	Date	Commencement	Maximum	Ending	Amp.	Remarks
			1898.				
			H. M. S.	H. M. S.	H. M. S.	MM.	
1	235	Oct. 11	16 44 34	—	—	—	Faint curve.
2	—	„ 22	0 40 0	—	1 17 0	2·5	Faint curve.
3	239	Nov. 17	13 7 0	Various plcs 14h. 50m.		0·5	Series of small shocks.
4	—	Dec. 11	6 53 58	—	—	—	—
5	—	„ „	7 13 52	7 25 0	9 19 0	1·2	Medium.
6	—	„ „	8 58 7	—	—	—	—
7	—	„ 19	10 17 0	Tremors extending 15h. 45m.			Very slight.
8	—	„ 20	8 11 0	—	—	—	Minute tremors.
9	—	„ 23	1 2 0	—	—	—	Minute tremor.

THE VICTORIA REGISTER—*continued.*

No.	Shide No.	Date	Commencement	Maximum	Ending	Amp.	Remarks
			H. M. S.	H. M. S.	H. M S.		
10	—	Dec. 23	4 1 0	—	—	—	Quake in Victoria. Some sections escaped.

Also on Dec. 1, 13h. to 14h., and again at 19h. 40m. small shakes.

1899.

No.	Shide No.	Date	Commencement	Maximum	Ending	Amp.	Remarks
11	246	Jan. 12	3 35 16	3 36 15	3 40 16	0·9	Small.
12	248	„ 14	2 42 30	2 55 28	3 43 30	8·1	Large.
13	—	„ 23	2 0 0	—	—	—	Marked little vibrations, 2h.
14	—	„ 24	12 17 30	12 17 50	12 23 30	0·2	Very small.
15	250	„ „	23 51 7	25th. 0 5 36	25th. 3 15 0	20.	Very large.
16	252	„ 31	11 40 0	11 41 26	11 46 0	0·1	—
17	—	Feb. 8	19 31 59	19 35 0	19 40 0	0·4	Very small.
18	254	„ 23	14 6 40	14 8 33	14 12 5	0·1	—
19	255	„ 26	14 6 23	14 8 24	14 17 19	0·1	—
20	—	„ 27	15 47 7	15 47 17	15 52 7	0·1	—
21	259	„ 28	Slight thickening of the line 20h. 5m. to 20h. 12m.				
22	263	Mar. 7	1 15 13	1 16 15	2 17 13	0·4	—
23	264	„ 12	9 49 55	9 59 30	10 49 55	0·4	—
24	266	„ 19	13 15 43	—	13 24 43	0·9	—
25	268	„ 23	10 35 47	11 17 17	12 4 37	1·9	—
26		„ „	10 45 51	—	—	—	Very small.
27	269	„ „	14 55 20	15 5 11	15 30 48	1·0	—
28	—	„ 24	5 19 39	5 20 54	5 27 15	0·6	—
29	270	„ 25	14 46 25	15 0 12	15 23 16	1·1	—
30	—	April 5	8 18 0	Thickening	of the line	—	—
31	—	„ 6	3 39 46	4 5 13	4 38 52	0·1	Very small shocks.
32	—	„ 12	17 47 4	18 19 0	18 59 35	0·5	Very small vibrations from 13h. 55m.
33	—	„ 13	3 59 15	4 25 59	5 12 28	0·4	Series of small shocks.
34	—	„ 14	7 9 10	7 9 39	7 16 20	0·4	Very small.
35	—	„ 16	13 42 30	Number of vibrations across slit	15 33 42	—	Large and continuous.
36	—	„ 17	1 59 8	2 26 37	3 34 57	1·15	Medium.
37	—	May 8	3 45 36	3 46 36	4 35 31	0·1	Very small.
38	—	„ 15	20 5 21	Thickening of the line	20 16 16	—	Very small, may be air currents.
39	—	„ 25	19 0 0	Thickening	of the li	—	—

Also Jan. 30 about 18h. 44m. 15s. a thickening of the line.
Feb. 27 about 10h. 12m. 0s. air current effect.

From January 7, 1899, swing was increased from 15 to 20 secs. March 25 boom put at 17 secs.; ending March 4, 15 secs.; April 1, 17 secs.; April 8, 17 secs.

5. *Spain: Cadiz. San Fernando. Instituto y Observatorio de Marina.* *Director,* Commodore J. Viniègra.

When first installed the instrument at this station showed but few movements of the ground, and these were slight. On April 27, 1899, it was therefore dismounted, but set up again on the same day; the position of the balance weight being slightly altered and a more perfect equilibrium of the boom assured. Its period is 16 seconds. Now it appears to work better, but the vibrations are not very intense as compared with those from other localities. This lack of sensitiveness may, Commodore Viniègra remarks, be due to the foundations, in which there are several 'stone furrows,' surrounded with mud.

The San Fernando Register.

No.	Shide No.	Date	Commencement.	Remarks
				1898.
			H. M. S.	
1		Feb. 18	16 25 49	Rapid barometrical fall.
2		,, 24	10 54 49	
3	170	,, 27	,,	Earthquake recorded.
4	172	Mar. 5	16 30 49	Small movements up to 10h.
5	185	April 3	7 44 4	
6	188	,, 6	12 36 49	
7	193	,, 22	23 59 51	Max. 23h. 0m. 36·6s. Amp. 34mm. D 1h. 40m.
8	196	,, 29	16 37 19	
9	199	May 7	5 57 49	
10	209	,, 31	0 21 30	Rapid deviation of 4 mm.
				June 19–July 21, main-spring of clock broken.
11	230	Aug. 31	,,	Earthquake recorded.
12	234	Sept. 13	18 10 49	
13		,,	19 19 4	
				September 20–24, not working.
14	235	Oct. 11	17 27 19	
				1899.
15	245	Jan. 6	19 14 4	
16	256	Feb.	11 35 49	
17	259	,, 28	19 56 49	
18	263	Mar. 7	1 49 49	
19	267	,, 21	15 58 19	
20	268	,, 23	11 40 34	Rapid deviations to 11h. 56m. and 15h. 42m.
21	270	,, 25	14 52 19	
				April 1–4, watch removed and replaced by an electrically moved pencil.
22	290	June 5	4 40 55	
23	291	,, 5	15 6 55	
24	293	,, 14	11 18 16	
25	299	July 2	12 59 20	
26		,, 7	7 0 12	
27		,, 7	8 0 2	
28	302	,, 7	9 0 42	
29	306	,, 11	7 57 22	
30	307	,, 12	1 41 12	
31		,, 12	15 13 27	
32	308	,, 14	12 46 30	
33		,, 17	5 17 0	

6. *India: Madras.* *Director*, Dr. C. Michie Smith.

Dr. C. H. Michie Smith writes as follows :—

'The instrument is placed in the old magnetic room of the Observatory on one of the old piers. The surrounding ground is mainly a stiff clay which cracks during the hot weather, leaving fissures many inches deep. The Observatory is on a plain, and is about three miles from the sea and 20 feet above sea level. No air tremors were experienced during the time under report, but the instrument gave a great deal of trouble specially owing to changes in the length of the suspending silk thread, caused probably by alterations in the amount of moisture in the air. The instrument will be removed to Kodaikanal as soon as a room is ready for it.'

The Madras Register.

No.	Shide No.	Date	Prelim. Tremors begin	Shock begins	Maximum	Amplitude	Shock ends	Final Tremor ends	Remarks
				1898					
			H. M. S.	H. M. S.	H. M. S.	MM.	H. M. S.	H. M. S.	
1	201	May 21 ?	17 14 25	17 20 1	17 20 1	0·75	17 26 5	17 35 38	—
—	201	—	—	19 54 0	—	0·5	19 55 0	—	—
2	210 ?	—	—	—	—	—	—	—	About this time a large number of small disturbances, but none characteristic of a true shock—possibly they were caused by a spider.
—	—	June 4 to Aug. 11	—	—	—	—	—	—	Instrument not working.
3	230	Aug. 31	20 2 5	20 12 25	20 18 0	1·0	20 33 35	20 43 36	—
4	—	Sept. 9	—	3 48 38	—	<0·5	3 40 47	—	—
5	232 ?	„ 13	—	17 34 25	—	—	17 35 37	—	Very slight.
6	233	„ 22	—	12 34 43	—	—	12 39 13	—	„
7	—	„ 25	—	12 24 13	—	—	12 31 19	—	„
8	—	Oct. 1	—	3 27 49	3 29 1	—	3 30 31	—	„
9	235 ?	„ 11	—	17 2 36	—	—	17 59 12	—	Probably due to a thunderstorm.
10	238	„ 15	—	3 50 19	3 52 25	1·2	3 56 40	4 6 26	Felt as a shock in N. India.
11	—	Nov. 12	—	9 47 1	—	—	9 48 31	—	Very slight.
12	—	„ 30	—	12 32 30	—	—	12 35 0	—	„
13	240	Dec. 1	12 45 14	12 52 21	12 55 9	1·0	13 3 43	13 9 11	—
14	—	„ 15	—	12 6 31	—	—	12 10 31	—	Very slight.
15	—	„ 21	—	13 15 31	—	—	13 19 1	—	„
				1899					
16	—	Jan. 23	—	2 4 25	2 4 49	0·5	2 10 25	—	—
17	251	„ 30	—	17 48 19	17 52 25	1·0	17 57 1	—	—
18	—	Feb. 5	—	14 8 29	14 18 31	3·0	14 52 46	—	—
19	—	„ 5	—	16 41 5	16 48 51	2·0	16 55 34	—	—
20	—	„ 6	—	18 32 36	18 37 35	1·5	18 43 47	—	—
21	—	„ 6	—	20 42 15	20 46 4	1·5	20 54 32	—	—
22	—	„ 7	—	4 53 29	5 3 31	1·0	5 18 0	—	—
23	—	„ 7	—	20 28 27	20 33 7	2·5	20 49 27	—	Time slightly uncertain.
24	—	„ 8	—	0 50 1	0 54 31	1·0	1 0 4	—	—
25	—	„ 10	—	13 36 28	13 43 21	1·0	13 46 54	—	?

Notes.—After November 12 the period of the oscillation may be taken as 16 secs. Before that time it was less, but the exact period is very uncertain and was variable.

7. *Bombay: Colaba. Abstract from Report by* N. A. F. Moos, Esq., *Director of the Government Observatory.*

The instrument at the Bombay Government Observatory is installed in a small isolated building 10 feet square and 14 feet up to the eaves, which was formerly used for electrostatical observations. It has a gable roof, and is well ventilated on all sides. On the west side, at a distance of 40 feet, is a carriage drive leading to the Directors' quarters, and at a distance of 70 feet in the same direction, and parallel to the drive, is the main road outside the Observatory compound. On the east side, there is to a distance of 60 feet open ground as far as the thermograph shed, beyond which an open tract continues to the sea. On the north side there is a small well and open ground for 120 feet, where the observers' quarters are situated. Probably in consequence of a copious ventilation, no troubles have been experienced with the so-called earth tremors.

The pier is oriented N.S. and E.W., and located in the centre of the room. Its foundation was dug $5\frac{1}{2}$ feet below the flooring of the room, which is $1\frac{1}{2}$ feet above the ground. At this depth a huge boulder was struck, upon which was laid a bed of concrete 5×5 feet square and 2 feet deep. Over this a mass of rubble masonry 4×4 feet and $1\frac{1}{2}$ feet thick was built, and upon this a brick pillar $1\frac{1}{2}$ feet square and $5\frac{1}{2}$ feet high. On the top of this there is 1 inch of cement and a $\frac{1}{2}$-inch marble slab. On the north side to carry the clock box there is a heavy table 3 feet 9 inches square. The Observatory stands on somewhat elevated ground formed of basaltic traps, with their inter-trappean beds of hard red earth.

The records commence on September 8, 1898. The period of the boom has been kept at 18 secs., the sensibility being such that a deflection of 1 mm. corresponds to a tilt of 0·38″. No difficulties have been experienced in the working of the instrument beyond an occasional slight falling of the boom, due, perhaps, to a stretching of the silk thread at the upper end of the tie. The sensibility is determined weekly by observation and by deflections whilst the film is in the box, thus preserving a photographic record of the same. By stretching a fine wire across the slit in the clock box an accurate zero line is obtained.

Regular tremors and pulsations are absolutely absent.

The list on the next page only contains records which correspond with records obtained in the Isle of Wight. The complete Bombay Catalogue, commencing on September 8, 1898, to June 2, 1899, contains 2,021 entries. These refer to shocks which were local, and do not appear to have reached Europe, curious irregular sinuosities varying in period from a few minutes to an hour, sudden displacements or dislocations in the position of the boom, and numerous thickenings of the normal record. The latter, in some instances, may be the result of slight earth tremors, but where they are continuous over several hours and have an irregular, bead-like appearance, it is likely that they are due to air currents. Movements due to such causes are most frequent at night. The cause of the sinuosities and sudden displacements is at present unknown.

In an official report on the condition and proceedings of the Colaba Observatory, dated April 29, 1899, in reference to Seismology, Mr. Moos says, that the seismograph appears to give every satisfaction. At first tremors were absolutely absent, but they appeared in the middle of November, and subsequently caused great trouble. To arrive at the causes producing these tremors, Mr. Moos has instituted a series of experiments, and he has found it possible to suppress their existence by regulating the temperature and draught in the room by four small kerosine lamps kept burning between 8 p.m. and 9 a.m. The introduction of these lamps also results in giving the zero of the boom a fluctuation almost analogous to that observed in the diurnal wave.

Excerpt from the Bombay Register.

No.	Shide No.	Date	Commencement	Maximum	End	Remarks
			1898.			
			H. M. S.	H. M. S.	H. M. S.	
1	232	Sept. 13	18 53 28	—	18 56 10	Thickening of line.
2	233	„ 22	12 40 45	12 49 8	12 54 24	Eleven bead-like movements.
3	234	„ 25	12 18 37	12 20 36	12 31 53	Small disturbance.
4	235	Oct. 11	17 2 36	17 36 42	17 48 57	Earthquake. Amp. 0″·78.
5	238	„ 15	3 46 41	3 47 24	4 8 49	Earthquake. Amp. 2″·03. Felt over Northern Bombay.
6	239	Nov. 17	13 14 19	13 34 0	14 39 10	Earthquake. Amp. 3″·80.
7	240	„ 30	21 4 35	—	(Dec.1) 3 49 25	Real movement masked by feeble tremors. Also Dec. 1 from 12h. 43m. 17s.
8	241 ?	Dec. 3	2 49 58	—	—	Dislocation.
9	244	„ 4	20 28 5	—	(5th) 3 15 58	Movement masked by tremors.
			1899.			
10	245	Jan. 6	19 13 40	—	(7th) 4 43 34	„ „
11	246	„ 11	19 23 44	—	(12th) 4 11 36	„ „
12	247	„ 12	9 33 24	—	—	Dislocation with vibration.
13	248	„ 13	19 41 37	—	(14th) 4 21 2	Movement masked by tremors.
14	249	„ 22	9 15 47	—	—	Dislocation W. with vibration.
15	250	„ 25	12 57 59	—	—	„ „
16	251	„ 30	17 50 16	17 58 34	18 15 28	Small disturbance.
17	252	„ 31	12 23 20	—	—	Dislocation E. with vibration.
18	253	„ 31	17 16 21	—	—	Thickening of line.
19	256	Feb. 27	10 42 20	—	—	Dislocation W. with vibration.
20	257	„ 27	14 40 50	—	—	„ „
21	259	„ 28	20 9 23	—	—	„ „
22	263	Mar. 7	0 3 47	—	1 31 13	Tremors mask the real record.
23	264	„ 12	10 31 41	—	—	Thickening of line.
24	268	„ 23	11 42 30	11 47 46	12 22 4	Small disturbance.

8. *India: Calcutta, Alipore Observatory.*

G. W. Küchler, *Assistant Meteorological Reporter.*

At the above Observatory, in consequence of an indifferent foundation, dampness, the presence of insects, and from other causes, great difficulties have been met with in working the instrument. These to some extent have been overcome, and it is expected that better results will be obtained.

The Calcutta Register.

No.	Shide No.	Date		Time			Remarks				
		1899.									
				H.	M.	S.		H.	M.	S.	
1	—	Jan.	18	16	12	2	End	16	50	10	
2	—	,,	25	21	57	3	,,	22	32	14	
3	—	Feb.	18	3	15	52	,,	3	29	45	Amp. less than 2 mm.
4	—	,,	23	3	3	33	,,	3	21	2	,, 2 mm.
5	264	Mar.	12	8	51	20	,,	10	41	3	
6	266	,,	19	12	36	18	,,	15	8	58	,, 2 mm.
7	—	,,	21	9	12	24				—	
8	267	,,	21	14	43	6	,,	15	29	53	
9	269	,,	23	13	12	38	,,	14	22	53	,, 4 mm.
10	—	,,	26	11	53	47	(about)				

The above have been extracted from a selected list of disturbances commencing January 15, 1899.

9. *Java: Batavia. Magneetisch en Meteorologisch Observatorium.*
Director, Dr. J. P. VAN DER STOCK.

Observations with the Milne horizontal pendulum commenced on June 1, 1898. The period or time of double swing is kept at an average of 17 seconds. It is installed in the magnetometer room. The observatory is situated on a plain of alluvium. Difficulties arising from 'air tremors' have not been reported from this station.

The Batavia Register.

No.	Shide No.	Date		Commencement				Duration	
				Small Pulsations		Maximum			
		1898.							
				H.	M.	H.	M.	H.	M.
1	—	June	4	15	3·7	15	3·9	0	13·9
2	—	,,	18	8	0·5	8	0·7	0	3·5
3	214	,,	22	6	42·3	6	44·8	0	12·3
4	219	July	12	11	38·1	11	38·4	0	6·5
5	—	,,	17	11	32·8	11	37·5	0	3·2
6	—	Aug	1	16	6·8	—		0	3·8
7	230	,,	31	20	1·3	20	21·7	1	14·4
8	—	Sept.	1	9	4·3	9	10·4	0	31·9
9	—	,,	2	18	47·8	18	55·8	0	17·0
10	—	,,	3	8	27·3	8	28·2	0	4·4
11	232	,,	13	18	2·1	18	10·7	0	57·7
12	233	,,	22	12	27·3	12	29·1	0	58·9
13	—	,,	30	12	4·0	12	5·2	0	5·8
14	—	Oct.	2	14	44·5	14	53·0	0	23·4
15	—	,,	3	0	9·5	—		Doubtful	
16	—	,,	7	20	27·7	20	36·2	0	21·8
17	235	,,	11	16	49·7	—		1	10·5
18	238	,,	15	4	11·7	4	21·2	0	13·0
19	—	,,	15	10	54·5	10	55·9	0	2·3
20	—	,,	18	19	25·0	19	29·0	0	39·3

THE BATAVIA REGISTER—*continued.*

No.	Shide No.	Date	Commencement		Duration
			Small Pulsations	Maximum	
			H. M.	H. M.	H. M.
21	—	Oct. 22	0 9·3	0 19·6	0 26·6
22	—	Nov. 2	11 28·8	11 29·3	1 0·1
23	—	„ 5	11 59·5	—	0 0·8
24	—	„ 13	15 33·4	15 33·6	0 10·2
25	239	„ 17	13 12·6	13 13·0	0 37·6
26	—	„ 28	7 45·2	7 46·8	0 9·3
27	—	„ 29	22 34·0	22 36·4	0 9·4
28	—	Dec. 2	12 21·6	12 27·2	0 13·4
29	243	„ 3	16 59·9	17 0·6	0 2·0
30	—	„ 4	7 18·0	7 25·4	0 9·0
31	—	„ 6	7 43·8	7 44·2	0 28·9
32	—	„ 6	10 28·6	10 28·8	0 2·1
33	—	„ 6	13 31·5	13 34·8	0 22·2
34	—	„ 10	3 0·7	3 1·7	0 6·0
35	—	„ 11	2 11·1	2 13·5	0 7·6
36	—	„ 17	1 51·1	1 51·2	0 0·6
37	—	„ 21	3 52·3	3 53·5	0 2·4
38	—	„ 22	9 2·9	9 4·9	0 29·8
39	—	„ 23	21 56·0	21 56·2	0 0·7
40	—	„ 29	2 44·6	2 44·9	0 1·1
41	—	„ 31	9 16·0	9 22·5	0 11·7
			1899.		
42	247	Jan. 12	8 4·3	8 8·8	0 19·0
43	264	Mar. 12	—	10 8·2	0 25·0

Nos. 15 and 19 were also recorded by Ewing's Bracket Seismograph. Nos. 1, 4, 5, 6, 12, 15 and 19 were also felt at different places in West Java and Sumatra. Earthquakes felt on the Eastern part of the Archipelago (Moluccas) are not yet regularly recorded.

10. *Mauritius: Royal Alfred Observatory. Director,* T. F. CLAXTON, *F.R.A.S.*

The Observatory, in lat. 20° 5′ 39″ S., and long. 3h. 50m. 12·6s. E., is situated on a plateau about four miles from the north-west coast, and 180 feet above mean sea level. The soil around the Observatory varies from 3 to 14 feet in depth, below which is solid basalt. Extending for about half a mile to the west is a forest, thickly wooded with thin acacia trees, and to the east are principally fields of sugar cane.

The instrument is mounted with its boom pointing north, in a small hut containing two brick pillars, formerly used for the electrometer. The building is 8 feet long by 5 feet wide, and 9 feet high. The roof and walls are of wood, covered on the outside with painted canvas, while the floor is of concrete. I am not at present in a position to state whether the foundation of the piers is on the solid rock, though it certainly is not more than a few feet above.

Observations were commenced in the middle of September, 1898. All the seismograms have been tabulated and subjected to analysis, and the results will be published in due time; they show principally five things:—

(*a*) That there is a large diurnal variation in level (probably larger than at any other observing station) with a marked bi-diurnal effect, as shown by Bessel's interpolation formula, which for the months of October 1898, to March 1899, is

$$2''\!\cdot\!61 \sin(\theta+295^\circ\!\cdot\!47')+0''\!\cdot\!73 \sin(2\theta+331^\circ\!\cdot\!57')+0''\!\cdot\!30 \sin(3\theta+272^\circ\!\cdot\!57'),$$

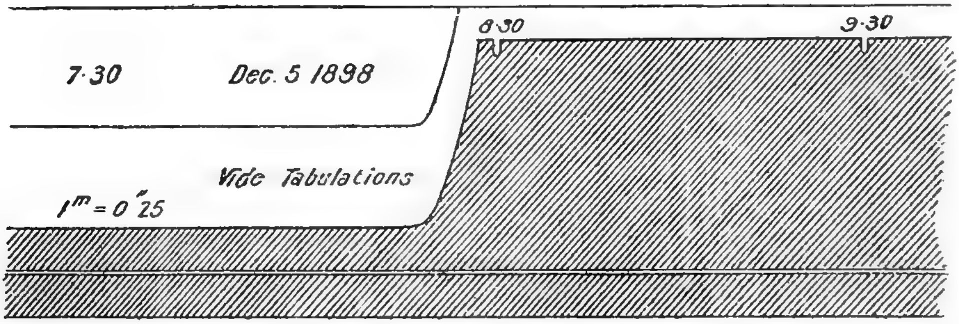
indicating a possible connection with the atmospheric pressure; the formula for the diurnal variation of which is

$$0\cdot0108 \text{ in. } \sin(\theta+49^\circ 32')+0\cdot0285 \text{ in. } \sin(2\theta+163^\circ 2') \\ +0\cdot0020 \text{ in. } \sin(3\theta+26^\circ 4').$$

(*b*) That rapid changes in the vertical occasionally occur on a large scale, notably on 1898 December 5, 6 and 7, and 1899 January 7, and February 10 and 11.

On December 5 (see diagram) after a dry period for a few days, a very heavy cloud formed at about 11 A.M.; its eastern edge was clearly defined, and extended for about a mile to the Eastward; shortly after noon very heavy rain began to fall at and to the west of the Observatory. The effect on the seismograph is seen in the accompanying diagram.

FIG. 1.



(*c*) That air tremors occur every night, in spite of every precaution to ensure copious ventilation, and the prevention of convection currents. They begin at sunset with small movements, which rapidly become larger, but, although of variable amplitude during the night, do not show a marked maximum: they finally die away at sunrise. As a general rule the tremors are greatest when the fall of temperature during the night is greatest; but this is not always the case.

(*d*) That on almost every day the westerly movement of the boom exceeds the easterly, indicating a gradual sinking of the land west of the instrument.

We must conclude that this movement is only local, for if the whole island tilted in this way as a rigid body, land would appear on the east coast, which was previously submerged, and *vice versâ* on the west coast, and up to now I have been unable to obtain evidence that such a thing has taken place.

(*e*) That the earthquake effects are comparatively small, as will be seen from an inspection of the accompanying list. This makes us question whether it is possible for the ocean to act as a damper to earthquake shocks.

When records are forthcoming from Honolulu we may learn more of this subject.

Beside the above five phenomena, there is another interesting point to be considered: the variation in the scale value of the instrument. As the boom points to the north, an increased sensibility means that the boom pillar has tilted towards the south, and *vice versâ.*

In the following table will be found the smoothed scale values for every four days from 1898, October, to 1899, January. (A bar represents an adjustment.)

Value of 1 *Mill.*

Day	October	November	December	January
4	33	38	25	32
8	32	$\overline{50}$	$\overline{42}$	41
12	31	45	$\overline{38}$	50
16	30	36	38	58
20	25	28	$\overline{32}$	$\overline{33}$
24	18	26	28	33
28	$\overline{54}$	25	24	33
32	46	25	21	33

If the above figures are plotted down on a curve, after allowing for the alterations for adjustment, it will be seen that the boom tilted towards the south till November 25; was then practically stationary till the middle of December, after which the tilting continued towards the south till the end of the month, when a northerly tilt set in, lasting till January 16, after which the boom was stationary.

Mauritius Register.

No.	Shide No.	Date	Commencement	Maximum	Remarks
			1898.		
			H. M. S.	H. M. S.	A.
1	—	Sept. 19	—	11 1 39	2″·4. Commencement 1h. earlier?
2	233	„ 22	—	13 50 25	0″·45.
3	238	Oct. 15	4 6 12	4 10 0	0″·15. D 22m.
4	239	Nov. 17	13 45 23	14 2 0	0″·66. D 40m.
5	240?	Dec. 1	—	0 58 43	Earthquake?
6	244?	„ 4	7 30 0	7 52 0	0″·12. D 45m.
7	—	„ 11	About 7 0 30	7 36 5	0″·38. D 1h. 22m. (See Register for Toronto, Victoria, Nicolaiew.)
			1899.		
8	250	Jan. 25	—	1 15 45 and	0″·99.
9	—	„ „	—	1 19 0	From 6.30 to noon, about 20 small disturbances. One about 9h. looks seismic.
10	263	March 6	—	23 20 0 to March 7 1 35 0	Slight thickenings of the line.
11	264	„ 12	—	8 20 0 to 10 50 0	Slight thickenings of the line.

11. *Cape of Good Hope: Royal Observatory. Director*, DAVID GILL, Esq., *F.R.S.*

The instrument was mounted on a concrete pier based on a rock foundation, and was experimentally started on June 20, 1899.

At first difficulties were experienced in attaining the necessary amount of sensitiveness. There appeared to be a large amount of friction which prevented the boom swinging freely. This, however, was remedied by a readjustment of the balance weights, and the instrument has been recording with occasional interruption since July 11.

The principal events so far registered are as below, the times being referred to Greenwich mean civil time.

The Cape Register.

1899.

1. July 14—

	H.	M.
Preliminary tremors	13	47·2
Commencement of decided motion . .	14	17·2
End of decided motion	15	32·6

Maximum amplitude, 3 mm.

Also recorded at Shide.

2. July 18—

	H.	M.
Preliminary tremors	21	14·6
Commencement of decided motion . .	21	18·0

Maximum amplitude, 3 mm.

Times of maxima, 21h. 23·2m., 21h. 34·4m.

3. July 20—

Slight tremors from about 0h. to 7h., commencement and end not well marked. More violent disturbance for about 10m.; maximum displacement $2\frac{1}{2}$ mm. at 3h. 40m.

4. July 20—

Disturbance commenced at 19h. 17m. The motion subsided from 19h. 26·8m. but restarted at 19h. 44·2m., and finally ceased at 19h. 59·5m.

5. July 27—

Disturbance commenced without preliminary tremors at 15h. 4·7m. Maximum displacement about $2\frac{1}{2}$m. after commencement. Greatest amplitude of swing, 9mm. Total duration, 45m., with calm interval of 10m.

6. July 31—Violent disturbance.

	H.	M.
Preliminary tremors	2	42·5
Commencement of decided motion . .	2	46·0
End of decided motion	3	39·8

The early part of this disturbance shows signs of a periodic character with a period declining from about 6m. to about 3m. The latter half is much more irregular in form. Well-marked maxima at 2h. 47m., 2h. 52m., 2h. 57m., 3h. 1m., 3h. 4m., and 3h. 25m. Displacements from centre amounting to 20 mm.

Several insignificant disturbances have also been recorded, besides those quoted above.

12. *Russia: Nicolaiew. The Observatory.*
Director, Professor T. KORTAZZI.

The Observatory of Nicolaiew (lat. 46° 58′·3, long. 2h. 7m. 9s.) is situated on a sandy hill with gently sloping sides at an elevation of 50m. above sea level. The streets of the town are at a distance of 150m., and the railway more than 1 km.

The von Rebeur Horizontal Pendulum, with its photographic registering apparatus, is placed in a cellar on a pillar isolated from the walls and the floor. The pillar is built of large blocks of very compact limestone, covered with tar to prevent the absorption of moisture. The annual change of temperature in the cellar does not exceed 4° R. Diurnal changes are not perceptible. A deviation of 1 mm. in the position of the light spot indicates a tilting of the pillar in the direction of the meridian of 0″·012. The recording surface moves at the rate of 22 mm. per hour.

The Nicolaiew Register.

The times for commencement, reinforcement, maximum, and weakening are indicated in Greenwich mean civil time:—½ amplitude = ½a in millimetres. P.T.'s = duration of preliminary tremors.

No.	Shide No.	Date	Commencement	Reinforcement	Maximum	½a	Weakening	Duration	P.T.'s	Remarks
		1898.								
			H. M.	H. M.	H. M.	MM.	H M.	H. M.	M.	
1	—	Mar. 6	2 46	3 2	3 5	3·5	—	0 36	16	
2	—	,, 19	13 14	13 19	13 20	4	—	0 13	5	
3	—	,, 25	19 39	19 47						
				0 57·5	19 58	9	20 31	2 58	8	
4	—	,, 26	9 44		9 56	5·5	10 7	0 40	3	
5	—	,, 28	15 37	15 59·5	16 2	10·5	16 9	1 15	22·5	
					0 16	7·5	0 19			
6	182	,, 31	8 22	8 30	8 34	4	—	0 30	8	
7	185	Apr. 3	6 53	—	6 58	3	—	0 8	—	
8	189	,, 15	7 54	—	7 57	23	—	0 23	—	
9	—	,, 21	22 48	22 57·5	23 22	16	23 52	2 44	9·5	
10	—	,, 22	23 47	—	23 58	10	—	—	—	Pendulum inclined 8 mm. to the S.
11	193	,, 23	—	0 2	0 4·5	38	1 37	3 37	—	
12	195	,, 25	11 10·5	11 19	11 44	9	11 49	1 42	8·5	
13	—	,, 28	14 27	14 44·5	14 54	7·5	—	0 57	17·5	
14	196	,, 29	16 30	16 44·5						
				17 2	17 7	21	17 47	2 22	14·5	
15	199	May 7	6 4	6 11	6 38	25	7 12	2 33	7	
16	—	,, 19	9 15	9 39	9 42	4·5	—	0 55	—	
17	—	,, 26	2 2	—	2 22	4	—	1 20	—	
18	—	June 1	5 47	5 52	5 54	6	6 7	0 48	8	
19	210	,, 3	16 57	—	17 0	5	—	0 30	—	
20	—	,, 6	19 37	—	19 58	5	—	0 21	21	P.T.'s followed by a single shock at 19h. 58m.
21	213	,, 21	0 37	0 41·5	0 44	38	—	0 45	—	
22	214	,, 22	6 54	7 11	7 18	17	7 46			
				—	7 51	15	7 55	3 1	—	
23	—	,, 26	23 38	—	23 47	2	—	0 9	6	
24	215	,, 29	18 42	18 59	18 59	50 ?	—	—	12	
					19 17	40 ?	—	3 45		At 18h. 59m. to 19h. 7m. and 19h. 7m. to 19h. 22m. the traces are scarcely visible.
25	216	July 2	4 22	4 23·5	4 25	9	—	—	1·5	
26	—	,, 9	19 39	—	19 41	3	—	0 15	—	
27	—	,, 13	0 48	—	0 54	3	—	0 34	—	
28	221	,, 14	17 30	17 45	17 52	10	—	0 37	15	
29	—	,, 15	6 22	6 37	6 37	2·5	—	0 32	12	
30	225	Aug. 8	8 25	8 44	8 54	7	9 17	1 47	19	
31	—	,, 13	0 4·5	—	0 7	6	—	0 27	—	
32	—	,, 28	16 37·5	—	16 39	2·5	—	0 75	—	
33	230	,, 31	20 39	—	20 42	20	—	0 58	—	The photogram indistinct.
34	—	Sept. 1	9 11	9 20	9 39	22	10 10	2 29	9	
35	—	,, 2	19 16	—	19 29	7	19 47			
					20 0	6	—	1 6	—	
36	231	,, 3	15 32	15 59	16 2	7	—	1 20	—	
37	232	,, 13	18 14·5	—	18 34	10				
					19 12	13	—	1 38	—	

THE NICOLAIEW REGISTER—*continued.*

No.	Shide No.	Date	Commencement	Reinforcement	Maximum	½a	Weakening	Duration	P.T.'s	Remarks
			H. M.	H. M.	H. M.	MM.	H. M.	H. M.	M.	
38	233	Sept. 22	12 44	12 53	13 19	29	14 10	2 38	9	
39	234	„ 25	12 25	12 34	12 37	22	12 42	1 7	9	
40	—	„ 26	22 37·5	—	22 42	5	—	0 18	5	
41	—	„ 27	5 42	—	5 52	3	—	0 10	—	
42	—	„ 30	16 35	16 54	16 57	7	—	0 32	9	
43	—	Oct. 1	15 4	—	15 55	8	—	1 18	—	
44	—	„ 7	2 36	—	2 44	2·5	—	0 8	—	
45	—	„ 8	23 40·5	—	24 18	2	—	—	—	
46	235	„ 11	16 49·5	16 59·5	17 7	13	—	3 8	—	At 17h. 20m. the paper was changed. No details.
47	—	„ 12	22 14	—	22 17	3	—	—	—	
48	238	„ 15	3 28	4 5	4 10 0 14	7	--	1 14	37	
49	—	„ 18	19 56·5	20 5	20 9·5	6	—	0 25	8·5	
50	—	„ 22	0 13·5	0 28	0 32	4·5	0 39	—	9	
				0 40	1 0	19	1 27	2 25		
51	—	Nov. 2	11 50	12 14	12 18	6	—	0 50	—	
52	—	„ 9	18 47	—	18 48	3·5	—	0 5	—	
53	—	„ 14	7 29	7 39·5	7 42	3	—	0 35	10·5	
54	239	„ 17	13 3	13 12 0 17	13 37	18	13 52	1 34	9	
55	240	Dec. 1	12 42	—	12 54	15	—	1 0	—	
56	241?	„ 3	6 18	—	6 19	3	—	—	—	
57	—	„ 4	7 57	—	8 5	3	—	0 30	—	
58	—	„ 6	8 10	—	8 20	4	—	0 52	10	
59	—	„ 6	13 57·5	—	14 12	2·5	—	0 20	—	
60	—	„ 11	7 8	--	7 28 7 48	3·5 6	7 34 8 7	1 49	9	
61	—	„ 12	16 58	17 9·5	17 12	3·5	—	0 49	11·5	
62	—	„ 27	15 1	—	15 4	3	—	11 0	—	
					1899.					
63	—	Jan. 3	6 49	7 17	7 19	3	—	0 38	28?	
64	245	„ 6	19 23	—	19 46	6·5	19 57	1 39	10	
65	247?	„ 12	8 37	8 48	8 50	7	8 59	0 45	11	
66	248	„ 14	2 51	3 0	3 32	8	3 20	1 28	6	
67	249	„ 22	8 19	—	8 21	15	—	0 24	—	Earthquake in Greece (*Comptes rendus*, cxxviii. No. 8).
68	—	„ 23	2 13·5	2 19	2 22	4	2 38	1 8	5·5	
					0 42	4				
69	250	„ 24 „ 25	23 57·5	0 1·5 0 8	0 12 1 2	30	—	2 55	4 or 10·5	
70	251?	„ 30	17 59·5	—	18 25	3	—	0 37	—	
71	253?	„ 31	17 1·5	17 14	17 15	4	—	0 30	12·5	
72	—	Feb. 10	4 14·5	4 24	4 27	2	—	0 22	9·5	
73	—	„ 11	8 17	8 34	8 40	5·5	—	0 35	17	
74	256	„ 27	11 31·5	11 34	11 37	3·5	11 41	0 15	2·5	
75	—	„ 28	3 6·5	3 22	3 32	16	3 42	0 55	15·5	
76	—	Mar. 3	0 52	0 54·5	0 56	11·5	1 12	1 0	2·5	
77	262	„ 6	20 30	—	20 34	2·5	—	0 17	—	
78	263	„ 7	1 5	1 15 1 32	1 22 1 39	7 27	1 27 1 44	1 13	10	
79	264	„ 12	9 41·5	10 7 10 24	10 11 10 27	6 15	10 21	1 59	25	

13. *Potsdam.*

Professor Dr. Eschenhagen, of the Königliches Meteorologisch-Magnetisches Observatorium, in place of a list, kindly sent me photographic copies of the various seismographic records he had obtained between October 2, 1897 and Jan. 6, 1898. The observations were made by means of a conical pendulum, carrying a small mirror on a glass boom, 20 cm. in length, and held horizontally with a glass fibre.

Out of forty-three records, on dates between March 3, 1898, which corresponds to the commencement of this year's list for Shide, and January 6, 1899, there are twenty-nine of them corresponding to the Isle of Wight observations.

In the discussion of registers the times of these are given approximately, but can be obtained with greater accuracy if required.

14. *Excerpt from the Trieste Register.*

Observations corresponding to those in the Shide list, made by Herr EDUARD MAZELLE, *Astron.-Meteorol. Observatorium, Trieste. Rebeur-Ehlert Horizontal Pendulum. Photographic record.*

No.	Shide No.	Date	Commencement	Maximum	Range and Tilt	End	Remarks
			1899.				
			H. M.	H. M.	MM.	H. M.	
1	249	Jan. 22	8 15·85	8 21·57	84 (1″·47)	9 20·20	The time of commencement is that of the pendulum first set in motion. For complete records see *K. Akad. der Wissenschaften in Wien*, February 1899, and subsequent publications.
2	250	,, 24 ,, 25	23 58·38	0 48·86	33 (0″·5)	2 35·70	
3	255	Feb. 26	13 48·36	14 0·77	8		
4	257	,, 27	15 28·28	15 40·55	4		
5	259	,, 28	19 50·20	20 4·54	5		
6	260	,, 28	22 42·83	23 14·52	2		
7	263	Mar. 7	1 6·89	1 42·88	10·5 (0″·3)	2 19·78	
8	264	,, 12	9 53·10	10 7·37	13·16 (0″·34)	11 0 abt.	
9	266	,, 19	1 24·29	—	2 (0″·06)	1 25·66	
10	267	,, 21	14 46·63	15 22·25	5·5 (0″·16)		
11	268	,, 23	10 42·80	11 5·12	5·8 (0″·13)	12 0 abt.	
12	269	,, 23	14 29·96	14 47·69	3·5 (0″·08)	15 30·45	
13	270	,, 25	14 53·48	14 55·31	1·5 (0″·32)	15 46·32	

15. *The Bidston Register.*

Darwin Bifilar Pendulum records, from the Liverpool Observatory, Bidston, Birkenhead, Cheshire. Director, W. E. PLUMMER, Esq.

No.	Shide No.	Date	Remarks
			1898.
1	—	Mar. 28	Moderate disturbance about 23h. 44m.
2	180	,, 29	Continual slight disturbances throughout this period. The smallness of the time scale prevents exact identification.
3	—	April 3	Trace lost by clock failure.
4	196	,, 29	Slight disturbance at about 17 hrs.
5	200	May 20	At 23h. 30m. Max. at 0h. 11m., and slight till 2h. 15m.
6	—	,, 21	Commences at 15h., with max. at 17h. 30m. The Shide record for 22h. 50m. may have been recorded, but it is mixed up with an alteration to determine the time scale.
7	—	,, 26	About 22h.
8	—	June 4	,, 1h. 50m. slight. Trace off the scale.
9	—	July 21	Very slight.
10	—	,, 29	10h. a disturbance.
11	225	Aug. 7	8h. to 8h. 30m.
12	—	,, 19	Considerable disturbance.
13	228	,, 21	16h. 50m. to 18h.
14	—	Nov. 7	12h. slight.
15	—	,, 24	18h. ,,
16	—	Dec. 31	6h. 20m. to 9h.

THE BIDSTON REGISTER—*continued.*

No.	Shide No.	Date	Remarks
			1899.
17	—	Jan. 26	13h. to 14h. tremors.
18	—	Feb. 9	18h. 30m. ,,
19	254	,, 23	12h. 50m. slight.
20	—	—	Slight.
21	—	—	,,
22	—	Mar. 2	12h. to March 3 2h. Slight tremors, clearly marked.

16. *The Edinburgh Register.*

Observations at the Royal Observatory, Edinburgh, with a Darwin Bifilar Pendulum. Director, Dr. R. COPELAND.

No.	Shide No.	Date	Time	Remarks
				1898.
			H. M.	
1	174 ?	Mar. 5	17 11	Slight tilt to South.
2	179	,, 28	18 25	Very slight tilt to South.
3	180 ?	,, 29	15 41	,, ,, ,, North.
4	182 ?	,, 31	7 36·5	,, ,, ,, ,,
5	189	April 15	7 39	,, ,, oscillation, just perceptible.

Mr. Thomas Heath, who is in charge of the instrument, states that only one of the above coincidences is of an oscillatory character. A number of tilts and slight bends were recorded, but only one of these, on April 23, from 0h. 18m. to 0h. 36m., was oscillatory. The bends and tilts were most numerous in March, April, and May. From May 30 to November 11 there is practically not a trace of any kind of disturbance. From the latter date to the end of the year the number of tilts is small. A second pendulum was placed in position on May 14, and a couple of thermometers were installed in the pendulum chamber on May 31. They are covered by an earthenware dish. Between May 31 and March 20 the maximum temperature was, on September 21, 63°·2 ; the minimum was 51°·0 on February 26.

17. *Excerpt from the Rocca di Papa Register.*

Observations made at the R. Osservatorio Geodinamico di Rocca di Papa. By the Director, Dr. ADOLFO CANCANI.

Horizontal and other pendulums recording on smoked paper.

No.	Shide No.	Date	Commencement	Maximum	End
		1898.			
			H. M. S.	H. M. S.	H. M. S.
1	189	April 15	7 54 0	8 2 0	8 20 0
2	193	—	23 48 40	0 23 0	0 34 0
3	195	,, 25	11 40 0	11 42 0	11 45 0
4	196	,, 29	16 40 0	16 43 0	17 18 0
5	199	May 7	6 5 30	6 14 0	6 53 0
6	213	June 21	0 53 20	0 58 0	1 8 0
7	214	,, 22	6 45 2	6 45 18	6 55 0

THE ROCCA DI PAPA REGISTER—*continued.*

No.	Shide No.	Date	Commencement	Maximum	End
			H. M. S.	H. M. S.	H. M. S.
8	215	June 29	18 48 42	18 59 about	21 0 0
9	216	July 2	4 19 0	4 21 0	4 48 0
10	230	Aug. 31	20 3 40	20 31 0	21 30 0
11	232	Sept. 13	18 11 38	18 11 55	18 13 30
12	233	,, 22	12 58 0	13 33 about	14 0 0 about
13	235	Oct. 11	16 50 35	17 32 0	18 0 0 ,,
14	239	Nov. 17	13 4 40	13 46 30	14 10 0
			1899.		
15	245	Jan. 6	19 49 0	19 52 30	20 0 0 about
16	249	,, 22	8 16 10	8 20 40	8 27 0
17	250	,, 25	0 0 0	—	0 50 0 ,,
18	263	March 7	1 13 0	1 52 0	2 15 0

None of the very small disturbances on the supplementary list were recorded.

18. *Excerpt from the Casamicciola Register.*

Records received from Dr. GIULIO GRABLOVITZ, *Director R. Osservatorio Geodinamico di Casamicciola, Ischia.*

Records from horizontal pendulums recording on smoked paper are marked, H.P.; and those from the Vasca Sismica, V.S.

No	Shide No.	Date	Commencement	Maximum	End	Remarks
			1898.			
			H. M. S.	H. M. S.	H. M. S.	
1	189	April 15	8 6 0	—	8 10 0	H.P.
2	193	,, 22	23 30 0	—	0 50 0	H.P. The V.S. commenced at 23h. 48m. 46s.
3	—	,, 24	—	0 25 0 and 0 33 0	—	H.P.
4	196	,, 29	16 58 0	—	17 8 0	
5	199	May 7	6 33 0	—	6 38 0	H.P. V.S. from 6h. 24m. 35s. to 6h. 26m. 9s.
6	214	June 22	6 51 48	—	—	By several instruments. Duration several mins. Origin, Greece.
7	— 215	,, 29	12 20 0 and 18 50 0	—	—	H.P. feeble oscillations. V.S. from 18h. 47m. 47s.
8	216	July 2	4 19 12	—	4 30 0	Various instruments. Strong. Origin, Dalmatia.
9	223	,, 21	11 31 0	—	11 41 0	H.P.
10	230	Aug. 31	20 3 45	20 30 0	21 0 0	
11	232	Sept. 13	18 12 0	—	20 0 0	
12	233	,, 22	12 54 0	—	14 4 0	
13	235	Oct. 11	16 50 34	—	18 14 0	
14	239	Nov. 17	13 30 0	—	14 0 0	
			1899.			
15	249	Jan. 22	8 14 37			Origin, Greece.
16	263	Mar. 7	1 30 0			

19. *Excerpt from the Catania Register.*

Observations made at the R. Osservatorio di Catania e dell' Etna by the Director, Dr. A. Ricco.

The records are from the 'grande seismografo,' a pendulum 25m. long, carrying 300 kilos.

No.	Shide No.	Date	Commencement	Maximum	Duration	Amp.	Remarks
			1898.				
			H. M. S.	H. M. S.	H. M. S.	MM.	
1	—	Mar. 29	2 13 45	2 15 30	1 6 33	1	
2	—	Apr. 3	—	—	—	—	Slight perturbations especially in the morning occasioned by a strong W. wind.
3	—	„ 4	—	—	—	—	As above, but the perturbations were stronger.
4	193	„ 22	23 48 58	0 33 47 0 34 29	0 56 25	1	
—		„ 25	—	—	—	—	Perturbations due to the movements of the sea for 24 hours.
5	196	„ 29	16 33 40	17 1 4	2 26 25	0·5	
6	199	May 7	6 1 40	6 45 33 7 56 18	1 11 56	0·37	
7	—	„ 20	—	—	—	—	Perturbations due to the sea.
8	201	„ 22	16 33 39	—	0 0 34	—	Local earthquake S.W. of Etna.
9	214	June 22	6 51 48	6 52 56	2 3 20	1·15	
10	215	„ 29	18 49 8	19 1 5	2 4 14	1·5	
11	216	July 2	4 19 52	4 23 37	0 26 56	3·8	
12	—	„ 12	—	—	—	—	Perturbations due to the sea.
13	220	„ 14	0 30 26	0 30 26	0 10 30	0·25	
14	—	„ 14	—	—	—	—	Perturbations due to the sea.
15	—	„ 20	—	—	—	—	Small perturbations in the morning.
16	223	„ 21	11 28 41	11 33 31	0 14 35	0·75	
17	—	Aug. 8	—	—	—	—	Small perturbations all day.
18	—	„ 22	—	—	—	—	Small perturbations in the morning.

THE CATANIA REGISTER—*continued.*

No.	Shide No.	Date	Commencement	Maximum	Duration	Amp.	Remarks
			H. M. S.	H. M. S.	H. M. S.	MM.	
19	230	Aug. 31	20 4 3	20 12 33	1 34 51	0·8	
20	—	Sept. 3	6 19 0	—	—	—	Of doubtful character.
21	232	,, 13	18 10 31	18 11 27	2 34 30	0·5	
22	233	,, 22	12 40 32	Uncertain	2 7 46		
23	235	Oct. 11	17 3 22	17 38 42 17 39 56	1 26 43	0·5	
24		,, 15	—	—	—	—	Movements due to the sea.
25	239	Nov. 17	11 59 33	Uncertain	1 57 47		
26	240	Dec. 1	12 38 11	12 49 51	0 48 59	0·17	
				1899.			
27	245	Jan. 6	19 46 11	Uncertain	0 28 8		
28	249	,, 22	8 14 11	8 19 48	0 22 37	2·5	
29	250	,, 25	0 1 43	Uncertain	1 19 51		
30	—	,, 26	—	—	—	—	Movements due to the sea.
31	263	Mar. 7	1 18 14	1 19 23	0 4 42	0·25	
32	—	,, 12	—	—	—	—	Movements due to the sea.
33	267	,, 21	14 46 24	14 57 30	0 22 24	0·5	
34	268	,, 23	10 34 15	11 9 48	1 15 45	0·25	
35	269	,, 23	14 18 1	14 54 45	0 59 25	0·15	

20. *Seismometrical Observation at Tokio.*

***Catalogue of Earthquakes recorded by a Gray-Milne Seismograph at the Central Meteorological Observatory, Tokio, January* 27, 1898, *to January* 29, 1899. (*Continuation of Catalogue commencing in the British Association Report,* 1886.)**

No.	Date	Local time of Occurrence. 9 hrs. in advance of Greenwich	Duration	Horizontal Motion					Vertical Motion	
				Direction	Maximum Range		Maximum Velocity	Maximum Acceleration	Maximum Range	
					Period	Amplitude	mm. secs.	mm. secs.	Period	Amplitude
						1898.				
		H. M. S.	M. S.		SECS.	MM.			SECS.	MM.
1 982	Jan. 27	10 43 27 P.M.	—	—	—	slight	—	—	—	—
1,983	Feb. 10	0 15 2 P.M.	—	—	—	,,	—	—	—	—
1,984	,, 13	11 52 47 A.M.	—	—	—	,,	—	—	—	—
1,985	,, 13	11 58 36 P.M.	2 49	S.S.E., N.N.W.	0·7	1·4	6·3	56·4	0·5	0·5
1,986	,, 14	6 5 48 A.M.	—	—	—	slight	—	—	—	—
1,987	,, 21	6 49 6 A.M.	—	—	—	,,	—	—	—	—
1,988	,, 23	5 57 10 P.M.	—	—	—	,,	—	—	—	—
1,989	,, 26	5 14 47 P.M.	—	—	—	,,	—	—	—	—
1,990	,, 28	3 51 31 A.M.	—	—	—	,,	—	—	—	—
1,991	Mar. 3	11 6 10 P.M.	—	—	—	,,	—	—	—	—
1,992	,, 4	9 5 20 A.M.	—	—	—	,,	—	—	—	—
1,993	,, 5	1 4 21 P.M.	—	—	—	,,	—	—	—	—
1,994	,, 5	5 44 47 P.M.	—	—	—	,,	—	—	—	—

CATALOGUE OF EARTHQUAKES RECORDED AT TOKIO—*continued*

No.	Date	Local time of Occurrence. 9 hrs. in advance of Greenwich	Duration	Horizontal Motion					Vertical Motion	
				Direction	Maximum Range		Maximum Velocity	Maximum Accelera-tion	Maximum Range	
					Period	Amplitude	mm. secs.	mm. secs.	Period	Amplitude
		H. M. S.	M. S.		SECS.	MM.			SECS.	MM.
1,995	Mar. 5	11 41 8 P.M.	—	—	—	slight	—	—	—	—
1,996	,, 9	4 45 9 A.M.	—	—	—	,,	—	—	—	—
1,997	,, 9	6 19 25 A.M.	—	—	—	,,	—	—	—	—
1,998	,, 9	10 2 24 A.M.	—	—	—	,,	—	—	—	—
1,999	,, 15	1 0 21 P.M.	—	—	—	,,	—	—	—	—
2,000	,, 16	10 13 4 P.M.	—	—	—	,,	—	—	—	—
2,001	,, 17	3 21 12 A.M.	—	—	—	,,	—	—	—	—
2,002	,, 17	3 26 54 A.M.	—	—	—	,,	—	—	—	—
2,003	,, 22	10 31 38 P.M.	—	—	—	,,	—	—	—	—
2,004	,, 24	10 29 7 P.M.	—	—	—	,,	—	—	—	—
2,005	,, 27	3 24 7 A.M.	1 6	N.N.W., S.S.E.	0·3	0·7	7·3	153·5	—	slight
2,006	,, 27	11 25 8 P.M.	—	—	—	slight	—	—	—	—
2,007	Apr. 3	6 10 6 A.M.	2 30	N.W., S.E.	0·5	1·5	9·4	118·4	0·3	0·3
2,008	,, 4	8 27 5 P.M.	—	—	—	slight	—	—	—	—
2,009	,, 4	10 42 32 P.M.	—	—	—	,,	—	—	—	—
2,010	,, 6	1 27 15 A.M.	—	—	—	,,	—	—	—	—
2,011	,, 9	3 40 5 A.M.	—	—	—	,,	—	—	—	—
2,012	,, 11	9 56 32 A.M.	—	—	—	,,	—	—	—	—
2,013	,, 12	5 41 29 A.M.	—	—	—	,,	—	—	—	—
2,014	,, 14	3 30 23 P.M.	—	—	—	,,	—	—	—	—
2,015	,, 18	8 57 11 P.M.	—	—	—	,,	—	—	—	—
2,016	,, 20	2 4 24 A.M.	—	—	—	,,	—	—	—	—
2,017	,, 21	8 4 7 P.M.	—	—	—	,,	—	—	—	—
2,018	,, 23	0 55 45 A.M.	—	—	—	,,	—	—	—	—
2,019	,, 23	8 36 49 A.M.	12 0	S., N.	0·9	0·8	2·8	15·6	—	—
2,020	,, 26	7 07 51 P.M.	—	—	—	,,	—	—	—	—
2,021	,, 29	0 23 8 A.M.	—	—	—	,,	—	—	—	—
2,022	,, 29	9 38 21 P.M.	—	—	—	,,	—	—	—	—
2,023	,, 30	3 17 0 A.M.	—	—	—	,,	—	—	—	—
2,024	May 6	7 22 59 A.M.	—	—	—	,,	—	—	—	—
2,025	,, 6	7 48 33 A.M.	—	—	—	,,	—	—	—	—
2,026	,, 7	5 38 0 P.M.	—	—	—	,,	—	—	—	—
2,027	,, 9	2 49 6 A.M.	—	—	—	,,	—	—	—	—
2,028	,, 9	6 21 40 P.M.	—	—	—	,,	—	—	—	—
2,029	,, 10	8 26 43 A.M.	—	—	—	,,	—	—	—	—
2,030	,, 14	8 31 0 A.M.	—	—	—	,,	—	—	—	—
2,031	,, 19	11 55 55 P.M.	—	—	—	,,	—	—	—	—
2,032	,, 22	1 14 48 A.M.	—	—	—	,,	—	—	—	—
2,033	,, 23	1 51 43 A.M.	—	—	—	,,	—	—	—	—
2,034	,, 23	11 1 8 P.M.	—	—	—	,,	—	—	—	—
2,035	,, 26	3 0 32 A.M.	2 10	N.W., S.E.	0·5	1·8	11·3	182·1	0·2	0·2
2,036	,, 26	3 37 4 A.M.	—	—	—	slight	—	—	—	—
2,037	,, 26	4 55 33 A.M.	—	—	—	,,	—	—	—	—
2,038	,, 26	6 28 2 A.M.	—	—	—	,,	—	—	—	—
2,039	,, 31	1 9 0 A.M.	—	—	—	,,	—	—	—	—
2,040	June 1	4 20 12 P.M.	—	—	—	,,	—	—	—	—
2,041	,, 6	10 39 51 P.M.	—	—	—	,,	—	—	—	—
2,042	,, 8	9 13 30 A.M.	—	—	—	,,	—	—	—	—
2,043	,, 9	11 40 23 A.M.	—	—	—	,,	—	—	—	—
2,044	,, 12	2 31 18 A.M.	—	—	—	,,	—	—	—	—
2,045	,, 12	10 25 52 A.M.	—	—	—	,,	—	—	—	—
2,046	,, 12	3 24 54 P.M.	—	—	—	,,	—	—	—	—
2,047	,, 13	3 43 15 P.M.	—	—	—	,,	—	—	—	—
2,048	,, 15	1 15 8 P.M.	—	—	—	,,	—	—	—	—
2,049	,, 21	10 22 19 A.M.	—	—	—	,,	—	—	—	—
2,050	,, 24	3 47 47 A.M.	—	—	—	,,	—	—	—	—
2,051	,, 30	0 12 6 P.M.	—	—	—	,,	—	—	—	—
2,052	,, 30	10 6 19 P.M.	1 10	N.E., S.W.	0·1	0·3	9·4	592·2	—	—
2,053	July 5	6 56 57 P.M.	—	—	—	slight	—	—	—	—
2,054	,, 7	6 35 49 P.M.	—	—	—	,,	—	—	—	—
2,055	,, 12	0 35 7 A.M.	—	—	—	,,	—	—	—	—
2,056	,, 12	5 40 30 P.M.	—	—	—	,,	—	—	—	—
2,057	,, 12	10 55 35 P.M.	1 50	S.W., N.E.	0·3	0·8	8·4	175·5	0·2	0·2
2,058	,, 13	1 19 35 A.M.	—	—	—	slight	—	—	—	—
2,059	,, 13	8 9 45 P.M.	—	—	—	,,	—	—	—	—
2,060	,, 14	7 8 50 P.M.	—	—	—	,,	—	—	—	—
2,061	,, 15	5 10 44 A.M.	—	—	—	,,	—	—	—	—
2,062	,, 18	3 20 26 P.M.	—	—	—	,,	—	—	—	—

CATALOGUE OF EARTHQUAKES RECORDED AT TOKIO—*continued.*

No.	Date	Local time of Occurrence. 9 hrs. in advance of Greenwich	Duration	Horizontal Motion					Vertical Motion	
				Direction	Maximum Range		Maximum Velocity	Maximum Acceleration	Maximum Range	
					Period	Amplitude	mm. secs.	mm. secs.	Period	Amplitude
		H. M. S.	M. S.		SECS.	MM.			SECS.	MM.
2,063	July 19	2 49 35 A.M.	—	—	—	slight	—	—	—	—
2,064	,, 20	6 41 54 P.M.	—	—	—	,,	—	—	—	—
2,065	,, 22	7 17 6 A.M.	—	—	—	,,	—	—	—	—
2,066	,, 25	6 20 11 A.M.	2 10	S.S.W., N.N.E.	0·3	0·4	4·2	87·7	—	—
2,067	,, 25	0 17 13 P.M.	1 20	S.E., N.W.	0 4	1·0	7·9	123·4	0·2	0·3
2,068	,, 27	2 35 21 A.M.	—	—	—	slight	—	—	—	—
2,069	Aug. 1	1 24 18 P.M.	—	—	—	,,	—	—	—	—
2,070	,, 4	8 48 45 A.M.	—	—	—	,,	—	—	—	—
2,071	,, 7	11 3 45 P.M.	—	—	—	,,	—	—	—	—
2,072	,, 11	5 40 47 P.M.	1 20	N.E., S.W.	0·3	1·2	12·6	263·2	0·1	0·2
2,073	,, 17	4 16 23 P.M.	—	—	—	slight	—	—	—	—
2,074	,, 21	0 9 39 A.M.	—	—	—	,,	—	—	—	—
2,075	,, 21	1 29 51 A.M.	—	—	—	,,	—	—	—	—
2,076	,, 22	11 40 33 P.M.	—	—	—	,,	—	—	—	—
2,077	,, 23	8 5 20 A.M.	—	—	—	,,	—	—	—	—
2,078	,, 23	11 47 59 A.M.	—	—	—	,,	—	—	—	—
2,079	,, 27	4 38 14 A.M.	—	—	—	,,	—	—	—	—
2,080	,, 27	5 5 19 A.M.	1 0	S., N.	0·8	0·4	1·6	12·3	—	—
2,081	,, 31	0 12 24 P.M.	—	—	—	slight	—	—	—	—
2,082	Sept. 1	6 2 19 P.M.	—	—	—	,,	—	—	—	—
2,083	,, 4	2 50 46 P.M.	—	—	—	,,	—	—	—	—
2,084	,, 4	3 53 5 P.M.	—	—	—	,,	—	—	—	—
2,085	,, 5	4 47 27 P.M.	—	—	—	,,	—	—	—	—
2,086	,, 7	1 6 42 P.M.	—	—	—	,,	—	—	—	—
2,087	,, 8	0 15 9 P.M.	—	—	—	,,	—	—	—	—
2,088	,, 9	8 59 25 P.M.	—	—	—	,,	—	—	—	—
2,089	,, 11	10 3 36 P.M.	—	—	—	,,	—	—	—	—
2,090	,, 15	7 2 45 P.M.	—	—	—	,,	—	—	—	—
2,091	,, 16	4 48 23 A.M.	2 30	S.S.E., N.N.W.	1·1	0·44	1·1	6·5	—	—
2,092	,, 16	8 32 42 A.M.	—	—	—	slight	—	—	—	—
2,093	,, 24	9 16 41 A.M.	—	—	—	,,	—	—	—	—
2,094	,, 26	10 28 43 A.M.	—	—	—	,,	—	—	—	—
2,095	,, 27	10 19 59 A.M.	—	—	—	,,	—	—	—	—
2,096	,, 28	1 43 2 A.M.	3 20	E.S.E., W.N.W.	0·8	1·5	5·9	46·3	0·1	0·1
2,097	Oct. 1	0 36 35 A.M.	—	—	—	slight	—	—	—	—
2,098	,, 6	4 55 59 A.M.	—	—	—	,,	—	—	—	—
2,099	,, 7	11 0 46 A.M.	—	—	—	,,	—	—	—	—
2,100	,, 20	3 16 2 P.M.	—	—	—	,,	—	—	—	—
2,101	,, 26	10 30 47 A.M.	—	—	—	,,	—	—	—	—
2,102	Nov. 6	9 2 24 A.M.	—	—	—	,,	—	—	—	—
2,103	,, 7	2 59 5 A.M.	2 40	E.S.E., W.N.W.	2·0	1·1	1·7	5·4	—	—
2,104	,, 10	10 20 43 A.M.	—	—	—	slight	—	—	—	—
2,105	,, 12	2 46 38 A.M.	—	—	—	,,	—	—	—	—
2,106	,, 12	9 42 19 A.M.	2 10	W.S.W., E.N.E.	0·3	1·2	12·6	263·2	—	slight
2,107	,, 13	11 33 12 A.M.	—	—	—	slight	—	—	—	—
2,108	,, 14	4 6 43 P.M.	—	—	—	,,	—	—	—	—
2,109	,, 20	3 41 12 A.M.	—	—	—	,,	—	—	—	—
2,110	,, 21	9 7 5 A.M.	—	—	—	,,	—	—	—	—
2,111	,, 28	7 2 47 A.M.	—	—	—	,,	—	—	—	—
2,112	,, 28	10 56 10 P.M.	—	—	—	,,	—	—	—	—
2,113	Dec. 4	1 57 0 A.M.	—	—	—	,,	—	—	—	—
2,114	,, 5	0 50 33 A.M.	—	—	—	,,	—	—	—	—
2,115	,, 5	0 13 46 P.M.	—	—	—	,,	—	—	—	—
2,116	,, 13	1 35 38 A.M.	—	—	—	,,	—	—	—	—
2,117	,, 14	3 26 9 P.M.	—	—	—	,,	—	—	—	—
2,118	,, 19	11 59 42 A.M.	—	—	—	,,	—	—	—	—
2,119	,, 21	3 2 15 A.M.	—	—	—	,,	—	—	—	—
2,120	,, 25	1 1 46 A.M.	—	—	—	,,	—	—	—	—
2,121	,, 27	4 49 40 P.M.	—	—	—	,,	—	—	—	—
2,122	,, 30	11 31 40 P.M.	—	—	—	,,	—	—	—	—
				1899.						
2,123	Jan. 1	1 51 1 A.M.	—	—	—	,,	—	—	—	—
2,124	,, 5	9 1 38 A.M.	—	—	—	,,	—	—	—	—
2,125	,, 8	1 10 41 A.M.	—	—	—	,,	—	—	—	—
2,126	,, 14	11 30 35 A.M.	—	—	—	,,	—	—	—	—
2,127	,, 22	8 4 59 A.M.	—	—	—	,,	—	—	—	—
2,128	,, 23	2 51 38 P.M.	—	—	—	,,	—	—	—	—
2,129	,, 29	7 59 33 P.M.	—	—	—	,,	—	—	—	—

21. *Hawaii: Honolulu.*

On February 19, 1898, the trustees of the Elizabeth Thompson Science Fund assigned me a grant of $250 in aid of a seismic survey of the world. This was expended in purchasing a horizontal pendulum, which was shipped to the care of H.M.'s Consul-General, W. J. Kenny, in Hawaii. When Mr. Kenny left Honolulu in March 1899, the instrument was handed to Professor Maxwell, who will work in conjunction with Professor Alexander and Professor Hosmer (Principal of the Government High School), and the latter, I understand, will kindly make arrangements for its installation. Professor George Davidson, Chairman of a Committee appointed by the Council of the University of California to undertake Seismic Investigations, writes me that Mr. Bishop of Honolulu has promised a site for the instrument, and that Professor Alexander will see that it is placed in working order. It is hoped that by next year a series of records will have been obtained from this exceedingly important station. Copies of the report based upon these records should be sent to the Secretary of the Board of Trustees of the Elizabeth Thompson Science Fund, Harvard Medical School, Boston, Mass., through the liberality of which body the Hawaiian Station has been established.

22. *Egypt: Cairo.*

Captain H. G. Lyons, R.E., Director-General of the Survey Department, writes on June 2, 1899, that owing to structural alterations and other causes, it has not been possible to commence continuous observations with the seismograph. The instrument was handed to him in February last, and in about three months' time observations will commence.

23. *U.S.A.: Philadelphia, Swarthmore College.* Professor S. J. CUNNINGHAM.

When observations commenced at this station Professor Cunningham experienced great trouble with 'air tremors,' but from the excellent character of the seismogram for the Mexican earthquake of January 24, 1899, it is anticipated that these difficulties have been overcome, but no report has been received.

III. *Discussion of the preceding Registers.*

Although in the following discussions a few disturbances are referred to in detail, all that is given for the majority are the time entries. The first of these refers to the instant when motion commenced at various stations. It is the commencement of the preliminary tremors referred to as P.T.'s. In the Milne H.P. records these are usually shown as a mere thickening of the line. If there is no entry in this first column it means that heavy motion commenced suddenly, or else in consequence of movements due to air currents the commencement of the P.T.'s was not determinable. The duration of these first P.T.'s, which are regarded as compressional waves which have travelled through the earth, is given where it is possible in the second column. These quantities are not the same as those given in the Shide Register, which refer to the duration of all movement from the commencement up to the maximum. The time of the maximum, which is not the time when the largest group of waves appears, but a point usually midway between this commencement and end, is noted in the third column. The difference between the first and third columns gives the duration of all P.T.'s, and corresponds to entries in the Shide Register. The sum of the first and second columns gives the commencement of the second phase of motion. For the commencement of other phases of motion, of which there may be several before the appearance of the largest waves (L.W.'s.), reference must be made to the seismogram.

For entries in the first column all records should be fairly comparable. The entries in the second column are only comparable in those instances where I have been able to place the seismograms for the stations to which they refer side by side. Where this has been the case will be seen by reference to the reproductions of such seismograms. The accuracy of the determinations of the times given in the third column is dependent upon conditions which govern the accuracy of the entries in the second column. If a station reports a series of times for the first, second, third, &c., sudden increases in range of motion, unless we have the seismograms before us it is by no means certain that these correspond to phases of movement which have been similarly numbered at a second station.

The time entries for Potsdam are only given approximately. (See p. 194.)

The first illustration of these three-column entries is Earthquake No. 182.

Determination of Origins.

The methods by which origins may be determined from time observations are numerous.[1] The simplest, perhaps, is that of circles, and its application is as follows :—If the large waves of an earthquake reach stations B, C and D four, six and eight minutes after reaching station A, then when they reach A the wave fronts are respectively about 600, 900 and 1,200 kms. distant from B, C and D. On a globe with B, C and D as centres I draw circles 600, 900 and 1,200 kms. radius. The centre of the circle, found by trial, which passes through A and touches the circles round B, C and D, is the origin required. The assumption is that whilst the P.T.'s are propagated with variable velocities through the earth, the large waves traverse the surface of the earth with a velocity that is nearly constant. In this illustration I have assumed this velocity to be 2·5 kms. per second.

The observations which support these assumptions are too numerous to require special reference.

With times of arrival at only three stations we are left to decide between two possible centres. See Earthquake 252.

In consequence of the want of sufficient records which are strictly comparable, no attempt has been made in the present report to determine origins with any degree of accuracy.

As an assistance in these determinations the times at which preliminary tremors have been recorded and intervals by which they have outraced the large waves at various stations are not neglected, whilst the topographical and geological character of the locality in which the origin is placed is often an indication as to whether the determinations are correct.

Earthquakes, Nos. 133 *and* 134, September 20 and 21, 1897.[2]

These earthquakes, which were separated from each other by an interval of about ten hours, evidently came from the same origin, and were

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[1] See 'Earthquakes,' *Int. Sci. Series*, pp. 200–212.

[2] See *British Association Report*, 1898, p. 211.

connected with the throwing up of a small island off the coast of North-West Borneo, near to Labuan.

The first of these disturbed an electrometer at Batavia at 7h. 14m. 20s. P.M., a magnetometer being disturbed two minutes later. These disturbances indicate the arrival of the larger waves, which coming from Labuan had travelled about 1,660 kms. The velocity of propagation of these movements may be taken at about 2·7 kms. per second. With this assumption the conclusion is that this earthquake originated at about 7h. 4m. 20s. P.M., the time to travel to Batavia having been 10 minutes.

The effect of the second earthquake was to disturb a magnetometer in Batavia at 5h. 22m. 45s. A.M., which by similar reasoning leads to the conclusion that it originated at about 5h. 13m. A.M. At Sandakan, which is about 300 kms. from the origin, it was noted at 5h. 18m. A.M., the inference from which is that the time at the origin would be about 5h. 16m. A.M. The mean between these two determinations gives as an approximation for the true time at the origin 5h. 14m. 30s. A.M.

Apparent Velocity of Preliminary Tremors.

Distance in kms.		Locality of Observation	September 20			September 21		
			Time	Velocity in kms. per sec.		Time	Velocity in kms. per sec.	
On Arc	On Chord			Arc	Chord		Arc	Chord
			H. M. S.			H. M. S.		
—	—	Origin .	7 4 20	—	—	5 14 30	—	—
9046	8302	Nicolaiew .	7 23 30	7·8	7·2	5 27 0	12·0	11·0
10212	9150	Potsdam .	7 26 0	7·8	7·0	5 30 0 (about)	10·9	9·8
10545	9378	Catania .	7 25 2	8·4	7·5	5 29 32	11·6	10·3
10656	9453	Ischia . .	7 21 54	10·1	9·0	5 28 12	12·9	11·5
10711	9489	R. di Papa .	7 25 0	8·6	7·6	5 32 8	10·1	8·9
10730	9490	Rome . .	7 21 54	10·1	9·0	5 29 42	11·7	10·4
11211	9815	Edinburgh .	7 56 0	3·6	3·1	6 7 30	3·4	3·0
11433	9954	Shide . .	7 24 47	9·3	8·1	5 28 51	13·2	11·5

In discussing the above table, the Edinburgh records may at once be excluded as referring to large waves rather than to preliminary tremors. Making this exception then, it will be observed that the velocities for September 21, are greater than those for September 20. Now as these two earthquakes, as recorded in Europe, indicate initial impulses of about the same intensity, it is extremely likely that they radiated from their origins with equal velocities, and therefore the differences seen in the tables in all probability are dependent upon errors in the times calculated for the origins of these shocks for which there is no sure method of correction. On comparing these velocities with velocities determined over paths of similar lengths (see 'British Association Report,' 1897, p. 174) it is noticed that one set of results lie about as much above average determinations, as the other does below the same.

A fair approximation to truth may therefore possibly be obtained by taking the average results recorded for the two shocks. In doing this, Catania, Ischia, Rocca di Papa and Rome, may be placed together as representing a path, which for each is practically 96° in length. The result of this operation is as follows:—

Localities	Distance in degrees	Velocity in kms. per sec.		¼√ Average Depth in kms.
		Arc	Chord	
Nicolaiew	81°	9·9	8·1	8·0
Potsdam	92°	9·3	8·4	9·1
Catania, Ischia . . Rocca di Papa, Rome .	96°	10·4	9·0	9 5
Shide	103°	11·2	9·8	10·2

The slight discrepancy in the Potsdam record no doubt depends on the want of accuracy in the original observation as indicated in the first table.

The figures in the fifth column express in kilometres one quarter of the square root of the average or mean depth of the chords connecting the origin and each of the observing stations. The close correspondence between these figures and those in the third and fourth columns so long as the records refer to wave paths exceeding 2,000 kms. was pointed out in the Report for 1898, p. 221. These two earthquakes have been discussed by Dr. G. Agamennone in the 'Atti della Reale Accademia dei Lincei,' September 18, 1898, vol. vii. Fas. 6, p. 135. Inasmuch as he has calculated velocities for the preliminary tremors, based on the supposition that the disturbance had only reached the Batavian isoseist when the magnetometers at that station were disturbed, he arrives at velocities practically reaching 30 kms. per second, which are very much higher than those discussed in the preceding tables. He also gives velocity tables for the large waves which are somewhat higher than those which are obtained when it is assumed that the disturbances originated at the times used in our calculations. For example, the shock of September 20, if it originated at 7h. 4m. 20s. apparently gives for the velocities of the large waves results like the following :—

	Velocity in kms. per sec.	
	On Arc	On Chord
First large wave . . .	3·1	2·7
Largest wave . . .	2·7	2·3
Last large wave . . .	1·8	1·6

In calculations of this description the assumption is that all the waves recorded at a distant station left their origin at practically the same time. If this were so, inasmuch as the last trace of movement at Shide took place three hours after the arrival of the preliminary tremors, then the last movement only travelled at a rate of 0·9 km. or 0·8 km. per second, a conclusion that is very improbable. The inference to be derived from the sections in this report relating to Earthquake Echoes (p. 227) and Earthquake Precursors (p. 280) is that the only movements which started from an origin at approximately the same time, are those lying between the first preliminary tremor and the large slow waves representing the maximum motion. The limiting velocities for this earthquake, therefore, lie between 9·3 and about 2·7 kms. per second.

No. 180, March 29, 1898.

	H.	M.	S.		H.	M.	S.	
Shide . . .	0	5	11	to	23	0	39	Series of disturbances.
Bidston . . .	About these times.							

These small movements may possibly have been connected with an earthquake noted at Cadiz on March 30.

No. 182, March 31. (Origin, California?)

	H.	M.	S.	M	H.	M.	S
Shide	8	21	1	4	8	26	1
Nicolaiew	8	22	0	8	8	34	0
Potsdam		—		—	8	26	0
Edinburgh	7	36	30	—		—	

No. 185, April 3.

	H.	M.	S.	M.	H.	M.	S.
Shide	7	38	35	—	7	41	0
Nicolaiew	6	53	0	—	6	58	0
Potsdam		—		—	7	30	0
San Fernando	7	44	4	—		—	

No. 188, April 6.

	H.	M.	S.	M.	H.	M.	S.
Shide	12	37	17	6·0	12	46	0
Toronto	12	44	40	7·0	12	54	44
Potsdam	12	39	0	3·0	12	40	0
San Fernando	12	36	49	—		—	

Origin, Western Atlantic.

The Shide seismogram shows symmetry between the shocks and first echo.

No. 189, April 15. (Origin, California.)

Locality	Commencement	P.T.'s	1st Max.	2nd Max.	3rd Max.
	H. M. S.	M. S.	H. M. S.	H. M. S.	H. M. S.
Shide	7 47 55	4 0	7 52 55	8 1 0	8 11 0
Nicolaiew	7 54 0	—	7 57 0	—	—
Rocca di Papa	7 54 0	—	8 2 0	—	—
Ischia	8 0 0	—	—	—	—
Potsdam	7 48 0	—	7 57 0	—	—
Toronto	—	—	7 26 40	—	—
Edinburgh	7 39 0	—	—	—	—

The above was noted at about 7.20 A.M., April 15, in California, at Albion, Mendocino Co., where it caused minor damage. The time at which the P.T.'s commenced at Shide, owing to air tremors, is not clearly defined. Neither is this phase clear in the seismogram from Potsdam. Mr. Ralph R. Funk, of Albion, California, writes me with regard to a series of shocks, of which the above is one, saying that 'frequently we would be called to the "phone," and in answering would be asked, "Did you feel that one?"' The movements reached us about the time of our reply. The other end of the line was about twenty miles inland, and the conclusion is that the shocks must have originated inland. Mr. Funk enclosed with his letter cards from a Draper's self-recording thermometer, showing the effect of shocks upon the record. Between April 15 and 18 I count twenty-two sudden displacements with ranges of from 2 to 10 mm.

Mr. Funk's observations lead to the conclusion that these earthquakes originated at a centrum from forty to sixty miles inland from Albion, and the times of their origin would be about one minute earlier than the times he noted. The time for the particular earthquake here considered would, therefore, be 7h. 19m. A.M.

With this assumption we obtain the following table of velocities :—

—	Time of travel		Distance		Velocity of L.W.'s in kms. per sec.
	P.T.'s	L.W.'s	Degrees	On Arc	
Shide	29m.	34m.	75°	8325 kms.	4·0
Nicolaiew	35m.	38m.	91°	10101 ,,	4·4
Rocca di Papa	35m.	43m	98°	9768 ,,	3·7
Potsdam	29m.	38m.	79°	8769 ,,	3·8
Toronto	—	8m.	32°	3552 ,,	7·0 ?

These velocities are distinctly too high, and as the time of arrival of the large waves in Europe is fairly accurate, we must conclude that the shock originated earlier than the time here assumed. For this reason, and for the reason that the times of arrival of the preliminary tremors in Europe do not appear to have been accurately noted, the velocities of these precursors have not been calculated.

No. 192, April 23.

	H.	M.	S.	M.	H.	M.	S.
Shide	9	8	47	3	9	13	0
Potsdam	9	6	0	—	9	12	0

No. 193, April 22–23. (Origin, N.-E. Japan.)

Locality	Commencement			Duration of P.T.'s	Maximum			Remarks
	H.	M.	S.	M.				
Shide	23	58	55	25	0	31	12	Commencement earlier
Rocca di Papa	23	48	40	3	0	23	0	—
Ischia	23	30	0	—		—		—
Catania	23	48	58	—	0	33	47	—
Toronto	23	59	50	25	0	34	26	—
San Fernando	23	59	51	20	0	36	36	—
Potsdam	23	51	0	—		—		—
Nicolaiew	23	47	0	—	23	58	0	—
Tokio		—		—	23	33	49	—

We have here the case of a large earthquake which reached Toronto, Shide, and San Fernando (Spain) and other places at about the same time.

The following accounts of this disturbance are taken from newspapers published in Japan :—

'The sharp shock of earthquake which was felt at Yokohama and Tokio on the morning of the 23rd instant was not unattended with accidents in the north-eastern districts. At Maizawa-cho, Iwata Prefecture, a house was thrown down ; at Nanamiki-cho fissures were produced in the ground at various places ; at Satokawaguchimachi a house was damaged, while the premises of the Kuji Police Station were also affected. At Sanumo, Miyagi Prefecture, two persons are reported to have been injured, while houses and godowns were damaged. At Sendai a large Buddhist image of the Shurin-ji temple was shattered to pieces, and the buildings of the Prefectural Office and other houses all suffered more or less injury. The districts of Ishinomaki, Fukushima and neighbourhood were also a good deal affected, while at Sakata, Yamagata Prefecture, the waters of all rivers overflowed their banks.—*Japan Times.*'

'On Saturday morning (April 23, 1898), at 8.36 A.M., a somewhat strong and prolonged shock of earthquake was felt in Tokio. According to the bulletin issued by the Central Meteorological Observatory, the seismic movement is described as follows :—

Vibration commenced at	8h. 36m. 49s. A.M.
Duration of movement	12m.
Direction of movement	North to South.
Maximum horizontal vibration	8 mm.
Nature of vibration	Slow.

'It is conjectured that the shock was caused by a subsidence of the sea bed in some part of the Northern Pacific. The following table shows the localities where the shock was felt :—

Localities	Time A. M. H.	M.	S.	Nature
Ishikawa	8	34	50	Strong
Fukushima	8	36	40	,,
Akita	8	30	0	,,
Awomori	8	36	0	,,
Yamagata	8	36	0	,,
Utsunomiya	8	36	30	,,
Mayebashi	8	36	34	,,
Kumagai	8	36	39	,,
Niigata	8	37	9	,,
Yokohama	8	36	15	,,
Tokachi	8	29	15	Weak
Mito	8	36	35	,,
Kofu	8	36	53	,,
Nagoya	8	37	40	,,
Yokosuka	8	38	47	,,
Fukui	8	35	0	Faint
Nemuro	8	37	3	,,
Numazu	8	37	53	,,

Japan Mail.'

From a consideration of the above time observations, and from the position of the places at which the movement was severe, it is probable that the origin was from 4° to 5° distant in a north-north-east direction from Tokio. The heavy movement travelled to Tokio at a rate of about 2·5 kms. per second. The time at the origin would, therefore, be 3m. 42s. earlier than that recorded in Tokio, or approximately on May 22 at 23h. 33m. G.M.T. This conclusion is fairly in accord with all the time observations made in Japan, excepting those for Akita and Tokachi.

Professor Ōmori, by different reasoning, places the origin 120 to 200 kms. E.S.E. from Miyako, the time at that place being 23h. 34m. 13s. The time at the origin and the position of the same are, therefore, practically identical with what has been stated, and we have here another illustration of a suboceanic yielding at a depth of from 1,500 to 4,000 fathoms on the face of the western bank of the Tuscarora Deep. That sea waves were not reported indicates that submarine landslips or sudden displacements of materials on the ocean floor were not of marked magnitude.

Place	Time in Transit		Distance			Velocity kms. per sec.		
	P.T.'s	L.W.'s	Degrees	On arc kms.	On chord kms.	P.T.'s on arc	P.T.'s on chord	L.W.'s on arc
	M. S.	M.						
Shide . .	25 55	58 0	86	9546	8675	6·1	5·6	2·7
Ischia . .	—3 0	—	87	9657	8756	—	—	—
Catania . .	15 58	61·0	90	9990	8994	10·4	9·3	2·4
San Fernando	27 0	64·0	99	10989	9672	6·7	5·9	2·8
Potsdam. .	18 0	—	79	8769	8091	8·1	7·5	—
Nicolaiew .	14 0	51·0	75	8325	7743	9·9	9·2	2·7
Toronto . .	26 50	62·0	89	9879	8915	6·1	5·5	2·4
Rocca di Papa	15 40	50 0	89	9879	8915	10·5	9·4	3·2

No. 195, April 25.

	H.	M.	S.	M.	S.	H.	M.	S.
Shide	11	14	17	—			—	
	to 12	25	10					
Kew	11	5	54	—			—	
	to 11	24	0					
Nicolaiew	11	10	30	8	30	11	44	0
Catania	11	40	0	—			—	
Potsdam	11	0	0 (about)				—	

No. 196, April 29.

	H.	M.	S.		H.	M.	S.
Shide	16	39	4	—	16	59	0 (about)
	to 17	37	34				
San Fernando . .	16	37	19	—		—	
Nicolaiew . . .	16	30	0	—		—	
Rocca di Papa . .	16	40	0	—	16	43	0
Ischia . . .	16	58	0	—		—	
Catania . . .	16	33	40	—	17	1	4
Bidston . . .	17	0	0 (about)	—		—	
Toronto . . .	16	28	20	—	16	35	5
Potsdam . . .	16	30	0 (about)	—	16	57	0 (about)

The Shide and Potsdam seismograms, although they have definite commencements, are but marked thickenings of the normal trace. The times for maxima are therefore uncertain. The tremors reached Shide at least eleven minutes after reaching Toronto, whilst the large waves at Shide were twenty-four minutes behind those at Toronto. With a velocity of 2·5 kms. per second when the large undulations reached Toronto they would be at a distance of 32° from Shide. Considerations of this description based upon the above data suggest the idea that this earthquake had its origin on the western side of the Atlantic in the direction of the West Indies.

No. 199, May 7.

	H.	M.	S	M.	S	H.	M.	S.
Shide	6	4	6	—		6	39	0
Kew	6	4	0	7	0	6	10	30
Nicolaiew	6	4	0	—			—	
Rocca di Papa	6	5	30	—		6	14	0
Catania	6	1	40	—		6	45	33
Ischia	6	33	0	—			—	
	or 6	24	35					
Toronto	6	0	42	—		6	16	40
San Fernando	5	57	49	—			—	
Potsdam	5	57	0	—			—	

From the difference in time of the arrival of the maxima movements at Toronto and Shide it is likely that the origin of this earthquake should be sought for in the direction of the West Indies (see Earthquake No.196).

No. 200, May 20.

	H.	M.	S.		H	M.	S.
Shide	23	29	5	—		—	
Bidston	23	30	0	—	0	11	0

No. 201, May 22.

	H.	M.	S.		H.	M.	S.
Shide	17	28	15	—		—	
	to 22	50	0	—		—	
Catania	16	33	39	Local earthquake		—	
Madras	17	14	25	—	17	20	1

No. 207, May 30.

	H.	M.	S.		H.	M.	S.
Shide	4	18	55	and	4	28	56
Potsdam	4	18	0	,,	5	30	0

No. 210, June 3.

	H.	M.	S.		H.	M.	S.
Shide	17	14	44	—		—	
Kew	10	10	42	—	17	14	30
Nicolaiew	16	57	0	—	17	0	0
Madras. Tremors recorded?							
Potsdam	17	0	0	—	17	9	0

This earthquake crossed Europe from the S.E. towards the N.W.

No. 211, June 19.

	H.	M.	S.		H.	M.	S.
Shide	7	8	50	—		—	
Kew	7	8	24	—		—	
Potsdam	7	0	0	—	7	3	0

Origin probably the same as No. 210.

No. 213, June 21.

	H.	M.	S.	M.	H.	M.	S.
Shide	0	46	42	12	1	0	2
Kew	0	46	18	—	0	59	6
Nicolaiew	0	37	0	—	0	44	0
Rocca di Papa	0	53	20	—	0	58	0

Origin probably the same as No. 210.

No. 214, June 22.

	H.	M.	S.		H.	M.	S.		H.	M.	S.	
Shide . .	6	52	42	—	7	14	42	&	7	13	42	Nine maxima.
to	9	7	42									
Nicolaiew .	6	54	0	—	7	18	0					
Rocca di Papa .	6	45	2	—	6	45	18					
Ischia . .	6	51	48	—		—						
Catania . .	6	51	48	—	6	52	56					
Batavia . .	6	42	18	—		—						
Kew . .	6	54	24,	6h. 56m., 6h. 57m., up to 7h. 5m.								At least 12 maxima.

Origin, Greece ?

No. 215, June 29.

	H.	M.	S.	M.	H.	M.	S.		H.	M.	S.
Shide . .	18	48	37	9	19	27	37				
Kew . .	18	47	12	9	19	21	36	or	19	27	0
Nicolaiew .	18	42	0	12	18	59	0				
Rocca di Papa	18	48	42	—	18	59	0	(about)			
Ischia . .	18	50	0	—		—					
or	18	47	47								
Catania . .	18	49	8	—	19	1	5				
Toronto . .	18	43	21	—	18	55	18				
Potsdam . .	18	57	0	—	19	8	0				

At Shide the duration exceeded three hours, the amplitude was 8 mm., indicating a tilting of 4″·8. The period of the large waves was 13·7s., which, with a velocity of 3 kms. per second, indicates a wave-length of 39 kms. The height of these waves may have been 30·2 cm.

The records for the preliminary tremors indicate that the movements commenced at Shide, Kew, Rocca di Papa, Ischia, and Catania about five minutes later than at Toronto. The largest group of waves were recorded at Shide and Kew 26m. or 32m. after they reached Toronto. The corresponding intervals for the remaining stations cannot be inferred with certainty from the above data, as the last column of this for Nicolaiew, Rocca di Papa and Catania apparently refers to the *commencement* of the large motion.

Although the data taken as a whole point to an origin much nearer Toronto than Europe, and the time intervals for large waves noted in Toronto, Kew and Shide suggest an origin on the western side of the Atlantic in the direction of the West Indies, the marked difference in the time at which the first heavy movements were recorded at Shide and Kew throw great uncertainty upon the localising of the originating centre

No. 216, July 2.

	H.	M.	S.	M.	S.	H.	M.	S.
Shide	4	27	24		—		—	
Kew	4	25	24		—	4	28	30
Nicolaiew	4	22	0	1	30	4	25	0
Rocca di Papa	4	19	0		—	4	21	0
Ischia	4	19	12		—		—	
Catania	4	19	52		—	4	23	37
Potsdam	4	21	0		—		—	

Origin, Dalmatia. Both the preliminary tremors and large waves have been recorded at distant stations in an expected order.

No. 217, July 2.

	H.	M.	S.	
Shide	17	3	23	The identity of these disturbances is doubtful.
Kew	16	25	48	

No. 218, July 3.

	H.	M.	S.
Shide	21	42	23
Kew	21	44	30

No. 219, July 12.

	H.	M.	S.		
Shide	10	30	0	(about)	The identity of these two shocks is doubtful.
Batavia	11	38	6		

No. 220, July 13–14.

	H.	M.	S.		H.	M.	S.
Shide	23	51	8	—		—	
Catania	0	30	26	—	0	30	26

No. 221, July 14.

	H.	M.	S.	M.	H.	M.	S.	
Shide	17	46	15	15	18	9	27	The P.T.'s are irregular.
Nicolaiew	17	30	0	15	17	52	0	
Potsdam	17	33	0	12	17	54	0	

Origin to the East or South of Nicolaiew.

No. 222, July 20.

	H.	M.	S.		H.	M.	S.
Shide	16	59	26	—	16	59	26
Toronto	(uncertain)			—	17	2	33

Origin, Mid-Atlantic ?

No. 223, July 21.

	H.	M.	S.		H.	M.	S.
Shide	11	35	56	—	11	37	0
Ischia	11	31	0	—		—	
Catania	11	28	41	—	11	33	31
Kew	11	35	0	—		—	

Origin, S.E. Europe ?

No. 224, July 26.

	H.	M.	S.	
Shide	23	21	14	This may be connected with a series of shocks recorded in Valparaiso and Concepcion, one or two of which appear to have been noted in Toronto. (See the *Toronto Register*.)

In a despatch to the Foreign Office, H.M.'s Minister in Chile, Audley C. Gosling, Esq., writes respecting these shocks as follows :—

'I have the honour to report the occurrence on the night of July 23 of severe shocks of earthquake at Concepcion, in Southern Chile, latitude 36° 50′, longitude 73° 10′.

'Nearly every building in the town suffered more or less damage, especially the cathedral and the Bank of Chile and Concepcion.

'The first shock happened at 10.30 P.M. (July 24, 3h. 16m. 30s. A.M. G.M.T.) lasting 30s., with an oscillation of 10 centimetres, direction south-east to north-east, followed by lesser shocks, which continued altogether for twelve hours, and the sea having receded fears were entertained of a tidal wave.

'The winter throughout Chile has been unusually severe and wet, the rainfall in May and June having amounted to 22 inches. Seismic disturbance has been frequent, especially in the neighbourhood of the Andes, where abnormal quantities of snow have fallen. In several passes of the Cordillera snow has attained the extraordinary depth of from 14 to 18 metres, and postal communication has been entirely stopped *viâ* the Andine route for close on two months, many hundred bags of postal matter having been abandoned in the snow by the carriers, several of whom lost their lives whilst performing their perilous duties.

'On the 12th inst. snow fell heavily in Santiago, a very unusual occurrence, to a depth of between 2 and 3 inches: indeed for twelve hours the capital presented the appearance of a city of Northern Europe.

'Valparaiso suffered considerable damage from inundation in the early part of this month, caused by excessive rainfall, which was followed by shocks of earthquake and a severe cyclone, causing considerable destruction to property.'

No. 225, August 8.

	H. M. S.	M. S.	H. M. S.
Shide	8 53 30	—	9 5 0
Nicolaiew	8 25 0	19 0	8 54 0
Potsdam	8 9 0	—	8 45 0

No. 228, August 21.

	H. M. S.
Shide	17 28 0
Bidston	16 50 0

The identity of these shocks is doubtful.

No. 230, August 31.

	H. M. S.	MM.	H. M. S.
Shide	20 5 2	5 to 6	20 36 25
Kew	20 4 0	8	20 35 0
Nicolaiew	20 39 0	—	20 42 0
Rocca di Papa	20 3 40	—	20 31 0
Ischia	20 3 45	—	20 30 0
Catania	20 4 3	—	20 12 33
Toronto	20 17 53	—	21 3 20
Batavia	20 1 18	—	—
Madras	20 2 5	—	20 18 0
Potsdam	20 0 0	—	—
San Fernando (recorded)	—	—	—

At Shide the first P.T.'s lasted about 6 minutes, after which they increased and decreased sometimes gradually and sometimes suddenly up to 20h. 31m. 21s. The maximum was attained at 20h. 36m. 25s., to be followed by its echo of nearly equal magnitude at 20h. 42m. 29s. Following this there were fairly symmetrical sets of earthquake followers. (See Earthquake Echoes, p. 227). The period of the P.T.'s reached 12s., and that of the L.W.'s 15·4s. The maximum amplitude was 9 mm., indicating tilting of 5″·4.

At Kew the chief movements were as follows :—

H. M.		
29 34·9	semi-amp. 5 mm.	or 2″·75
0 37	2·8	1″·55
0 37·8	3·2	1″·75
0 40·7	3	1″·65

It will be observed that the amplitude at Kew is smaller than the one from Shide.

An inspection of the time records shows that the disturbance first reached Batavia and Madras. The heavy movement reached Ischia and Rocca di Papa 12m. or 13m. later, Shide and Kew 18m. later, and Toronto about 45m. later. With the assumption that the large waves travelled at a rate of about 2·5 kms. per second, these time intervals would lead us to look for the origin of this earthquake in the South Indian Ocean eastwards of Madagascar.

No. 231, September 3.

	H.	M.	S.	M.	S.	H.	M.	S.	
Shide . .	16	4	48	15	8 ?	16	21	57	Commencement badly defined.
Nicolaiew .	15	32	0	—		16	2	0	
Toronto .	16	17	22	—		16	18	30	
Kew . .	15	54	0	—			—		
Potsdam .	3	54	0	—		16	15	0	

The L.W. records for Shide and Toronto would indicate an origin on the west side of the Atlantic, but this does not accord with the records from Potsdam and Nicolaiew.

No. 232, September 13.

	H.	M.	S.		H.	M.	S.	
Shide . . .	18	11	37	—		—		Record small and not clear.
	to 20	7	35	—		—		
San Fernando .	18	10	49	—		—		
Nicolaiew . .	18	7	30	—	18	34	0	
Rocca di Papa .	18	11	38	—	18	11	55	
Ischia . . .	18	12	0	—		—		
Catania . .	18	10	31	—	18	11	27	
Batavia . .	18	2	6	—		—		
Toronto . .	18	21	45	—	19	15	44	
Kew . . .	18	11	18	—		—		
Madras . . .	17	34	25	—		—		
Bombay . .	18	53	28	—		—		
Potsdam . .	18	0	0	—	19	54	0	

The minuteness and irregularity of the earlier movements render it impossible for Shide, Kew, and other places to give an exact commencement. The large movement recorded in Toronto suggests an origin nearer to that place than to Europe.

No. 233, September 22.

	H.	M.	S.	M.	S.	H.	M.	S.
Shide	12	30	54	—			—	
	to 13	37	52	—			—	
Kew	12	46	30	—		13	10	0
Nicolaiew	12	44	0	9	0	13	19	0
Rocca di Papa	12	58	0	—		13	33	0 about
Ischia	12	54	0	—			—	

	H.	M.	S.	H.	M.	H.	M.	S.
Catania	12	40	32	—		Uncertain		
Batavia	12	27	18	—			—	
Madras	12	34	43	—			—	
Bombay	12	40	45	—		12	49	8
Potsdam	12	39	0	—		13	21	0
Mauritius		—		—		13	50	0

No. 234, September 25.

	H.	M.	S.	M.	S.	H.	M.	S.
Shide	0 cr 12	51	50	—		0 or 12	54	0
Kew	0	50	18	—		0	53	0
Nicolaiew	12	25	0	9	0	12	37	0
Bombay	12	18	37	—		12	20	36

The movement apparently crossed Europe from the east towards the west.

No. 235, October 11.

	H.	M.	S.	M.	S.	H.	M.	S.
Shide	16	58	52	—		17	33	39
Kew	16	59	12	—		17	38	42
Nicolaiew	16	49	30	—		17	7	0
Rocca di Papa	16	50	35	—		17	32	0
Ischia	16	50	34	—			—	
Catania	17	3	27	—		17	38	42
Toronto	16	47	29	7	0	17	29	30
Batavia	16	49	42	—			—	
Victoria	16	44	34	4	0		—	
Madras	17	2	36	—			—	
Bombay	17	2	36	—		17	36	42
Potsdam	17	6	0	—		17	30	0 (?)
San Fernando	17	27	19	—			—	

The probability is that this shock originated in the Pacific, and after reaching Victoria spread eastwards to Toronto and Europe. In the seismograms received there are several maxima, and it seems impossible to recognise similar groups of large waves at different stations.

No. 237, October 12.

	H.	M.	S.	H.	M.	S.
Shide	13	21	2		—	
Kew	13	20	42	13	23	30

No. 238, October 15.

	H.	M.	S.	M.	S.	H.	M.	S.
Shide	4	2	44	—		4	30	0
Kew	4	28	0	—			—	
Nicolaiew	3	28	0	37	0	4	10	0
Batavia	4	11	42	—			—	
Madras	3	50	19	—		3	52	25
Bombay	3	46	41	—		3	47	24
Mauritius	4	6	12	—		4	10	0

The disturbance apparently crossed Europe from east to west.

No. 239, November 17.

	H.	M.	S.	M.	S.	H.	M	S.
Shide	13	20	15	- -			—	
Kew	13	37	12	—		13	46	24
Nicolaiew	13	3	0	9	0	13	37	0
Rocca di Papa	13	4	40	—		13	46	30

	H.	M.	S.	H.	M.	H.	M.	S.
Ischia	13	30	0		—		—	
Catania	11?	59	33		—		—	
Batavia		—			—	13	12	18
Toronto	13	9	46		—	13	44	50
Victoria	13	7	0		—		—	
Bombay	13	14	19		—	13	34	0
Potsdam	13	0	0		—	13	45	0
Mauritius	13	45	23		—	14	2	0

It seems probable that from its origin the shock radiated westwards to Java and India, whilst eastwards it successively reached Victoria, Toronto, and Europe.

No. 240, December 1.

	H.	M.	S.		H.	M.	S.
Shide	12	48	16	—		—	
Nicolaiew	12	42	0	—	12	54	0
Catania	12	38	11	—	12	49	51
Victoria, B.C.		?		—		—	
Kew	12	51	18	—		—	
Madras	12	45	14	—	12	55	9
Bombay (November 30)	12	43	17?	—		—	
Potsdam	12	42	0	—	12	57	0
Mauritius		—		—	0	58	43?

The Shide seismogram consists of a series of small broadenings of the normal line, like No. 239.

No. 241, December 3.

	H.	M.	S.
Shide	3	18	43
Kew	3	1	18
	and 3	7	0
Nicolaiew	6	18	0?
Potsdam	6	15	0
Bombay	2	49	58?

No. 243, December 3.

	H.	M.	S.
Shide	17	42	26
Batavia	16	59	54

It is doubtful whether these refer to the same shock.

No. 244, December 4.

	H.	M.	S.		H.	M.	S.
Shide	20	20	40	—		—	
Bombay	20	28	5?	—		—	
Mauritius	7	30	0?	—	7	52	0?

No. 245, January 6, 1899.

	H.	M.	S.	M.	S.	H.	M	S.
Shide	19	11	9	—			—	
Kew	19	3	42	—			—	
	and 19	41	30	—		20	4	12
Nicolaiew	19	23	0	10	0	19	46	0
Rocca di Papa	19	49	0	—		19	52	30
Catania	19	46	11	—		Uncertain		
Toronto	19	9	8	—			,,	
Bombay	19	13	40?	—			,,	
Potsdam	19	9	0	—			,,	
San Fernando	19	14	4	—			—	

No. 246, January 12.

	H.	M.	S.		H.	M.	S.
Shide	3	58	18	—		—	
Toronto	3	47	50	—		—	
Victoria	3	35	16	—	3	36	15
Bombay (January 11)	19	23	44 ?	—		—	

Probably originated in the Pacific, and passed across North America to Europe.

No. 247, January 12.

	H.	M.	S.	M.	S.	H.	M.	S.
Shide	9	2	26	—			—	
Nicolaiew	8	37	0	11	0	8	50	0
Batavia	8	4	18 ?	—		8	8	48
Bombay	9	33	24	Dislocation of the line.				

No. 248, January 14.

	H.	M.	S.	M.	H.	M.	S.
Shide	2	48	55	—	3	22	48
Kew	2	58	12	27 ?	3	26	30
Nicolaiew	2	54	0	6	3	32	0
Toronto	2	42	18	13	2	57	6
Victoria, B.C.	2	42	30	9	2	55	28
Bombay (13th)	19	41	37 ?	—		—	
Potsdam	2	54	0	—	3	30	0

We have here well-defined maxima for Shide, Kew, Toronto, and Victoria. The latter place was reached first, whilst at intervals of 2, 29, and 36 minutes, Toronto, Kew and Shide, and Nicolaiew and Potsdam were reached. These data lead to the conclusion that the origin was in the Pacific, at no great distance from the coast of Central America.

No. 249, January 22. Origin, Greece.

	H.	M.	S.	M.	S.	H.	M.	S.
Shide	8	22	53	—		8	33	0
Kew	8	22	12	5	18	8	29	0
Nicolaiew	8	19	0	—		8	21	0
Rocca di Papa	8	16	10	—		8	20	40
Ischia	8	14	37	—			—	
Catania	8	14	11	—		8	19	48
Trieste	8	15	48	—		8	21	30
Bombay	9	15	47	Dislocation of the line.				
Potsdam	8	9	0	—			—	
	or 8	18	0	—			—	

This earthquake originated in Greece, and is described in the *Daily Telegraph* of January 23 as follows :—

> ‘Athens, Sunday.
>
> ‘A severe earthquake shock was felt in several parts of the Peloponnesus early this morning. The shock was most violent in the departments of Philiatra, in the province of Messinia, and Kyparrisia, in the province of Laconia, the two most fertile and beautiful districts of the peninsula. Several villages are completely destroyed, and in the towns practically every house is uninhabitable.
>
> ‘The loss of life would have been very great had not the majority of the inhabitants, warned by the first shocks, left their houses in the early morning, and camped in the open plains and fields. A great many, however, have been injured, and several are killed, though it is impossible at present to state the exact number.
>
> ‘The people, panic-stricken, have been in the fields all to-day, and are in a distressing condition.
>
> ‘The greatest efforts must be made to give them the urgent succour which is necessary.—*Central News.*’

The fact that the large waves reached Trieste, Rocca di Papa, and Nicolaiew at about the same time, and the English stations 10 minutes later, also indicate that the origin of this shock was in Greece.

No. 250, January 24–25. Origin, Mexico.

	H.	M.	S.	M.	S.	H.	M.	S.
Time at the origin		—			—	23	43	31
Shide	23	47	42?		—	0	34	42
Kew	23	47	24	9	0	0	35	30
				or 43	24			
Nicolaiew	23	57	30	4	0	0	12	0
				or 10	0			
Rocca di Papa	0	0	0		—		—	
Catania	0	1	43		—	Uncertain		
Toronto	23	50	24			0	7	10
Victoria, B.C.	23	51	7		—	0	4	10
Trieste	23	58	24		—	0	48	0
Bombay (25th)	12	57	59?		—		—	
Potsdam	23	48	0		—		—	
Mauritius		—			—	1	15	45
						and 1	19	0

At Shide the early part of the disturbance is eclipsed by air tremors. The first echo, the amplitude of which is equal to that of the maximum at 0h. 34m., was at 0h. 37m. The Kew record is distinctly smaller than the one from Shide, the amplitudes at these places being 4 mm. and 6 mm. respectively.

The following notes throw light upon the nature of the shock near to its origin, and other disturbances, with which it has been confused.

The Sub-Director of the Central Meteorological and Magnetic Observatory in Mexico, Senor José Zandejas, writes to Professor R. F. Stupart of Toronto, as follows:—

> 'Owing to the temporary absence of Senor Barcena, I have great pleasure in answering your favour of January 26 last, and inform you that the shock of earthquake on the 24th of the same month was felt here at 5h. 23m. (local time) and lasted 2 minutes, causing some damage to old buildings, but cannot be classified as very strong. Generally they are not in the capital. It was felt from Vera Cruz on the east to St. Blas on the west, both seaports, one in the Gulf and the other on the Pacific, declining towards the south to the Pacific Ocean and Tehuantepec Isthmus, including the States of Jalisco, Colima, Michoacan, Guerrero, Pueblas, Flaxcala, Mexico, Oaxaca, and Vera Cruz, which is the territory where earthquakes are generally felt and in which the volcanos of the Republic are situated.
>
> 'As these phenomena have not been sufficiently studied, it would be hazardous to point out a determinate point of convergence of their probable origin, but it has been noticed that the greatest intensity and frequency of these earthquakes take place in the States of Michoacan, Guerrero, Oaxaca, and Chiapas to Guatemala, &c., and might extend with still greater violence to the Pacific Ocean.'

In a subsequent letter Senor Zandejas corrects the above time to January 24, 5.29 A.M., and adds that there was a second shock at 5.9 P.M. (mean local Mexican time). The former was slight and the latter was strong.

The *United States Monthly Weather Review* for January gives the following note :—

> 'Reports from Mexico describe the earthquake of Monday evening, January 24, as the severest ever known in the City of Mexico. The first oscillation began at 9·09 (local time). It was from north-east to south-west, and lasted 1m. 56s. Three minutes later came a second shock, which lasted 5s., oscillating north-west and south-east. The earthquake was felt over the entire Republic of Mexico. At Colima it lasted 1m. 20s.; at Vera Cruz it lasted 10s. But few reports of this earthquake have been received from the United States, although it must have been feebly felt at many stations.
>
> 'At San Barnardino, Cal., a shock was felt at 4.55 P.M., January 25. The newspapers of that city state that the shock was of little greater severity than usual, and that the barometer dropped from 30·12 to 29·86, "an unusual occurrence, &c."'

Mr. O. H. Howarth, who is interested in recording earthquakes, writes to me from Hacienda de Zavalita, Oaxaca, Mexico, as follows :—

> 'I think you may be interested to have a local note about the earthquake shock which occurred here on Tuesday, January 24, being the longest and strongest I have yet experienced in this country. The time was 5.25 A.M., and the duration, as near as I could get it, 20 seconds. We are situated here about 13 miles south-west of the city of Oaxaca, in a winding cañon, well up into the mountain range : altitude, 6,200 feet. We seem to be all agreed that the wave approached from the south. The formation of the whole district here is a very hard gneissic granulite in which occur the quartz veins with gold. The feature which struck me most was the sensation (which I have not experienced before), of the wave grinding its way through a hard resisting medium. Just at the climax there was a peculiar jerk, as if it had changed its direction, or met with some exceptional obstruction. The noise was considerable, and some of our people were on their knees saying their "Ora pro nobis" with great vigour. One of them told me to watch the clouds, and for three hours afterwards I noticed heavy mist down upon the high ridge at the head of the cañon (8,700 feet), which otherwise we never see at this time of the year—the middle of the dry season. I cannot see any direct reason for an atmospheric change, but there is no doubt that a big condensation occurred. The shock seems to have been unusually long and severe in the city of Mexico (200 miles north from here)—1m. 36s. (this I doubt), and damage was done at some points; but probably the accounts which reach England will be exaggerated as usual.'

On May 29 Mr. Howarth again wrote me, saying that in Oaxaca where he was (200 miles south from Mexico City), there was a severe shock at 5.25 A.M., a slight tremor about 11 A.M., and another slight shock about 5 P.M. In Mexico City this was reversed, the slight shock being at 5.23 A.M. and the heavy one causing damage about 5 P.M. The first coming from the south to reach Mexico City would have to traverse the great range of Popocatepetl, Ixtaccehuall, and Ajusco, by which it would be absorbed or diverted, and therefore whilst strong in Oaxaca, it would be feeble in Mexico City. If the second came from the north or north-west these effects would be reversed. The only effect at Zavalita, near Oaxaca, on January 24, was to crack walls, and to bring down a load of loose rock at the entrance to a mine tunnel, and in this way it acted as a service. In Oaxaca the intensity of local shocks is remarkably variable at short distances.

The conclusion we arrive at from the above notes is that we have to deal with the shock felt severely in Mexico at 5.9 P.M., or at 11h. 45m. 31s. G.M.T. The time at the origin would be about 2m. earlier than this, or 11h. 43m. 31s.

Velocities of transit, on the assumption that the disturbance originated at 23h. 43m. 31s.

Place	Time of Transit		Length of path			Velocities in kms. per sec.		
	P.T.'s	L.W.'s	Degrees	Arc	Chord	P.T.'s		L.W.'s
						Arc	Chord	Arc
	M. S.	M. S.		KMS.	KMS.			
Shide . .	4 11	51 11	80	8880	8170	35	32	2·5
Kew . .	3 53 or 12 53	51 59	80	8880	8170	38 or 11·5	35 or 10·5	2·6
Nicolaiew . .	14 1	28 29	100	11100	9744	13·1	11·5	6·4?
Rocca di Papa .	16 21	—	92	10212	9150	10·4	9·3	—
Catania . .	18 12	—	97	10767	9526	9·8	8·7	—
Toronto . .	6 53	23 39	30	3330	3292	8·0	7·9	2·3
Victoria, B.C. .	7 36	20 39	34	3774	3719	8·2	8·1	3·0
Trieste . .	14 53	64 21	91	10101	9072	11·3	10·2	2·6
Bombay . .	14 28?	—	141	15651	11990	—	—	—

Because the commencement of the Shide seismogram is partially eclipsed by air tremors, there is no certainty in the determination for the time of transit of the P.T.'s. The Kew seismogram is perfectly clear, and shows a very small movement, commencing at 23h. 47m. 24s., which nine minutes later is reinforced by slightly larger tremors. The commencement of this second group leads to the determination of the velocities 11·5 and 10·5 kms. per second. Records from Shide, Kew, Toronto, and Victoria, which relate to large waves, are distinctly comparable, and the resulting velocities are fairly in accord to what previous investigations would lead us to expect. The velocities obtained for the preliminary tremors are, however, apparently too high, and suggest that the time determined for the origin of the shock is a little late. When more definite information is obtained from Mexico this may be altered.

The amplitude of the first maximum and the time interval to its 'echo.'

	Interval	Amp.
	M. S.	MM.
Shide	3 0	6
Kew	6 30	3·5
Toronto	5 0	7·5
Victoria	4 30	17

A good seismogram has been received from Swarthmore, Penn., U.S.A., but its time scale has not arrived in time for publication.

No. 251, January 30.

	H.	M.	S.		H.	M.	S.
Shide	18	55	42	—		—	
Kew	18	45	48	—		—	
Nicolaiew	17	59	30	—	18	25	0
Victoria, B.C.		?		—		—	
Madras	17	48	19	—	17	52	25
Bombay	17	50	16	—	17	58	34

No. 252, January 31.

	H.	M.	S.		H.	M.	S.
Shide	11	22	47	—	11	25	0
Kew	11	21	48	—	11	25	0
Toronto	11	36	0	—	11	37	12
Victoria, B.C.	11	40	0	—	11	41	26
Bombay	12	23	20	Dislocation.			

The time intervals for the L.W.'s indicate an origin to the south of the Azores or off the coast of North Norway.

No. 253, January 31.

	H.	M.	S.	M.	S.	H.	M.	S.
Shide	17	32	31	2	30	17	35	0
Kew	17	31	18	—			—	
Nicolaiew	17	1	30	12	30	17	15	0
Bombay	17	16	21	—			—	

No. 254, February 23.

	H.	M.	S.	M.	S.	H.	M.	S.
Shide	13	47	23	2	0	13	49	53
Kew	13	49	30	—			—	
Bidston	12	50	0	—			—	
Toronto	Uncertain			—		14	4	0
Victoria	14	6	40	—		14	8	33

The time intervals for the L.W.'s suggest an origin west of Cape Verd.

No. 255, February 26.

	H.	M.	S.		H.	M.	S.
Shide	13	47	29	—	13	48	0
Kew	13	49	0	—		—	
Victoria	14	6	23	—	14	8	24
Trieste	13	48	18	—	14	0	42

Origin probably near to that of No. 254.

No. 256, February 27.

	H.	M.	S.	M.	S.	H.	M.	S.
Shide	10	12	19	—		Light out		
Kew	11	27	30	—			—	
Nicolaiew	11	31	30	2	30	11	37	0
Toronto	11	41	10	—		11	42	20
Victoria		?		—		11	48	0
Bombay	10	42	20	Dislocation.				
San Fernando	11	35	49	—			—	

Origin probably the same as 252, 254, and 255.

No. 257, February 27.

	H.	M.	S.		H.	M.	S.
Shide	15	26	40	—		—	
Kew	15	27	12	—		—	
Trieste	15	28	12	—	15	40	30
Bombay	14	40	50	Dislocation.			

No. 259, February 28.

	H.	M.	S.		H.	M.	S.
Shide	19	47	38	—	19	48	38
Kew	19	48	30	—		—	
Toronto	20	0	15	—	20	1	0
Victoria	20	5	0	—		—	
Trieste	19	50	12	—	20	4	30
Bombay	20	9	23	Dislocation.			
San Fernando	19	56	49	—		—	

Origin like 255, &c.

No. 260, February 28.

	H.	M.	S.		H.	M.	S.
Shide	23	1	5	—		—	
Trieste	22	42	48	—	23	14	30

No. 262, March 6.

	H.	M.	S.		H.	M.	S.
Shide	20	52	31	—	20	56	0
Nicolaiew	20	30	0	—	20	34	0
Kew	20	36	42	—		—	

No. 263, March 7.

	H.	M.	S.	M.	S.	H.	M.	S.	
Shide	1	31	1 ?	—		1	53	42	P.T.'s eclipsed by air tremors.
Kew	1	17	42	—		1	53	24	
Nicolaiew	1	5	0	10	0	1	22	0	
Rocca di Papa	1	13	0	—		1	52	0	
Ischia	1	30	0	—			—		
Catania	1	18	14	—		1	19	23	
Toronto	1	19	29	—		2	1	0	
Victoria, B.C.	1	15	13	—		1	16	15 ?	
Trieste	1	6	54	—		1	42	48	
Bombay	0	3	47 ?	—			—		
Mauritius, Mar. 6,	23	20	0	to	Mar. 7,	1	35	0	
San Fernando	1	49	49	—			—		

This earthquake had its centre in Central Japan, but until the time of its origin is more definitely known its complete discussion is impossible. The *Japan Mail* of March 11 gives the following description of the occurrence :—

'The earthquake on the 7th instant belongs to the category of serious shocks. Our daily life in this country is perpetually disturbed by tremblings and shakings, which become at last so familiar that we scarcely notice them. Yet not a few of these ugly visitors fall short of calamitous dimensions by only a narrow margin, and the unconcern with which we receive them is simply the result of habit. Apparently the centre of disturbance on the 7th instant was somewhere in the vicinity of Osaka.

Such, at least, is the conclusion arrived at by the Meteorological Bureau, though the record of damage done suggests that Nagoya may share the honour. The time telegraphed from Nagoya is 9.45 A.M., and that telegraphed from Osaka 9.56, but it is not possible to place much reliance on these figures. Nagoya city does not seem to have suffered. The damage occurred chiefly at Ono, Handa, and Chirin, where houses are said to have been overturned. Wakayama, also, was severely visited, houses and godowns being overthrown in the two districts of Nishi-mura and Higashi-mura. The most accurate accounts come from Osaka. There the direction of the shock was from south-east to north-west. At first vertical, the movement presently became horizontal, the latter phase, which lasted about two minutes, developing the maximum intensity. Apparently the only personal injuries were not directly due to the shock, but resulted from a panic among the employees at the Osaka Cotton-spinning Factory. In attempting to escape from an upper story, several fell downstairs, and twenty-eight were hurt, two severely. Fuller details may show, however, that the falling of chimneys and buildings was not unaccompanied by loss of life.

'Considering the wide area through which the seismic disturbance on the 7th instant was felt, it is inferred that the origin of the force must have been at a point very deep below the surface. The great majority of the earthquakes experienced in this country are of distinctly limited scope. Thus the statistics collected by the Seismological Bureau show that out of 2,670 shocks felt in 1891, only eight were felt throughout an area of over 10,000 square miles. The great earthquake on August 28 in that year made itself perceptible throughout an area of 15,750 square miles, and the shock on the 7th of this month had a range of 15,000 square miles. The latter did not reach farther north than Yokohama: it was not felt at all in Tokio.

'A telegram received by the Home Department from Nara Prefecture gives details of the damage done by the earthquake:—"A strong shock was felt at 10 A.M. on the 7th. At Takata-machi twenty farmers' houses fell, and two children were buried in the ruins. At Sakmaimachi a man was crushed to death. Other damage is in course of investigation."

'A telegram received subsequently says: "The result of investigation shows that three persons were killed and 11 injured, 67 houses destroyed and 24 damaged. The mountains in Amanowawa Mura, Yoshino district, shook greatly and emitted a thunderous sound, and the ground opened in parts, landslips occurring here and there. Roads westward of Hirase have been broken away in places."

'Ten workers in the Tenwa mine were buried alive, but were dug out safely.'

—	Time of transit of L.W.'s	Distance	Velocity per sec on arc
	M.	°	KMS.
Shide	59	87	2·7
Kew	59	86	2·7
Nicolaiew	26	74·5	5·2 ?
Rocca di Papa	56	88	2·9
Catania	24	90	6·9 ?
Toronto	65	95	2·7
Trieste	47	84·5	3·3

The velocity of transit for the P.T.'s is not given, because small errors in the time observations lead to marked discrepancies in the final results.

A point of interest in the seismograms is that whilst at Shide and Kew the range of motion was 3 and ·8 mm., at Toronto it was only ·5, and at Victoria, the nearest station to the origin (71°), the movement was barely visible, and so indefinite that certain determinations of time are impossible. This latter place would be reached along a path entirely beneath the Pacific, Toronto by a path crossing Behring Straits, and Shide by a land path across Asia and Europe.

Observations of this nature suggest that oceanic waters exert a damping effect upon the earth waves traversing their beds.

No. 264, March 12.

	H.	M.	S.	M.	H.	M.	S.
Shide	9	55	10	9	10	26	12
Kew	9	55	42	—		—	
Nicolaiew	9	41	30	25	10	11	0
Toronto	9	52	11	—	9	58	7
Victoria, B.C.	9	49	55	—	9	59	30
Trieste	9	53	6	—	10	7	18
Batavia		—		—	10	8	12
Bombay	10	31	41	—		—	
Calcutta	8	51	20	—		—	
Mauritius		—		8h. 20m. to	10	50	0

The L.W. records for Toronto and Victoria, followed 13 and 27 minutes later by records at Batavia and Shide, suggest an origin in the Mid-South Pacific.

No. 266, March 19.

	H.	M.	S.
Shide	13	45	35
Victoria	13	15	43
Trieste	1?	24	12
Toronto	13	24	29 ?
Calcutta	12	36	18

This disturbance probably travelled from the western side of North America towards Europe.

No. 267, March 21.

	H.	M.	S.		H.	M.	S.
Shide	14	58	47	—	15	38	17
Kew	15	25	30	—		—	
Trieste	14	46	24	—	15	22	12
Catania	14	46	24	—	14	57	30
Calcutta	14	43	6	—		—	
San Fernando	15	58	19	—		—	

The movement apparently crossed Europe from the east or south-east.

No. 268, March 23.

	H.	M.	S.	M.	S.	H.	M.	S.
Shide	10	45	16	18	0	11	16	18
Kew	11	0	30	—		11	20	12
Toronto	10	41	52	—		11	6	0
Victoria, B.C.	10	35	47	—		11	17	17
Trieste	10	42	48	—		11	5	6
Catania	10	34	15	—		11	9	48
Bombay	11	42	30	—		11	47	46
San Fernando	11	40	34	—			—	

Apparently we have two small shocks, and it is difficult to discriminate between the commencements of the first and the second. For Shide, Toronto, and Victoria the times of the L.W.'s refer to the second disturbance, which may have originated on the western side of the Atlantic.

No. 269, March 23.

	H.	M.	S.		H.	M.	S.	
Shide	14	57	41	—	14	59	0	First of three maxima.
Kew	15	0	24	—	15	14	42	
Victoria, B.C.	14	55	20	—	15	5	11	
Trieste	14	30	0	—	14	47	24	
Toronto		—		—	14	45	47?	
Catania	14	18	1	—	14	54	45	
Calcutta	13	12	38	—		—		

No. 270, March 25.

	H.	M.	S.		H.	M.	S.
Shide	14	53	19	—	15	28	0
Kew	14	54	0	—		—	
Toronto	14	44	37?	—	14	46	57
Victoria, B.C.	14	46	25	—	15	0	12
Trieste	14	53	30	—	14	55	18
San Fernando	14	52	19	—		—	

To suit the L.W. intervals for Toronto, Victoria, and Shide, an origin may be sought on the West Coast of South America.

No. 271, March 25.

	H.	M.	S.
Shide	20	39	52
Kew	20	46	6

Earthquakes recorded at Shide, I.W., and also at distant stations, between February 27, 1898, *and April* 3, 1899.

Milne's H. P. (Photographic Record)									H.P. with Mirror (Photographic)			Bifilar Pendulum (Photographic)			H.P. and Ordinary Pendulums (Mechanical Registration)		
Shide, I.W.	Kew	Toronto	Victoria, B.C	San Fernando	Madras	Bombay	Calcutta	Batavia	Mauritius	Nicolaiew	Potsdam	Trieste	Bidston	Edinburgh	Rocca di Papa	Ischia	Catania
174	..	..	..	..	..	..	..	..	..	..	..	..	..	▬	..	..	..
179	..	..	..	..	..	..	..	..	..	..	..	..	..	▬	..	..	..
180	..	..	..	..	..	..	..	..	..	..	..	..	▬	▬	..	..	..
182	..	..	..	..	..	..	..	..	..	▬	▬	..	..	▬	..	..	..
185	..	..	..	▬	..	..	..	..	..	▬	▬	..	..	..	..	..	..
188	..	▬	..	▬	..	..	..	..	..	..	▬	..	..	..	..	..	..
189	..	▬	..	..	..	..	..	..	..	▬	▬	..	..	▬	▬	▬	..
192	..	..	..	▬	..	..	..	..	..	..	▬	..	..	..	..	..	..
193	..	▬	..	▬	..	..	..	..	..	▬	▬	..	..	..	▬	▬	▬
195	▬	..	..	..	..	..	..	..	..	▬	▬	..	..	..	▬	..	..
196	..	▬	..	▬	..	..	..	..	..	▬	▬	..	..	..	▬	▬	▬
199	▬	▬	..	▬	..	..	..	..	..	▬	▬	..	..	...	▬	▬	▬
200	..	..	..	..	..	..	..	..	..	..	..	..	▬	..	..	..	..
201	..	..	..	..	▬	..	..	..	..	..	..	..	..	..	..	..	▬
207	..	..	..	..	..	..	..	..	..	..	▬	..	..	..	..	..	..
209	..	..	..	▬	..	..	..	..	..	..	..	..	..	..	..	..	..

EARTHQUAKES RECORDED AT SHIDE, I.W. &c.—*continued.*

Milne's H. P. (Photographic Record)									H.P. with Mirror (Photographic)			Bifilar Pendulum (Photographic)			H.P. and Ordinary Pendulums (Mechanical Registration)		
Shide, I.W.	Kew	Toronto	Victoria, B.C.	San Fernando	Madras	Bombay	Calcutta	Batavia	Mauritius	Nicolaiew	Potsdam	Trieste	Bidston	Edinburgh	Rocca di Papa	Ischia	Catania
210	—	..	..	..	..	..	..	..	..	—	—	..	..	..	..	..	..
211	—	..	..	..	..	..	..	..	..	..	—	..	..	..	..	..	..
213	—	..	..	..	..	..	..	..	..	—	..	..	..	..	—	..	..
214	—	..	..	..	..	..	..	—	..	—	—	..	..	..	—	—	—
215	—	—	..	..	..	..	..	..	..	—	—	..	..	..	—	—	—
216	—	..	..	..	..	..	..	..	..	—	—	..	..	..	—	—	—
217	—	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
218	—	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
220	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	—
221	..	..	..	..	..	..	..	..	..	—	—	..	..	..	..	..	..
222	..	—	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
223	—	..	..	..	..	..	..	..	..	..	..	..	..	..	..	—	—
225	..	..	..	..	..	..	..	..	..	—	—	..	..	..	..	..	..
228	..	..	..	..	..	..	..	..	..	..	..	..	—	..	..	..	..
230	—	—	..	—	—	..	..	—	..	—	—	..	..	..	—	—	—
231	—?	—	..	..	..	..	..	..	..	—	—	..	..	..	..	..	..
232	—	—	..	—	—	—	..	—	..	—	—	..	..	..	—	—	—
233	—	..	..	..	—	—	..	—	—	—	—	..	..	..	—	—	—
234	—	..	..	..	..	—	..	..	..	—	..	..	..	..	..	..	..
235	—	—	—	—	—	—	..	—	..	—	—	..	..	..	—	—	—
237	—	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
238	—	..	..	..	—	—	..	—	—	—	..	..	..	..	..	..	..
239	—	—	—	..	..	—	..	—	—	—	—	..	..	..	—	—	—
240	—	—	—	..	—	—	..	..	—?	—	—	..	..	..	..	..	—
241?	—	..	..	..	..	—?	..	..	..	—	..	..	..	..	..	..	..
242	..	..	..	..	..	..	..	..	..	..	—	..	..	..	..	..	..
244	..	..	..	..	..	—	..	..	—	..	..	..	..	..	..	..	..
245	—	—	..	—	..	—	..	..	..	—	—	..	..	..	—	..	—
246	..	—	—	..	..	—	..	..	..	..	..	..	..	..	..	..	..
247	..	..	..	..	..	—	..	—	..	—	..	..	..	..	..	..	..
248	—	—	—	..	..	—	..	..	..	—	—	..	..	..	..	..	..
249	—	..	..	..	..	—	..	..	..	—	—	—	..	..	—	—	—
250	—	—	—	..	..	—	..	..	—	—	—	—	..	..	—	..	—
251	—	—	—	..	—	—	..	..	..	—?	..	..	..	..	..	..	..
252	—	..	—	..	..	—	..	..	..	..	..	..	..	..	..	..	..
253	—	..	..	..	..	—	..	..	..	—?	..	..	..	..	..	..	..
254	—	..	—	..	..	..	..	..	..	..	..	..	—	..	..	..	..
255	—	..	—	..	..	..	..	..	..	..	..	—	..	..	..	..	..
256	—	—	—	—	..	—	..	..	..	—	..	..	..	..	..	..	..
257	—	..	..	..	..	—	..	..	..	..	..	—	..	..	..	..	..
259	—	..	—	—	..	—	..	..	..	..	..	—	..	..	..	..	..
260	..	..	..	..	..	..	..	..	..	..	..	—	..	..	..	..	..
262	—?	..	..	..	..	..	..	..	..	—	..	..	..	..	..	..	..
263	—	—	—	..	..	—	..	..	—	—	..	—	..	..	—	—	—
264	—	—	—	..	..	—	—	—	—	—	..	—	..	..	..	..	..
266	..	..	—	..	..	..	—	..	..	..	..	—	..	..	..	..	..
267	—	..	..	..	..	..	—	..	..	..	..	—	..	..	..	..	—
268	—	—	—	..	..	—	..	..	..	..	..	—	..	..	..	..	—
269	—	..	—	..	..	..	—	..	..	..	..	—	..	..	..	..	—
270	—	—	—	..	..	..	..	..	..	..	..	—	..	..	..	..	..
271	—	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Totals . 67	42	23	18	13	8	24	4	9	8	35	29	13	4	5	18	15	22

Records were kindly sent to me from Rome, Pavia, Livorno Castello, and Catanzaro, which unfortunately arrived too late for insertion in this report.

Earthquakes recorded at Shide and at Distant Stations.

The preceding table shows the earthquakes which were recorded in the Isle of Wight and also at distant stations. When comparing the records at one station with those taken at any other station, consideration must be given to the dates on which these stations commenced their observations. For example, the Kew entries corresponding to those at Shide lie between Nos. 195 and 271 or April 25, 1898, and March 25, 1899. Just as comparisons may be made between the Isle of Wight list and that from Kew, showing that many earthquakes were recorded at the former place which were not recorded at the latter, exactly opposite comparisons might be made. For example, whilst the above list indicates that Kew only recorded forty-two disturbances out of fifty-seven noted at Shide, the complete register for Kew (p. 166) indicates that at that place seventy-five disturbances were noted, and it is possible that more than forty-two of these were common to other countries.

Although the Indian stations have recorded earthquakes which have also been observed in other parts of the world, in consequence of difficulties largely the result of a tropical environment the value of many seismograms has been impaired. Until these difficulties have been overcome the frequency of earthquakes common to India and other parts of the world can only be imperfectly indicated.

Although the instruments at Bidston and Edinburgh have yielded excellent results respecting slow changes in the vertical, and as such are important adjuncts to a seismological laboratory, yet the above table indicates that they fail to pick up many earthquakes.

Analysis of the Table from a Seismometrical Point of View.

The last line of the table shows that Kew, Toronto, Victoria, Bombay (?), Nicolaiew, Potsdam, and Trieste have recorded more earthquakes in common with the Isle of Wight than have been recorded at the Italian stations. This conclusion is more clearly indicated in the following table :—

Out of	57	records at	Shide	42, or 73	per cent.,	are common to	Kew
,,	61	,,	,,	23 ,, 37	,,	,,	Toronto
,,	32	,,	,,	18 ,, 56	,,	,,	Victoria, B.C.
,,	42	,,	,,	9 ,, 21	,,	,,	Batavia
,,	60	,,	,,	35 ,, 58	,,	,,	Nicolaiew
,,	48	,,	,,	29 ,, 60	,,	,,	Potsdam
,,	20	,,	,,	13 ,, 65	,,	,,	Trieste
,,	66	,,	,,	25 ,, 38	,,	,,	Italy

If the Italian stations are taken separately the percentage for each is lower than that for Italy as a whole. When we compare the twenty-four earthquakes recorded at Shide, Nicolaiew, and Potsdam which lie between Nos. 182 and 250 with those noted in Italy, we see that six of these, viz. Nos. 182, 185, 210, 231, 248, and 264, apparently escaped observation in the latter country.

Again, out of thirteen disturbances noted in Trieste and in the Isle of Wight, only six of these, viz. Nos. 255, 257, 259, 260, 264, and 266, are found in the Italian register. It will also be observed that some of the shocks which escaped the Italian instruments were well recorded in Toronto, Victoria, B.C., Batavia, and other places; and it may be added that if we except Nos. 182, 260, and 266, the seismograms representing these shocks from Shide, Potsdam, and other places are of marked magnitude.

Although it may be suggested that these omissions in the Italian registers of earthquakes which have spread over large portions of the world are due to a want of sensibility in the instruments employed in that country, such an explanation does not accord with the fact that these same instruments with their frictional indices pick up the small preliminary tremors of large earthquakes with apparently the same exactitude as the seismographs do which record photographically.

Whatever may be the true explanation of these *lacunæ*, it must be remembered that the open diagrams from the Italian instruments furnish information not obtainable from the majority of the photographic apparatus, and they are, therefore, indispensable to fully equipped laboratories.

Time Intervals between the arrivals of Earthquakes in Victoria, B.C., Toronto, and Shide.

1. *Intervals in Minutes between the arrival of P.T.'s and L.W.'s at Toronto and Shide after reaching Victoria.*

No. of Shock	Toronto	Shide	Toronto	Shide	
	M.	M.	M.	M.	
235	3 P.T.'s	14 P.T.'s	—	—	
239	3 ,,	13 ,,	—	—	
246	12 ,,	23 ,,	—	—	
248	0 ,,	7 ,,	2 L.W.'s	28 L.W.'s	
250	—	—	3 ,,	31 ,,	Origin, Mexico.
266	9 ,,	30 ,,	—	—	
268	6 ,,	10 ,, ?	—	—	

As it is known that No. 250 originated in the vicinity of Mexico it may be inferred, from the similarity in time intervals, that No. 248 originated from the same region. No. 246 probably travelled from the Pacific in an east direction through Victoria across North America to Toronto and on to Shide. Nos. 235 and 239 had similar origins well out in the Pacific considerably to the south of Victoria. The group, as a whole, apparently represents adjustments along the western frontier of the North American continent.

2. *Intervals in Minutes between the arrival of P.T.'s and L.W.'s at Toronto and Victoria after reaching the Isle of Wight.*

No. of Shock	Toronto	Victoria	Toronto	Victoria
	M.	M.	M.	M.
188	—	— P.T.'s	9	— L.W.'s
252	—	— ,,	12	16 ,,
254	—	— ,,	15	19 ,,
256	—	— ,,	x	$x+6$,,
259	3	18 ,,	13	—

The above shocks probably originated on the eastern side of the Mid-Atlantic, along the line of the Azores and Cape Verde Islands, or off the coast of Norway.

3. *Intervals in Minutes between the arrival of P.T.'s and L.W.'s at Victoria and Shide after reaching Toronto.*

No. of Shock	Victoria	Shide	Victoria	Shide
	M.	M.	M.	S.
264	—	— P.T.'s.	1	28 L.W.'s.
270	2	9 ,,	14	42 ,,

Origins probably in the Mid-South Pacific.

A shock from Japan, No. 263, reached Victoria first, whilst two and four minutes later it reached Shide and Toronto.

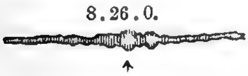
Illustrations of Seismograms.

The following illustrations of seismograms are only to be regarded as *sketches* of the original photograms. They show the range of motion and principal characteristics of wave-groups, but they do not show details like small serrations clearly exhibited in the records from which they are derived. The numbers correspond with the numbers given for particular earthquakes in the preceding text. The arrow with its time-mark gives the time for a particular phase of movement, which is usually that of the commencement. The number following the letter S gives the time-scale in millimetres per hour. Thus S=60 means that 60 millimetres equal one hour.

The locality at which a seismogram was obtained is indicated by the following initial or initials :—

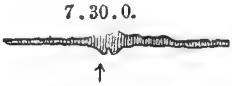
Isle of Wight . . .	I.W.	Bombay . . .	B.
Kew	K.	Calcutta . . .	C.
Toronto	T.	Batavia . . .	Ba.
Victoria, B.C. . . .	V.	Mauritius . . .	M.
San Fernando . . .	S.F.	Potsdam . . .	P.
Madras	Md.	Philadelphia . . .	Ph.

No. 182.—I.W. S=59.

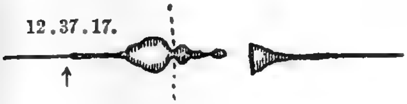


No. 182.—P. S=20.

No. 185.—I.W. S=59·5.



No. 185.—P. S=20.

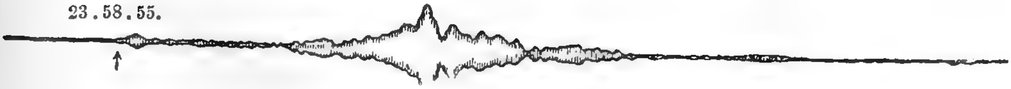


No. 188.—I.W. S=59.

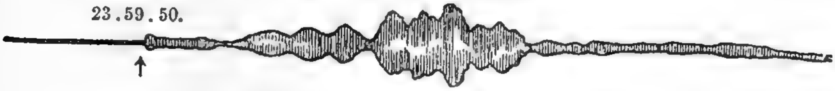
No. 188.—T. S=58·25.

No. 189.—I.W. S=59·5.

No. 189.—P. S=20.



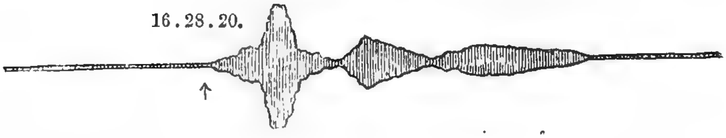
No. 193.—I.W. S=59.



No. 193.—T. S=58·5.

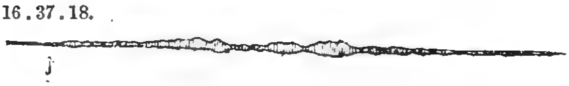
No. 193.—P. S=20.

No. 196.—I.W. S=59·75.



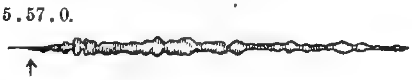
No. 196.—T. S=59.

No. 196.—P. S=20



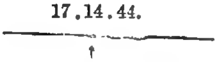
No. 196.—S.F. S=60.

No. 199.—I.W. S=59.

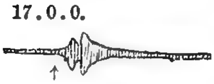


No. 199.—P. S=20.

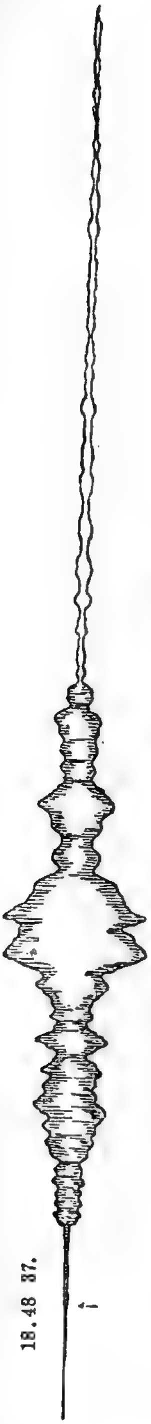
No. 199.—T. S=59.



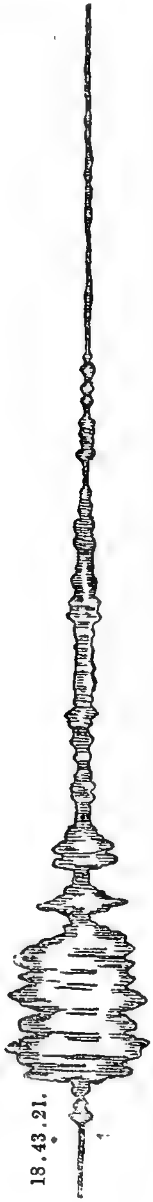
No. 210.—I.W. S=60.



No. 210.—P. S=20

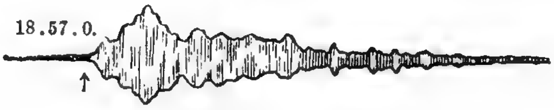


No. 215.—I.W. =60. (Also see Figs. 3 and 4.)



No. 215.—T. S=57·5.

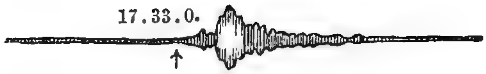
No. 215.—K. S=61



No. 215.—P. S=20.

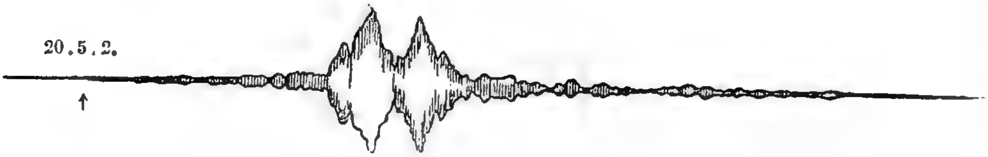
No. 221.—I.W. S=59·5.

No. 225.—I.W. S=59·5.



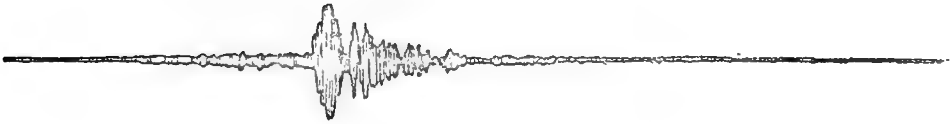
No. 221.—P. S=20.

No. 225.—P. S=20.

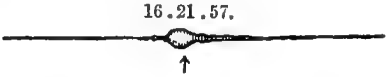


No. 230.—I.W. S=59·25. (Compare with Fig. 2, p. 228.)

No. 230.—K. S=61.



No. 230.—Ba. S=60·5.

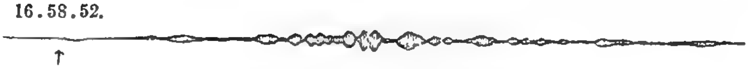


No. 231.—I.W. S=59·5.

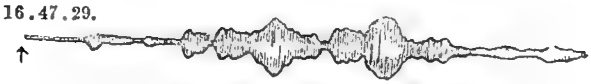
No. 231.—P. S=20.

No. 232.—P. S=20.

No. 232.—T. S=59.



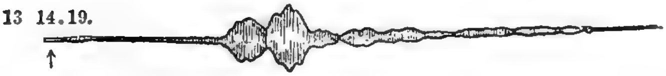
No. 235.—I.W. S=59·5.



No. 235.—T. S=58.

No. 238.—B. S=59.

Toronto, Oct. 21. S=58·25.



No. 239.—B. S=59.

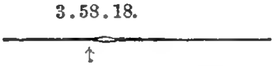
No. 240.—I.W. S=59.

No. 240.—P. S=20.

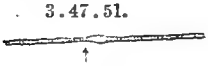
No. 240.—B S=59.

No. 245.—I.W. S=58.

No. 245.—T. S=58·75.



No. 246.—I.W. S=58.

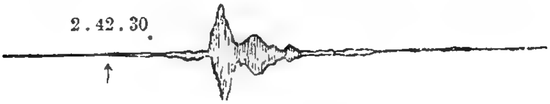


No. 246.—T. S=58.

No. 246.—V. S=60·5.

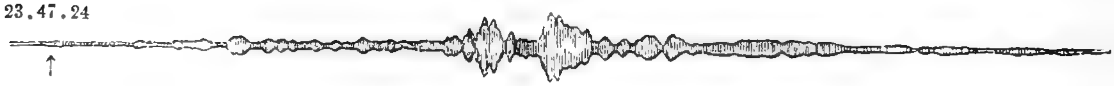
No. 248.—I.W. S=58.

No. 248.—T. S=58.

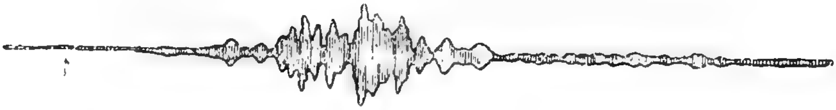


No 248.—V. S=60.

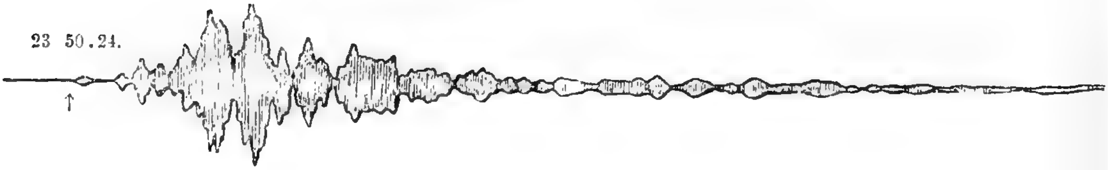
No. 250.—I.W. S=60.



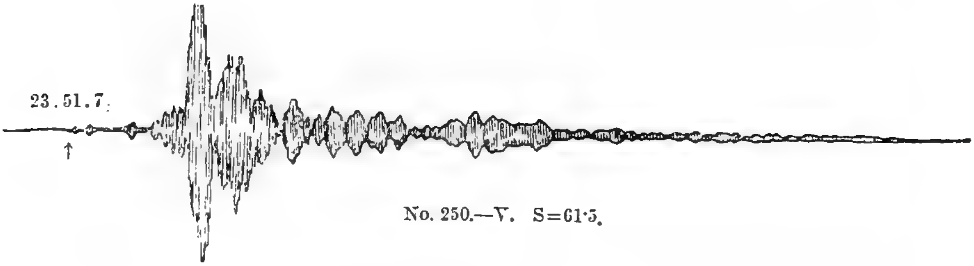
No. 250.—K. S=61.



No. 250.—Ph. S=61.



No. 250.—T. S=58·5.

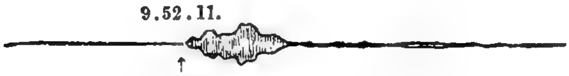


No. 250.—V. S=61·5.

No. 263.—I.W. S=58·25.

No. 263.—T. S=59.

No. 264.—I.W. S=58·25.

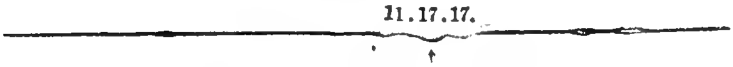


No. 264.—T.

No. 264.—V. S=60·75.

No. 268.—I.W. S=58·5.

No. 268.—T. S=58·25.



No. 268.—V. S=60·5.

No. 269.—I.W. S=58·25.

No. 269.—V.

No. 270.—I W. S=58·5.

No. 270.—V.

No. 270.—T. S=59.

IV. *Varieties of Earthquakes and their Respective Durations.*

Those who live in a country where earthquakes are frequent must have observed that the shocks they feel may at least be divided into two groups. The members of one of these groups are phenomena characterised by their short duration and by the rapidity of their vibrations. The other group, which in Tokio form about 5 per cent. of the whole, can be felt for several minutes, and the period of movement is long. With many persons earthquakes having this character produce feelings of nausea, and there is abundant evidence to show that they represent undulations of the surface of the ground. By the former of these groups, although they may sometimes alarm a city, free horizontal pendulums, unless constructed like a bracket seismograph, are seldom disturbed, whilst the latter throw such instruments into violent and fitful motion which, rather than extending over two or three minutes, continues for as many hours.

One class of earthquake consists of what are practically elastic vibrations, which have a short life and do not travel to great distances from their origin, whilst the other class gives rise to surface waves which are propagated to very great distances.

The earthquakes which are merely elastic shiverings may possibly be represented at their origin by a blow delivered on a small surface, whilst those which are shiverings accompanied by surface heaving are the result of collapse in and along an extensive region.

If we divide earthquakes into these two groups, between which connecting links, if they exist, are very rare, we then see an escape from the prevalent idea that as earthquakes radiate their duration apparently increases.

Although we know that preliminary tremors outrace large waves, that both of these forms of movement increase in period, and that a single wave at one station may at a more distant station be represented by two waves, all of which phenomena tend to the spreading out of a disturbance, it is difficult to realise that an earthquake recorded in Japan as having a duration of two or three minutes should, when it reaches this country, be represented by movements continuing over two or three hours. The circumstances which have led to this supposition are twofold. First, no distinction has been drawn between the two kinds of earthquakes ; and, secondly, the duration of a disturbance near to its origin has been determined by a method very different from that by which it was determined at a distance.

When these considerations are neglected the results we may arrive at are well illustrated in a paper on 'Earthquake Duration' by Dr. E. Odone ('Atti della Reale Accademia dei Lincei,' vol. iv. fas. 10, p. 425). We here find a list of twenty-four earthquakes, the origins of which were at distances varying between 25 and 11,170 kms. from Rocca di Papa, Rome, and Siena. At these places the duration of these shocks were noted by fairly similar seismographs of the heavy pendulum type. A glance at this table apparently indicates that the durations of these earthquakes had steadily increased with the distances of their origins from the observing stations. With an origin at a distance of, say, 25 kms., we find a duration of about 70 seconds, whilst if the origin was at a distance of 9,000 kms. the duration becomes 4,800 seconds.

For the first members of this series, which I will call local shocks, had the instruments employed been free horizontal pendulums it is very doubtful whether they would ever have been recorded, neither would they have been noted had the pendulums with their multiplying indices been at distances of a few hundred kilometres from their origins. The common experience, based on seismographic records of local shiverings in Japan, is that the duration of movement decreases with distance from an origin, and it is only very large earthquakes which can be recorded with steady point seismographs at distances exceeding 300 miles.

Directly we come to the other members in the list we are apparently dealing with the duration of earth tilting, and with regard to any particular earthquake we may ask for information respecting the duration of the same near to its origin or at stations between this point and Central Italy, or in countries further afield. The information we have on these points is, however, scant, but such as exists is far too definite to be ignored. For example, Dr. Odone gives in his list the Japan earthquake of March 22, 1894, on which occasion the seismographs at Rocca di Papa and at Rome were respectively agitated for 1h. 3m. and 1h. 20m.

Because the duration of this earthquake as recorded by a bracket seismograph in Tokio was ten seconds, it must not be assumed that we have here an illustration of a seismic movement increasing in its duration as it radiated. On this occasion, after feeling the first heavy movement, I went to my observatory and watched the boom of a horizontal pendulum follow very irregular heavings of the ground for some fifteen minutes, when I was joined by my colleague, Mr. C. D. West, and we continued to watch the erratic, fitful movements for 1h. 47m. longer.

We have in this instance—and others might be quoted—distinct evidence of earth movements near to their origin continuing for a very much longer period than they were observable at distant localities. What was noted in Europe were the earthquake precursors or preliminary tremors, the duration of which increases with distance from an origin, and, after that, the earthquake echoes with possible traces of waves which had travelled round the world in a direction opposite to that constituting the maximum phases in the seismograms. In Tokio, although the preliminary movements were of shorter duration than in Europe, the total duration of the disturbance in that city, on account of the great length of the concluding vibrations, seems to have exceeded that which was recorded in Italy.

The shiverings of our world recur on the average every thirty minutes, but the heavy breathing or true ground swell does not happen more than once a week. Popularly they are both earthquakes, but they differ in their character, in their duration, and probably in their origin, and as they radiate, their life, as exhibited at stations farther and farther remote from their origin, rather than increasing becomes less.

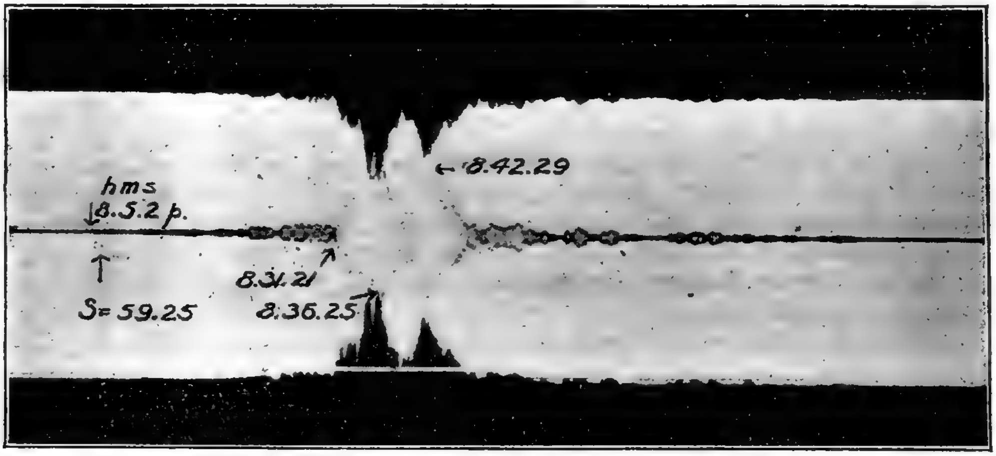
V. *Earthquake Echoes.*

(This and the following Section are in part abstracted from Notes published in 'Nature,' February 16 and March 1, 1899.)

An earthquake disturbance as recorded at a station far removed from its origin shows that the main movement has two attendants, one which precedes and the other which follows. The first of these by its characteristics indicates what is to follow, whilst the latter in a very much more pronounced manner will often repeat at definite intervals but with decreasing intensity the prominent features of what has passed. Inasmuch as these latter rhythmical but decreasing impulses of the dying earthquake are more likely to result from reflection than from interference I have provisionally called them Echoes.

When an earthquake is comparatively small, and has originated as a single effort at no great distance (one or two thousand miles) from the observing station, the seismogram shows a single set of preliminary tremors, of short duration, a single set of pronounced vibrations corresponding to irregularly delivered originating impulses, and finally a series of concluding vibrations which rise and fall in value every three or four minutes. That which appears on a seismogram as a two-blow earthquake terminates with dual reinforcements. As illustrative of this I may refer to the Isle of Wight seismogram of the South Indian Ocean earthquake of August 31, 1898 (see Earthquake No. 230). We have apparently here two large disturbances—the first I regard as the shock, and the second as its echo. They are followed by pairs and groups of echoes. If we closely examine the group of movements which I call the shock, and compare the same with its echo (the second pair being too small to exhibit details), we find that the sub-divisions of each roughly agree in character ; each shows five phases (three of which are very distinct) of the same relative magnitudes. After this we get another five-phase group, followed by two groups each of four phases, beyond which point rhythmical recurrence is lost.

Fig. 2—Shide, Isle of Wight, August 31, 1898.
Duration, 2h. 18m. 0s. Max. Amp. = 9 mm. = 5″·4.



A very good illustration of what may be multiple echoes is found in the Isle of Wight seismogram for June 29, 1898 (see Earthquake No. 215). This is a very large earthquake which probably caused the whole of the earth to pulsate, and the duration of its preliminary tremors indicates that it originated at a very great distance. It had a duration exceeding three hours. The main disturbance shows more than fourteen maxima of motion which have a fairly symmetrical arrangement to the right and left of a central dividing line. In the accompanying figure (Fig. 3), which is an enlargement (1·7 times) of the central portion of the original seismogram, the line of symmetry is marked SS. To the left of this is the main shock 1, and on the right is its echo, 1′, a repetition common to many earthquakes. That violent shocks are, a few minutes later, sometimes followed by a second severe movement, is well recognised in certain earthquake countries. In Japan they are called the Uri Kaishi, or return shaking, and conditions leading to their production are readily imagined. All that can be said about 2, 3, 4, and 5 is that they have approximately the same characters as 2′, 3′, 4′, and 5′, but inasmuch as the first series have travelled more quickly than 1, whilst the latter have travelled more slowly than 1′, it is difficult to recognise the latter as echoes of the former. Beyond 5′ the vibrations suddenly become small, but they apparently show such a marked repetition in form and uniformity in their time of recurrence that these characteristics can hardly be the result of accident. To facilitate comparison these have been enlarged, and are here reproduced, the later group being placed beneath those which arrived earlier. (Fig. 4.)

The triangularly-headed echo 2′ is not unlike 2; its spherically formed successor 3 is repeated in 3′; and so we may continue through the series until we reach the gourd formed 9 and 10 reflected in corresponding shape by 9′ and 10′.

The time intervals between these corresponding groups are from twenty-eight to thirty-one minutes. We here appear to be dealing with a series of vibrational groups each of which took almost exactly half an hour to travel to and fro between two reflecting surfaces or districts. If the waves were compressional in character the distance between these surfaces would be about 8,000 kms., but if they travelled with the velocity of the waves of shock this distance would be reduced to something under 3,000 kms. From their period and amplitude it is probable that the distance lies between these values.

FIG. 3.

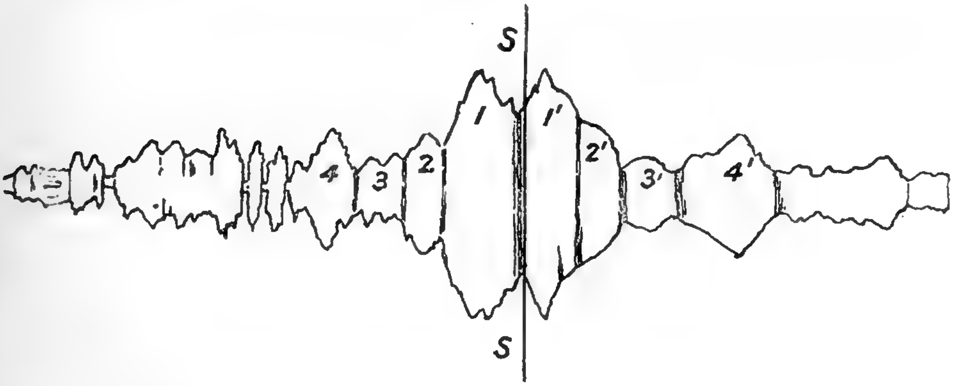
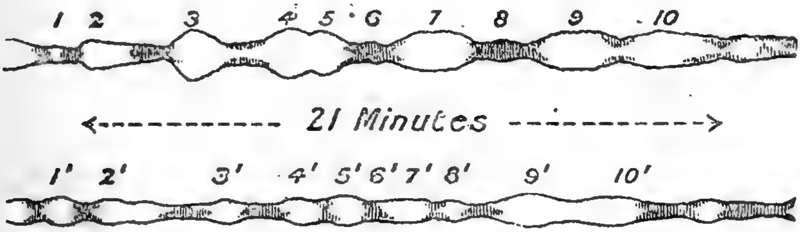


FIG. 4.



The main point at issue, and the one to be answered before we enter into further speculations, is whether seismograms showing this musical-like repetition can be interpreted in the manner here suggested. The concluding vibrations of an earthquake have usually been regarded as a disorderly mob of pulsatory movements resulting from spasmodic impulses which gradually grew feebler as the activity at a seismic centre became exhausted. The question before us is whether an earthquake dies by a process analogous to repeated and irregular settlements of disjointed materials, or whether it is simply a blow or blows which come to an end with musical reverberations inside the world. For the present my opinion inclines to the latter, and I see in the earthquake followers the likeness of their parents.

VI. *Earthquake Precursors.*

The series of movements to which I now refer is the procession of vibrational groups which run before the main disturbance, with the smaller of which, under the name of preliminary tremors, we are already more or less familiar. These precursors have in several respects characters which are exactly the opposite to those of the earthquake followers. They have a definite commencement, and with large earthquakes group after group usually increases suddenly in amplitude and period.

Another characteristic of the precursors is that whilst group after group may grow larger, they become more and more irregular in their contours. The first of the preliminary tremors, if they ever had any *frétillements* have lost the same, whilst those which follow carry serrations which are marked. This observation, together with that of growth in amplitude, suggests the idea that each group of precursors starting from a common origin has reached an observing station by different routes: the first have come along the path of least time, and the latter, culminating in the shock, along paths continually approximating to that of free surface waves.

Now and again we see in groups of preliminary tremors a likeness in contour and arrangement of what is to follow. Near to an origin they may have a duration of from 1 or 2 up to 10 or 20 seconds, and their period has been recorded at from $\frac{1}{5}$ to $\frac{1}{20}$ of a second. When they are preceded by a sound wave, we have evidence of a very much higher frequency. If these vibrations have travelled long distances and through our earth, most records indicate a period of 3 or 4 seconds. Records from Rome have shown periods of less than half a second, but even these are probably much too large. My own records only indicate a slight switching at the end of a light elastic boom, or that the same has been moved very rapidly to and fro relatively to its steady point. Until a steady point seismograph with extremely light multiplying indices or some other special form of apparatus has been employed as a recorder, our knowledge of this end of the seismic spectrum is not likely to increase.

The last points connected with the earthquake precursors are the intervals of time which elapse between the arrival of the first tremor and the largest wave or waves corresponding to the originating impulse and the duration of the first series of preliminary tremors. As measured on seismograms for disturbances which have originated at different distances from the Isle of Wight Observing Station, these two intervals are given in the following table :—

Origin	Distance in degrees	First P.T. to Max. motion in minutes	Duration of first group of P.T.'s in minutes
Iceland	17°	4 or 5	1·4
Greece	22°	6	3
Tashkend	48°	14	8
Hayti	62°	30	13*
Japan	84°	47	8·5
Borneo	112°	55	6·0

* This is dependent on a single observation, and may be too high.

These figures are too few in number to be used as a foundation for any certain conclusions, but they may possibly indicate results to be sought for in future records. With regard to the first set of intervals, we know that for distances up to 8° from an origin that the time by which tremors outrace the main movement may be reckoned by seconds. Adding this fact to our list, it seems that here we have a table which indicates that as earthquakes travel at first the tremors only outrace the large waves at a very slow rate, but as the distance from the origin increases this rate increases. This goes on until a point between 48° and 62° distant from the origin has been reached, after which the rate at which the large movements are left behind decreases.

One explanation for this is to suppose that the first precursors came through the earth with an average velocity which observation shows to increase approximately with the square root of the average depth of the chord joining the centrum and the observing station, whilst the large waves travelled round the surface. One objection to this view is that observations exist which show the large waves have apparently travelled over paths varying between 20° and 110° at rates which, rather than being constant, have increased from 2·1 to 3·3 kms. per second.

The velocities giving this comparatively slight difference were however determined on the assumption that the times at which various earthquakes originated were known, and there is therefore a possibility that they may be apparent rather than real.

Also it must be remarked, as pointed out by Dr. C. G. Knott, that if we regard the large waves as being distortional, inasmuch as the coefficient of elasticity determining the velocity of propagation of such waves may not be greatly influenced by pressure, it is quite conceivable that they should follow the preliminary tremors through our earth. The question then arises, whether these larger movements would be left farther and farther behind their precursors in the manner indicated.

When we come to our second set of intervals, which indicate the duration of the first preliminary tremors before they are eclipsed by groups of vibrations, which usually grow in size, and appear from their periods to be distortional, we see that up to a point about 62° from an origin these figures apparently increase, but beyond that point they grow less.

What we have to explain, in addition to this fact, is that of the continuity and growth in magnitude of what very often forms a long and continuous series of preliminary motions. As I have already stated, their very appearance indicates that they have travelled on different paths. The first have followed a path entirely through our earth, whilst its successors have travelled shorter and shorter distances through the earth to meet a crust, through which they have completed their journey to the observing station. The first followed Knott's brachistrochronic path, or that of least time, whilst the successors took paths the latter parts of which were along arcs of increasing length. The result of this would be that at an observing station vibrations would arrive in series, each group corresponding to an originating impulse. The last of the rabble would be the series representing that portion of the main shock which had travelled entirely round and through the crust.

To complete this hypothesis, I here reproduce a sketch given to me by Dr. C. G. Knott, showing the probable form of wave fronts and paths of compressional vibrations passing through our earth.

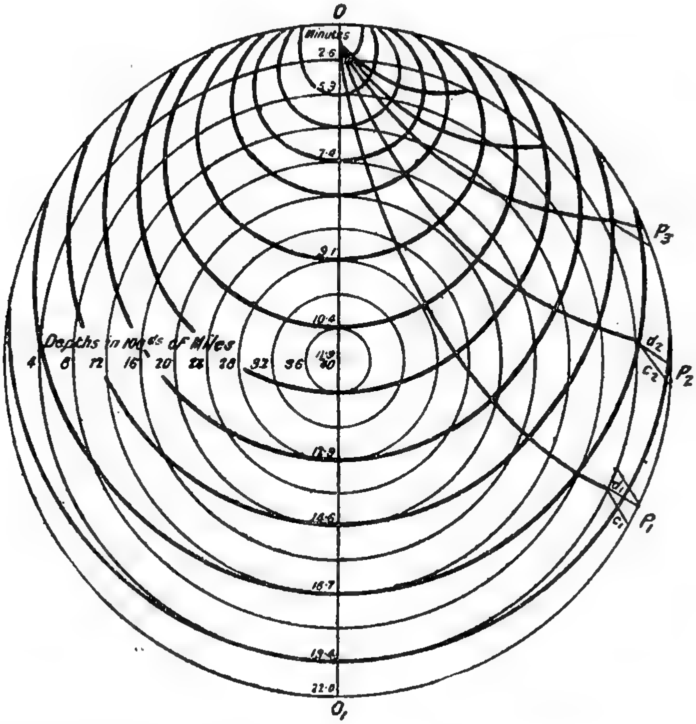
The assumption on which this is based is that the square of the speed of the movements is a linear function of the average depth, which corresponds, as already indicated, with observation.[1]

The result at which Knott arrives indicates that the square of the speed increases at 0·9 per cent. per mile of descent in the earth, the formula being

$$v^2 = 2{\cdot}9 + {\cdot}026d \text{ in mile second units.}$$

With an initial velocity of 1·7 mile per second the velocities at depths of 400, 800, 1,200, ... 4,000 miles, are 3·7, 4·9, 5·8, 6·7, 7·4, 8·1, 8·7, 9·3, 9·8 and 10·3 miles per second. The times taken for wave fronts to reach the positions shown are indicated in the diagram, the time taken to pass through the earth being twenty-two minutes.

FIG. 5.



I assume that when a wave has passed from its origin beyond the region vaguely referred to as the crust of our earth, it then spreads in all directions through a mass in which there is only an extremely gradual change in elasticity and density with regard to its centre. All wave paths, however, before they emerge at the surface, encounter at varying obliquities the under surface of this crust. For purposes of illustration we will assume this region of abrupt change to lie on the 400-mile circle. The path P_1 meets this nearly at right angles, whilst P_2 P_3 meet the same at decreasing angles less than right angles. After each of these incidences a condensational wave will be refracted and split up into condensational and distortional rays. Now it will be observed that these two waves, which I will call c and d, will have different distances to travel before

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[1] See *Brit. Assoc. Report*, 1898, p. 221.

actual emergence, which distances will increase from P_1 towards P_3. Directly d_1 emerges, not only will c_1 be eclipsed, but also c_2 c_3, coming from the direction P_2 P_3, will also be hidden.

At some point like P_3, when the duration of the preliminary tremors reaches a maximum on towards the origin, the quantity will decrease, if only on account of the fact that the velocity along the brachistrochronic ray differs less and less from that of the distortional wave within the crust. Such a view may possibly explain the rise and fall in the values of our last column.

The growth in amplitude of the groups of tremors may be due to the fact that the first group has travelled on the path OP_1, whilst the second has travelled OP_2 P_1, &c., whilst the crests of these groups, especially of those immediately in advance of the large waves, should roughly agree with the impulses which these represent.

VII. *On Certain Disturbances in the Records of Magnetometers and the Occurrence of Earthquakes. By* JOHN MILNE.

In the 'British Association Reports for 1898,' pp. 226–251, a large number of records were brought together, showing what has happened at or about the time of large earthquakes to magnetic needles at various Observatories. These records may be classified as follows :

1. Those which show that magnetographs have very frequently been disturbed at the time when their foundations have been moved by the large but unfelt waves of earthquakes originating at a great distance. Examples of such movements are to be found in the registers from Utrecht, Potsdam, and Wilhelmshaven. For the particular kind of earth movement referred to, magnetic instruments at these places furnish records of value to the seismologist.

2. Those which show that magnetographs are seldom, and then only very slightly, or in some instances apparently never disturbed at the time of large earthquakes. This appears to be the case at Greenwich, Kew, Falmouth, Stonyhurst, Pola, Vienna, Copenhagen, and Toronto.

3. Those which show that magnetic needles have exhibited perturbations, frequently of considerable magnitude, a short time before the occurrence of large earthquakes. As illustrative of such observations, reference may be made to the registers from Zikawei, Mauritius, Utrecht, and Greenwich. Similar observations have been made in Japan.[1]

On pp. 248–251 of the above-mentioned report, an attempt is made to explain these observations, whilst to extend the same I append the following table received from P. Barrachi, Director of the Melbourne Observatory.

Declinometer Disturbances observed at the Observatory, Melbourne.
P. BARRACHI, Esq., *Director.*

The magnetographs at Melbourne are of the same form and dimensions as those at Kew. The value of an ordinate of 1 inch in the curves is very nearly 29′, and the time scale corresponds to 14·7 inches for twenty-four hours.

In dealing with the curves for Observatory purposes—as, for instance, taking mean values, &c.—oscillations whose amplitudes are less than 2′

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[1] See *Seismology*, Int. Sci. Series, pp. 225, 226.

are not considered disturbances, but much smaller oscillations than these can easily be detected in the curves. In order to avoid any arbitration as to what disturbance should be singled out for the purpose of comparing with the list of earthquakes, in cases where the curves appeared to be generally disturbed, or where more than one disturbance occurred, or where several disturbances presented different characteristics, Mr. Barrachi has put down in the following notes all the distinctive features of the curves occurring within several hours, in some cases 10 or 12 hours, before and after the times specified in the earthquake register, noting also every appreciable oscillation, however small, so that those who make comparisons may discriminate for themselves. All times in the list are indicated as Melbourne Mean Astronomical Time, the day commencing at Melbourne noon, the hours being reckoned from 0 to 24. By amplitude is meant the whole range of displacement. Period means the time taken for the double swing. When there is a movement from the neutral line upwards and back to the same, followed some time later by a movement downwards and back to the same, the latter is said to be in the 'opposite phase' to the former. As these two movements may be independent of each other it will be recognised that the term 'opposite phase' is one of convenience. 'Superimposed waves' means that there are small waves which appear as regular or irregular, large or small, serrations on the trace of larger waves.

The earthquake list referred to by the numbers, dates, and times in the first three columns is given in the 'British Association Report' for 1898, p. 227.

Melbourne astronomical time is 9h. 39m. 53·8s. in advance of Greenwich.

1889.

		M.M.A.T.		
		H.	M.	
1	April 18 .	3	1	Minute wave from 1h. 40m. to 1h. 45m., amp. under 30″ followed by still minuter waves from 2h. 0m. to 2h. 20m.
2	July 11 .	20	2	Minute oscillations commenced 13h. 45m. to 14h. 5m., amp. under 20″, larger oscillations of longer period, amp. above 2′, from 14h. 15m. to 17h. 45m., maximum amp. at 17h. 20m. about 3′.
3	„ 28 .	13	10	Slightly disturbed from 15h. 40m. to 18h. One oscillation of long period from 15h. 0m. to 15h. 22m., amp. above 2′, followed by minute waves of shorter period. Commencement (more accurately), probably 15h. 35m. No other disturbance before that hour appears on this curve.
4	„ „ .	15	40	
5	Aug. 25 .	17	17	Decided disturbance commencing 9h. 50m., with one oscillation, amp. $3\frac{1}{2}'$, period 40m., followed by another wave, amp. $5\frac{1}{2}'$, time of max. amp. 11h. 5m., then followed by less marked and irregular oscillations for 6h., gradually becoming normal shortly after.

1891.

6	Oct. 27 .	19	18	Curve disturbed from 7h. 5m. max., disturbances at 7h. 5m., with a large wave amp. 6′, period 33m., and at 14h. 40m., with a large wave in opposite direction, amp. 7′, period 47m., followed by minute waves of very short period till 22h.

1892.

7	Mar. 16 .	11	2	Slight, but well marked disturbance, commenced 8h. 30m. ending 9h. 35m., consisting of two waves, amp. from 4′ to 5′.

		M.M.A.T.		
		H.	M.	
8	Mar. 16 .	15	2	Curve very slightly disturbed, from 12h. 50m., showing minute waves of irregular period and amp., but less than 2′. Almost normal after 15th.
9	April 19 .	9	10	No disturbance.
10	May 12 .	3	23	Minute, sudden, and very short disturbance commencing 23h. 45m., May 11, duration 6m., consisting of two minute waves, amp. 1′.
11	Oct. 19 .	2	1	Sudden decrease of E. declination indicative of sudden disturbance, commencing 1h. 10m., max. amp. of disturbance 6′, followed by minute waves of two hours, amp. only a few seconds of arc. Very considerable disturbances from 6h. 10m. continued for many hours after.
12	Nov. 4 .	15	4	Disturbance, commenced 11h., with a large wave, amp. 11′, period 1h., followed by another large wave, amp. 6′, period 25m., minute and irregular waves between.
13	„ 27 .	15	37	No disturbance preceding, but minute oscillations shown after 17h. 30m., amp. about 1′.
14	Dec. 8 .	22	59	Slight disturbance at 19h., Dec. 7, consisting of a wave, amp. 3½′, period 1h. 20m., commencing 18h. 20m., followed by very minute oscillation of amp. under 1′.
15	„ 19 .	22	14	Very minute disturbance at 19h. 37m., consisting of a small wave, amp. under 2′.

1893.

16	Jan. 28 .	21	26	Minute and irregular oscillations commencing at 17h. 10m., amp. generally under 1′, but in one wave at 19h. 10m., and in another at 19h. 34m., the amp. is 3′.
17	„ 31 .	1	59	No disturbance.
18	„ „ .	22	19	Very slight disturbance shown, consisting of minute oscillations, commencing at 19h. 27m., max. amp. 2¼′ at 20h. 15m.
19	Feb. 6 .	14	47	Curve considerably disturbed from about 11h. 30m. Sudden and more marked disturbance at 12h. 0m., amp. of oscillation being 9′, another marked oscillation at 14h. 47m., amp. 7¼′ in opposite phase from the former. Followed by a large wave, period 1h., amp. 6′ in opposite phase to the preceding. This wave is superimposed by minute oscillations.
20	„ „ .	16	44	Minute waves of very short period following after from 16h. 30m. for several hours afterwards, amp. from under 1′ to 2½′.
21	„ 9 .	15	53	Very minute oscillations from 17h. 50m. continued for more than 4h., max. amp. about 1½′. Only one of these is somewhat more conspicuous than the others, this occurring at 18h. 55m. and perhaps another at 20h. 0m.
22	„ „ .	19	20	
23	„ „ .	20	40	
24	„ 13 .	14	40	No disturbance.
25	„ 16 .	2	57	Curve disturbed considerably from 22h., Feb. 15, but shows no special characteristic to indicate the commencement of a sudden disturbance. The curve shows a series of waves of irregular period and slightly varying amp. not exceeding 3′ generally; but one wave is quite conspicuous. This occurs at 8h. 40m. max. phase, period 1h. 20m., amp. about 10′ (ten minutes of arc).
26	„ „ .	9	44	
27	„ 21 .	4	53	No disturbance preceding a wave, amp. 3′, commences 6h. 25m., ends 6h. 57m., followed by two minor very minute waves ending 7h. 45m.
28	„ „ .	11	58	Curve almost normal, a few very minute oscillations, amp. under 1′ occur from 11h. 10m. and continue for nearly 12 hours after; of these only one is somewhat more conspicuous than the other. This occurs at 13h. 25m., amp. about 2′.

		M.M.A.T.		
		H.	M.	
29	Feb. 22 .	20	56	Minute oscillations occur throughout for about 13 hours preceding this given time. The most conspicuous of these small and irregular oscillations occurs at 11h. 35m., period 28m., amp. 3′.
30	Mar. 2 .	20	46	Very minute oscillations commence at 18h. 25m., continued till 22h., amp. under 2′.
31	„ 14 .	4	0	No disturbance preceding. The curves commence to be disturbed at 7h. 30m.; oscillations at first very small, but greatly increasing after 11h. 30m., considerably disturbed for more than 30 hours after.
32	„ 20 .	14	50	No disturbance whatever.
33	„ 23 .	18	23	Very slight disturbance commencing 15h. 20m., consists of a small wave, period 5m., amp. 1½′, followed by other very minute waves, amp. under 1′.
34	April 8 .	11	31	Decided disturbance commenced at 7h. 0m., consisting of a large oscillation, period from 7h. 0m. to 8h. 27m., amp. 7¼′, with some minute waves superimposed.
35	„ 17 .	3	28	Very slight disturbance at 2h. 15m., showing a small oscillation, period 15m., amp. 1½′, followed by a few almost inappreciable waves, amp. only a few seconds of arc.
36	„ 23 .	11	12	No disturbance.
37	„ 29 .	15	42	Disturbance commencing 8h. 30m. consisting of two consecutive waves, period about 25m., amp. 4′, followed by a few very minute oscillations.
38	May 2 .	7	38	No disturbance.
39	„ 18 .	12	19	Disturbance commencing 12h. 19m., ending 15h. 10m., consisting of a sudden small oscillation amp. under 2′, followed by four waves, period 45m., amp. 3′.
40	May 18 .	22	43	Small oscillation at 22h. 25m., period 10m., amp. under 2′.
41	„ 23 .	18	18	Very slight disturbance, commencing at 17h. 15m., amp. of oscillation about 2′, period one hour.
42	June 3 .	14	5	No disturbance.
43	„ 7 .	19	50	Curve for this day slightly disturbed throughout its length. No particular disturbance shown for some hours before or after the given time.
44	„ 11 .	18	49	Curve for this day slightly disturbed throughout its length. No particular disturbance shown for some hours before or after the given time.
45	„ 13 .	8	45	No disturbance.
46	„ 14 .	4	27	Very slight disturbance (if it can be so called) at 3h. 45m., consisting of a small oscillation, period 20m., amp. about 1′. This curve shows oscillations of this kind throughout at irregular intervals. Probably this should not be called a disturbance.
47	July 3 .	7	45	Minute oscillations throughout the curve. No special disturbance showing.
48	„ 5 .	9	4	No disturbance.
49	„ 10 .	9	54	No disturbance.
50	Aug. 1 .	23	23	Disturbance very slight at 18h. 15m., consisting of a small wave, period 30m., amp. under 2′.
51	„ 3 .	22	32	Very minute disturbance at 16h. 55m., consisting of a small wave or oscillation, period 9m., amp. under 2′.
52	„ 6 .	17	22	This curve is very much disturbed throughout; but it shows two very conspicuous and larger disturbances, viz.:—One from 8h. 20m. to 9h. 50m. with amp. of 17′, and another with amp. of 11′, at from 10h. 5m. to 10h. 40m.
53	„ 10 .	18	49	Minute disturbance commencing at 19h. 55m., consisting of a series of minute waves, max. amp. 1½′.
54	„ 14 .	17	28	Disturbance commencing at 5h. 10m. and continuing till 17h., but gradually decreasing in amp. from 5½′ to nothing.

1894.

		M.M.A.T.		
		H.	M.	
55	Mar. 22 .	8	17	Large disturbance commencing suddenly (after a long series of minor oscillations) at 5h. 30m., max. amp. 21m., curve disturbed throughout its length.
56	Apr. 20 .	15	22	Curve somewhat disturbed throughout, but a slightly more marked disturbance is shown at 14h. 0m., with an amp. of 4¼′.
57	„ 27 .	17	35	Disturbance (slight) at 9h. 55m., rather sudden displacement of 3½′, followed by a series of oscillations of very small amplitude and long period.
58	„ 29 .	1	5	Very minute series of oscillations commencing at 23h. 10m., April 28, ending at 23h. 55m., amp. under 2′.
59	June 20 .	3	25	Small oscillations appear throughout the curve. No special disturbance noticeable.
60	July 10 .	8	10	Same as above, but a slightly larger oscillation occurs at from 6h. to 7h., amp. 3½′.
61	„ 12 .	11	57	Disturbance at 9h. 20m., rather sudden displacement of 5′, followed by a series of minute oscillations.
62	Oct. 7 .	9	20	Disturbance commencing 8h. 0m., with a displacement attaining its maximum of 6′ in 20m., then followed by a long series of minute and short waves for four hours.
63	„ 22 .	6	40	Disturbance at 11h. 4m., rather sudden displacement of 4′, returning to normality at 12h. 40m.
64	„ 27 .	18	48	Disturbance commencing 11h. 15m., curve continued disturbed for 11 hours after; but there are two oscillations more conspicuous than others; one of these occurs at 15h. 20m., amp. 6′, period 50m., and the other at 18h. 0m., amp. 5′, period 35m.

1895.

65	Jan. 18 .	12	17	Curve slightly disturbed throughout, viz:—From 22h. January 17 to 22h. January 18; but shows two waves, or displacements a great deal more conspicuous than all others. One of these occurs at from 7h. 20m. to 7h. 55m., being a wave of 4′ amp. The other is a sudden displacement of 8½′, and occurs at 18h. 0m.
66	July 8 .	20	23	Curve slightly wavy throughout. No special disturbance noticeable.
67	Aug. 9 .	15	18	Large disturbance from 5h. to 7h. 30m., consisting of a single wave, amp. 11′, superimposed by minute and irregular waves, amp. under 2′.
68	Nov. 13 .	19	11	Curve disturbed at several places. The most conspicuous displacement occurs between 17h. 0m. and 18h. 0m., consisting of a wave of 10′ amp., followed by short minute waves for several hours.

1896.

69	June 16 .	9	26	Disturbance commencing at 8h. 5m. showing a wave, period 45m., amp. 8′. Another larger displacement commences at 10h. 40m., amp. 12′, curve considerably disturbed for the following 12 hours.
70	„ 29 .	18	42	Curve very slightly wavy (minute oscillations amp. under 2′) from 16h. to 22h. No special disturbance.
71	Aug. 26 .	21	2	Slight displacement commencing 11h. 55m., ending 13h. 30m., amp. 5′, followed by a series of minute oscillations, amp. less than 1′.
72	„ 31 .	6	3	No disturbance.
73	Sept. 5 .	21	42	Curve disturbed largely at several places, conspicuous isolated disturbance at from 6h. 20m. to 7h. 15m., amp. 12′. Another at from 14h. 40m. to 15h. 5m., amp. 8′, followed by minute and short waves till 20h.

		M.M.A.T. H.	 M.	
74	Sept. 14 .	8	10	Slight disturbance at 6h. 55m., being a wave period 20m., amp. $2\frac{1}{2}'$.
75	„ 22 .	2	33	Conspicuous isolated disturbance at from 6h. 30m. to 7h. 30m., being an oscillation with amp. $= 11\frac{1}{2}'$.
76	Nov. 1 .	2	58	No disturbance.

1897.

		H.	M.	
77	Jan. 10 .	18	58	Very minute oscillations, amp. under 2′, commencing 14h. 8m., continued for 5 hours, then at 19h. 40m. a slightly larger oscillation occurs, amp. $2\frac{1}{2}'$, followed by another of same amp., but opposite phase.
78	June 12 .	9	9	No disturbance.
79	Aug. 4 .	22	2	Very slight oscillations of small amp. about 2′, and long period, commencing at 14h. 50m. Hardly to be called a disturbance.
80	Sept. 20 .	17	4	No disturbance.
81	„ 21 .	3	8	No disturbance.
82	Dec. 28 .	18	34	
83	„ 29 .	9	20	

VIII. *Form of Reports.*

It is desirable that Reports on Earthquakes should contain the following information :—

1. Greenwich Mean Civil Time (midnight = 0 or 24 hrs.) of the commencement of motion.

2. The duration of the *first* preliminary tremors (P.T.'s) usually represented by a broadening of the normal line.

3. The interval between the commencement of motion and the maximum motion.

4. The interval between the maximum and its apparent repetition, which, when it occurs, does so a few minutes later. This is the interval 1 to 1′ seen in fig. 3, p. 229.

5. The amplitude or half-range of the maximum motion expressed in millimetres and seconds of arc.

6. The total duration of the disturbance.

7. For large earthquakes a contact print, or at least a tracing of the disturbance, may be appended.

8. The time, duration, and amplitude of isolated broadenings of the normal trace. These must not be confounded with air tremors.

For the ordinary working of the instrument, see 'Brit. Assoc. Report,' 1897, p. 137.

Photographic Meteorology.—Report of the Committee, consisting of Mr. G. J. SYMONS (*Chairman*), Mr. A. W. CLAYDEN (*Secretary*), Professor R. MELDOLA, Mr. JOHN HOPKINSON, *and* Mr. H. N. DICKSON, *appointed to apply Photography to the Elucidation of Meteorological Phenomena.* (*Drawn up by the Secretary.*)

THE work of the Committee has for some years past been practically limited to the photographic measurements of cloud altitudes by the Secretary. During the year just brought to a close very little progress has been possible with such systematic observations, but some particularly good examples of rare types of cloud have been photographed, and some valuable studies of lightning have been secured. So far as these latter have been examined they fully confirm the conclusions of this Committee as expressed in the reports for 1891, 1892, and 1893, which may be briefly summarised thus :—

1. The reality of the narrow ribbon structure.
2. The existence of visible multiple discharges.
3. The compound nature of many discharges.
4. The long duration of many discharges.

During a storm which passed over Exeter on July 22, about sunset, a phenomenon was many times observed which seems to deserve further study.

This was a narrow ribbon flash of somewhat long duration (1·5 to 2·5 seconds) which broke up into a long train of sparks like the trail of a rocket. These sparks faded away gradually, some of them lasting for a second or two.

The phenomenon does not seem to have been recorded photographically, but is doubtless the explanation of the beads of extra bright light shown on some photographs of lightning.

It is worthy of note that the beaded discharges referred to accompanied exceptionally heavy rain. This suggests that the explanation may be the dissociation of water and recombination of the liberated gases.

The appreciable duration of the combustion may be due to the greater diffusibility of the hydrogen carrying some of it beyond the oxygen and thereby slackening the velocity of combination. Each dissociated drop would give a ball of mixed gases in proportions exact at the centre, but departing more and more from exactness towards the margin, where the time of combustion would be correspondingly prolonged.

The relation between the thunder-cloud and lightning has been very clearly visible on several occasions. The cloud has always a peculiar structure, which may be described as a lower cumulus disc uprising as a thick column in the middle, which spreads out again at perhaps twice as great an altitude in a more or less cirriform disc. In such a storm, which is typical, the majority of the discharges pass between the margins of the upper and lower discs, or from one side to the other of either disc. Such flashes seem to be generally of a comparatively simple type. They may branch or twist about or resemble the ordinary discharge of an induction coil or Wimshurst machine.

These flashes are often accompanied by, or *immediately followed* by more brilliant discharges between the lower disc and the earth. This is the 'impulsive rush' of Dr. Lodge, and it is in such discharges that the phenomena of multiple and beaded structures are presented. They are analogous to the discharges between the knobs of two oppositely charged Leyden jars whose outer coatings are imperfectly connected.

No grant is asked for; but the work of the Committee cannot be regarded as complete until a much larger number of measurements of altitude have been made, and they therefore ask for reappointment.

Experiments for improving the Construction of Practical Standards for use in Electrical Measurements.—Report of the Committee, consisting of Lord RAYLEIGH (*Chairman*), Mr. R. T. GLAZEBROOK (*Secretary*), Lord KELVIN, Professors W. E. AYRTON, J. PERRY, W. G. ADAMS, OLIVER J. LODGE, *and* G. CAREY FOSTER, Dr. A. MUIRHEAD, Sir W. H. PREECE, Professors J. D. EVERETT *and* A. SCHUSTER, Dr. J. A. FLEMING, Professors G. F. FITZGERALD *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. J. RENNIE, Mr. E. H. GRIFFITHS, Professor A. W. RÜCKER, *and* Professor H. L. CALLENDAR.

THE Committee have been engaged during the year on the consideration of the details of the new ampère balance, for which a grant of 300*l.* was voted at Bristol.

Professors Ayrton and Viriamu Jones have completed the plans and specifications, and the construction of the balance has been authorised.

An important addition to the plan proposed at Bristol consists of an arrangement for adjusting accurately the position of the fixed coils. Sir Andrew Noble has generously undertaken to have this constructed at Elswick free of cost, and the Committee desire to thank him for the offer, which they have gladly accepted.

In consequence of the fact that the balance is not yet completed, the grant of 300*l.* made last year has not been expended, and the Committee apply for its renewal.

An appendix to the Report contains a proof by Lord Rayleigh of a theorem due to Professor J. V. Jones, on which the mathematical theory of the new balance is based.

Details of the balance are reserved until it has actually been constructed.

Professor Callendar has brought before the Committee proposals for the adoption of a standard scale of temperature based on the Platinum Resistance Thermometer. These are printed in an appendix and formed the basis of a discussion in the Section. A sub-Committee has been formed to consider these proposals and to report to the Committee.

The ordinary testing of standards has been interrupted by the removal of the Secretary to Liverpool, and still further by his proposed removal to Kew. With respect to this the Committee have passed the following resolution :—

That Mr. R. T. Glazebrook, as Secretary of the Committee, be authorised and requested to retain the custody of the Electrical Standards of the Association, and to remove them from Liverpool to London when he takes up his post as Director of the National Physical Laboratory.

The removal of the Standards and the investigations of a Platinum Thermometry will necessitate some expenditure during the year.

The Committee therefore recommend that they be reappointed, with the addition of Sir William Roberts-Austen and Mr. Matthey, and with a grant of 25*l.* in addition to the unexpended balance (300*l.*) of last year's grant, and that Lord Rayleigh be Chairman and Mr. R. T. Glazebrook Secretary.

APPENDIX I.

The Mutual Induction of Coaxial Helices. By Lord RAYLEIGH.

Professor J. V. Jones[1] has shown that the coefficient of mutual induction (M) between a circle and a coaxial helix is the same as between the circle and a uniform circular cylindrical current-sheet of the same radial and axial dimensions as the helix, if the currents per unit length in helix and sheet be the same. This conclusion is arrived at by comparison of the integrals resulting from an application of Neumann's formula; and it may be of interest to show that it may be deduced directly from the general theory of lines of force.

In the first place, it may be well to remark that the circuit of the helix must be supposed to be completed, and that the result will depend upon the manner in which the completion is arranged. In the general case the return to the starting-point might be by a second helix lying upon the same cylinder; but for practical purposes it will suffice to treat of helices including an integral number of revolutions, so that the initial and final points lie upon the same generating line. The return will then naturally be effected along this straight line.

Let us now suppose that the helix, consisting of one revolution or of any number of complete revolutions, is situated in a field of magnetic force symmetrical with respect to the axis of the helix. In considering the number of lines of force included in the complete circuit, it is convenient to follow in imagination a radius-vector drawn perpendicularly to the axis from any point of the circuit. The number of lines cut by this radius, as the complete circuit is described, is the number required, and it is at once evident that the part of the circuit corresponding to the straight return contributes nothing to the total.[2] As regards any part of the helix corresponding to a rotation of the radius through an angle $d\theta$, it is equally evident that in the limit the number of lines cut through is the same as in describing an equal angle of the circular section of the cylinder at the place in question, whence Professor Jones's result follows immediately. Every circular section is sampled, as it were, by the helix, and contributes proportionally to the result, since at every point the advance of the vector parallel to the axis is in strict proportion to the rotation. It is remarkable that the case of the helix (with straight return) is simpler than that of a system of true circles in parallel planes at intervals equal to the pitch of the helix.

The replacement of the helix by a uniform current-sheet shows that the force operative upon it in the direction of the axis ($d\text{M}/dx$) depends only upon the values of M appropriate to the two terminal circles.

If the field is itself due to a current flowing in a helix, the condition of

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[1] *Proc. Roy. Soc.* vol. lxiii. (1897), p. 192.

[2] This would be true so long as the return lies anywhere in the meridional plane. In the general case, where the number of convolutions is incomplete, the return may be made along a path composed of the extreme radii vectores and of the part of the axis intercepted between them.

symmetry about the axis is only approximately satisfied. The question whether both helices may be replaced by the corresponding current-sheets is to be answered in the negative, as may be seen from consideration of the case where there are two helices of the same pitch on cylinders of nearly equal diameters. In one relative position of the cylinders the paths are in close proximity throughout, and the value of M will be large, but this state of things may be greatly altered by a relative rotation through two right angles.

But although in strictness the helices cannot be replaced by current-sheets, the complication thence arising can be eliminated in experimental applications by a relative rotation. For instance, if the helix to which the field is supposed to be due be rotated, the *mean* field is strictly symmetrical, and accordingly the mean M is the same as if the other helix were replaced by a current-sheet. A further application of Professor Jones's theorem now proves that the first helix may also be so replaced. Under such conditions as would arise in practice, the mean of two positions distant 180°, or at any rate of four distant 90°, would suffice to eliminate any difference between the helices and the corresponding current-sheets, if indeed such difference were sensible at all.

The same process of averaging suffices to justify the neglect of spirality when the observation relates to the mutual attraction of two helices as employed in current determinations.

APPENDIX II.

Proposals for a Standard Scale of Temperature based on the Platinum Resistance Thermometer. To be submitted to the Electrical Standards Committee. Drawn up by Professor H. L. CALLENDAR, *M.A., F.R.S.*

The following proposals are submitted in consideration of the importance of adopting a *practical* thermometric standard for the accurate verification and comparison of scientific measurements of temperature. The gas thermometer, which has long been adopted as the *theoretical* standard, has given results so discordant in the hands of different observers at high temperatures, as greatly to retard the progress of research.

The arguments in favour of the adoption of the platinum resistance thermometer as a practical standard were given by Professor H. L. Callendar, in a paper 'On the Practical Measurement of Temperature,' communicated to the Royal Society in June 1886, and published in the 'Phil. Trans.' in the following year. These arguments have since been confirmed and strengthened by the work of many independent observers.

The Electrical Standards Committee of the British Association has done so much in the past with reference to the adoption of the present electrical standards, and more recently in connection with the adoption of the *joule* as the absolute unit of heat, that it would appear to be the most appropriate authority for the discussion and approval in the first instance of proposals relating to an electrical standard of thermometry.

The suggestions for the standard scale of temperature here proposed may be embodied in the following resolutions:—

(1) That a particular sample of platinum wire be selected, and platinum resistance thermometers constructed to serve as standards of the platinum scale of temperature.

(*Note.*—A degree centigrade of temperature on the scale of a platinum resistance thermometer corresponds to an increase of resistance equal to the hundredth part of the change of resistance between 0° and 100° C. In other words temperature pt on the platinum scale is defined by the formula

$$pt = 100\,(R - R^\circ)\,/\,(R' - R^\circ),$$

in which the letters R, R°, and R′ stand for the resistances of the thermometer at the temperatures pt, 0°, and 100° C., respectively. The melting-point of ice is taken as the zero of this scale in accordance with common usage.)

(2) That the scale of temperature t deduced from the standard platinum scale by means of the parabolic difference formula,

$$t-pt=d\,(t\,/\,100-1)\;t\,/\,100,$$

which has been proved to give a very close approximation to the true or thermodynamic scale, be recommended for adoption as a practical standard of reference, and be called the British Association Scale of Temperature.

(*Note.*—The gas thermometer would still remain the ultimate or theoretical standard, and the exact relation of the British Association scale to the absolute scale would be the subject of future investigation. In the present state of experimental science, the difference between the two scales over the greater part of the range is less than the probable errors of measurement with the gas thermometer, and the possible accuracy of measurement with a platinum thermometer, especially at high temperatures, is of a much higher order than with the gas thermometer. Measurements directly referred to the British Association scale would therefore be of greater permanent value, because they could be subsequently corrected when the relation between the scales had been more accurately determined.)

(3) That the value of the difference-coefficient d in the parabolic difference-formula be determined for the British Association standard thermometers by reference to the boiling-point of sulphur as a secondary fixed point in the manner described by Callendar and Griffiths, 'Phil. Trans. A, 1891.'

(*Note.*—It is probable that this method gives the best results over the whole range at temperatures above $-100°$ C. At very low temperatures there appear to be singularities in the resistance variation of metals which require further investigation. The boiling-point of liquid oxygen would be a more convenient secondary fixed point to choose for low temperature research, especially for testing thermometers the construction of which did not permit their exposure to a temperature as high as that of boiling sulphur.)

(4) That the temperature of the normal boiling-point of sulphur under a pressure of 760 mm. of mercury reduced to 0° C., and latitude 45°, be taken for the purposes of the British Association scale as 444·53° C., as determined by Callendar and Griffiths (*loc. cit.*), with a constant pressure air-thermometer.

(*Note.*—Until the relation between the various gas-thermometer scales, and the expansion of glass and porcelain, have been more accurately determined, it does not appear that anything would be gained by changing this value to which so much accurate work has already been referred.)

APPENDIX III.

A Comparison of Platinum and Gas Thermometers made at the International Bureau of Weights and Measures at Sèvres. By Dr. P. Chappuis *and* Dr. J. A. Harker.

Professor Callendar in 1886 investigated the method of measuring temperature based on the determination of the electrical resistance of a platinum wire.

He pointed out that if R_0 denote the resistance of the spiral of a particular platinum thermometer at 0°, and R_1 its resistance at 100°, we may establish for the particular wire a scale, which we may call the *scale of platinum temperatures*, such that if R be the resistance at any temperature T°, this temperature on the platinum scale will be $\frac{R-R_0}{R_1-R_0}\times 100$ degrees. For this quantity Callendar employs the symbol pt.

In order to reduce to the standard scale of temperature the indications of any platinum thermometer, it is necessary to know the law connecting *pt* and T. These are identical at 0° and 100°, but the determination of the relationship between them at other temperatures is a matter for experiment.

The work of Callendar established for a particular sample of platinum the relation

$$d = T - pt = \delta\left[\left|\frac{T}{100}\right|^2 - \left|\frac{T}{100}\right|\right]$$

over the range 0° to 600°, T being measured on the constant pressure air-scale, and δ being a constant.

Later experiments by Callendar and Griffiths showed that this relation holds for platinum wires generally, provided that they are not very impure. They propose that the value of δ, the constant employed in the formula, should be determined by taking the resistance of the thermometer in the vapour of sulphur, and a new determination by them of the boiling-point of this substance, under normal pressure, gave 444°·53 on the air scale.

The present communication gives a short account of some experiments which are the outcome of the collaboration of the Kew Observatory Committee and the authorities of the Bureau International des Poids et Mesures at Sèvres, for the purpose of carrying out a comparison of some platinum thermometers with the recognised International Thermometric Standards. A full account of the work will shortly appear in the 'Philosophical Transactions of the Royal Society' and in the 'Travaux et Mémoires du Bureau International des Poids et Mesures.'

A new specially designed resistance-box, together with several platinum thermometers, and the other accessories needed, were constructed for the Kew Committee, and after their working had been tested at the Kew Observatory, they were set up at the Sèvres Laboratory in August 1897. The resistance-box in its general design was very similar to the one previously described before this Section by Mr. Griffiths, but the plugs were replaced by a special form of contact maker, and the coils were of manganine instead of platinum-silver. The methods adopted for the standardisation of the apparatus only differed in a few details from those of Callendar and Griffiths.

The comparisons made between the platinum thermometers and the standards of the Bureau may be divided into several groups. The first group of experiments covers the range (– 23° to 80°), and consists of a large number of comparisons between each platinum thermometer and the primary mercury standards of the Bureau, whose relation to the normal hydrogen scale had previously been studied by one of us.

Above 80° the mercury thermometers were replaced by a gas thermometer, constructed for measurements up to high temperatures.

We at first attempted to use hydrogen as the gas for these measurements, but, owing probably to a slow chemical action taking place between the gas and the glass reservoir in which it was enclosed, we were afterwards compelled to substitute nitrogen, which we have not observed to exert any action on the material of the envelope up to a full red heat.

The comparisons between 80° and 200° were made in a vertical bath of stirred oil, heated by different liquids boiling under varying pressures. For work above 200° a bath of mixed nitrates of potash and soda was substituted for the oil tank. In this bath comparisons of the two principal platinum thermometers with the gas thermometer were made up to 460°, and with a third thermometer, which was provided with a porcelain tube, we were able to go up to 590°, the glass reservoir of the gas thermometer being replaced by one of porcelain, whose dilatation had previously been measured by the Fizeau method. Comparisons of the platinum and gas scales were carried out at over 150 different points, each comparison consisting of either ten or twenty readings of the different instruments.

By the intermediary of the platinum thermometers a determination of the boiling-point of sulphur on the nitrogen scale was also made. Three independent sets of determinations of this point gave the following results:

(1) Platinum thermometer K. 9, and *glass* gas-thermometer, 445°·27.
(2) „ „ K. 9, *porcelain* „ 445·26.
(3) „ „ K. 8, „ „ 445·29.

The mean of these, 445°·27, representing the temperature on the scale of the constant volume nitrogen thermometer, differs only 0°·7 from that found by Callendar and Griffiths for the same temperature expressed on the constant pressure air-scale.

If, for the reduction of the platinum temperatures in our comparisons, we adopt the parabolic formula, and the value of δ obtained by assuming our new number for the sulphur point, we find that below 100° the differences between the observed values on the nitrogen scale and those deduced from the platinum thermometer are very small, seldom exceeding 0°·01, and that even at the highest temperatures the difference only amounts to a few tenths of a degree.

APPENDIX IV.

On the Expansion of Porcelain with Rise of Temperature.

By T. G. Bedford, *B.A. Cambridge.*

In direct comparisons of the scales of temperature given by air and by platinum-resistance thermometers at high temperatures, the expansion of the porcelain envelope enters as a small correction.

In the experiments described in this paper, a direct determination of the linear expansion of porcelain was made at temperatures from 0° C. to 830° C. The method used was essentially the same as that described by Callendar ('Phil. Trans.' 1887, A. p. 167).

On a tube of Bayeux porcelain two fine transverse marks were made at a distance about 91·3 cm. apart. The tube was heated to as high a temperature as possible in a gas furnace, and was then slowly cooled by diminishing the gas supply. During cooling the variation in the distance between the marks was determined by a pair of reading microscopes which were mounted on stone blocks and not touched except by the screw-head during an experiment. The readings of the microscopes for a standard length (a glass tube kept in melting ice) were taken at intervals.

The temperatures corresponding to the length measurements were deduced from the resistance of a platinum wire running from mark to mark in the axis of the tube and supported on a plate of mica. The resistances in ice and steam were taken after each exposure to a high temperature. The sample of platinum wire from which the piece used in these experiments was cut is known to have a value of δ, in Callendar's formula, from 1·50 to 1·51. The value $\delta = 1{\cdot}505$ was used, and thus a direct determination of the resistance at the temperature of boiling sulphur was avoided. An error of ·01 in δ causes an error of less than 1° in the calculated value of t at 1,000° C.

Four main experiments were made; the results were plotted and are reproduced on the accompanying slide.

From 0° C. to 600° C. the results are represented fairly well by the formula

$$l_t = l_o \left(1 + 34{\cdot}25 \times 10^{-7}t + 10{\cdot}7 \times 10^{-10}t^2\right).$$

Above 600° C. the points are more erratic, but still do not depart far on either side from the curve given by the above formula.

A length of about 6 cm. at either end of the tube was not directly heated by the furnace. Hence there is an uncertainty due to the ends (greater at the higher temperatures), since the coefficient of expansion varies with the temperature.

For cubical expansion the above formula gives

$$v_t = v \ \left(1 + 102{\cdot}75 \times 10^{-7}t + 32{\cdot}4 \times 10^{-10}t^2\right).$$

Heat of Combination of Metals in the Formation of Alloys.—Report of the Committee, consisting of Lord KELVIN (*Chairman*), Professor G. F. FITZGERALD, Dr. J. H. GLADSTONE, Professor O. J. LODGE, *and* Dr. ALEXANDER GALT (*Secretary*).

AT last year's meeting at Bristol Dr. Galt submitted to Section A an account [1] of some experiments which he had made on the heat of combination of zinc and copper. The Association then granted 20*l.* for the continuance of the experiments. The work was accordingly continued by Dr. Galt, and the Committee have received from him the following account of his experiments made since the Bristol Meeting :—

Altogether twenty-two different alloys of zinc and copper, whose composition varied from 5 to 90 per cent. of copper, were made for this investigation from practically pure metals, and their analyses determined by Messrs. Johnson, Matthey, and Co., London. The first set of five, numbered A, B, C, D, E, was sent on March 16, 1898 ; the second set, of seven, numbered 1–7, on December 1, 1898, and the third and final set of ten, numbered L–V, on March 8, 1899. With these alloys and with the corresponding mixtures of the metals, all in fine filings, the experiments were carried out. The procedure adopted was exactly similar to that described in detail in last year's paper, and each experiment was repeated from three to six times, until consistent results for the heat of solution in each case were obtained, and the mean of these was taken. The heat of solution of zinc alone and of copper alone was also ascertained in a similar manner. The total weight of the whole apparatus (excluding acid and metallic filings) was 42 grammes, and its water equivalent was found to be 5·7 grammes. The specific heat of the nitric acid used, density 1·360 at 15° C., was determined, and the mean of several values was ·658.

A tabular statement of results is appended. The absolute amount of heat evolved in dissolving 1 gramme of metal is calculated from the following formula :—

$$H = t\{(v.g.s.) + c\}, \text{ where}$$

t = increase of temperature in Centigrade degrees of the acid used per gramme of metal dissolved,
v = volume of the acid in cubic centimetres,
g = density of the acid,
s = specific heat of the acid,
c = water equivalent of the apparatus.

The specific heat of the metal used is negligible, and is not taken into account.

The heat units evolved by the solution of 1 gramme of each alloy and of the corresponding mixture are shown on fig. 1, values for mixtures being denoted by a small circle, those for alloys by a small cross. On the same figure are shown the results for 1 gramme of zinc alone, and also for 1 gramme of copper alone, and on joining these two points by a

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[1] *Brit. Assoc. Rep.* 1898, pp. 787, 788.

FIG. 1.—Heat of Solution of Copper-Zinc Mixtures and Alloys. Sept. 1899.

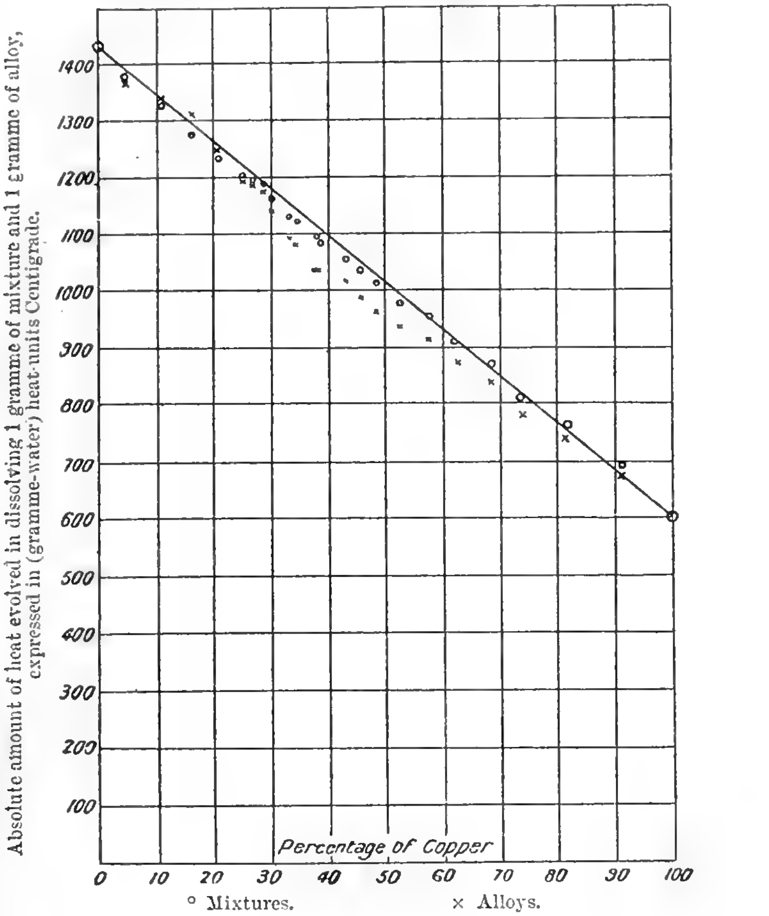
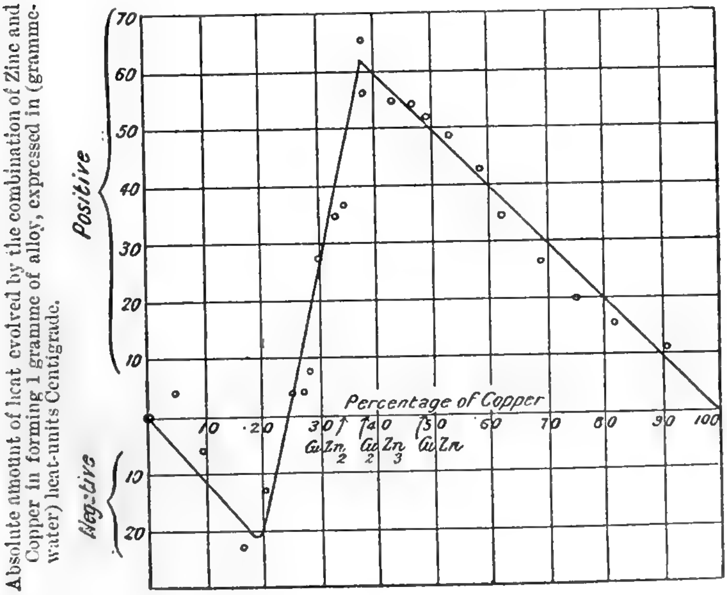


FIG. 2.—Heat of Combination of Copper-Zinc Alloys.



straight line one might expect all the results for mixtures to lie on this line; and this is approximately true for all, except in the case of those mixtures containing from about 15 to about 40 per cent. copper which indicate a drop, probably due to unavoidable errors in the experimental work.

The difference between the absolute heat of solution of 1 gramme of each mixture and its corresponding alloy indicates the heat of combination of the metals in forming 1 gramme of alloy. These differences are shown on fig. 2, and they indicate that the heat of combination is at first negative, which reaches a maximum when the alloy contains about 16 per cent. of copper. With greater percentages of copper the negative value of the heat of combination rapidly falls to zero and then becomes positive. The maximum positive value is very soon reached at about 38 per cent. copper, which is near the formula Cu_2Zn_3. Beyond this point the heat of combination gradually becomes less, until at 90 per cent. copper it almost vanishes.

No. of Alloy	Percentage Composition		Weight of metal dissolved in each experiment	Quantity of acid used in each experiment	Mean increase of temperature of acid *per gramme* of metal dissolved, expressed in degrees Centigrade			Absolute amount of heat evolved in dissolving 1 gramme of metal, expressed in (gramme-water) heat-units Cent.		The difference between the last two columns represents the absolute amount of heat evolved by the combination of the metals in forming 1 gramme of alloy
	Copper	Zinc	Grm.	Cubic centimetres	Mixture	Alloy	Difference	Mixture	Alloy	
1	5.00	95·00	·4	100	14·52	14·47	+0·05	1385	1380	+ 4·7
2	10·50	89·50	·4	95	14·77	14·85	−0·08	1340	1347	− 6 8
3	16·00	84·00	·4	80	16·65	16·95	−0·30	1287	1310	−23·0
4	20·50	79·50	·4	85	15·23	15·40	−0·17	1244	1258	−14
A	25·14	74·86	·5	90	13·94	13·90	+0·04	1202	1198·5	+ 3·5
5	26·50	73 50	·5	100	12·54	12·50	+0·04	1176·3	1192·5	+ 3·8
L	28·75	71 25	·5	90	13·84	13·74	+0·10	1194	1185·4	+ 8·6
M	30 00	70·00	·5	90	13·58	13·26	+0 32	1171	1144	+27
N	33·00	67·00	·5	80	14·60	14·14	+0·46	1129	1094	+35
O	34·50	65 50	·5	80	14·52	14·04	+0·48	1123	1086	+37
6	38·00	62·00	·5	90	12·74	11·98	+0·76	1099	1034	+65
B	38·38	61·62	·5	90	12·66	12·00	+0·66	1092	1035	+57
P	43 00	57·00	·5	90	12·36	11·72	+0·64	1066	1011	+55
7	45·50	54·50	·5	80	13·54	12·84	+0·70	1047	993	+54
C	49·10	50·90	·5	80	13·14	12·48	+0·66	1016	965	+51
Q	52·50	47·50	·5	75	13·58	12 90	+0·68	988·8	939·8	+49
R	58·00	42·00	·5	70	13·94	13·32	+0·62	952·8	910·8	+42
D	62·27	37 73	·5	70	13·40	12·88	+0·52	915 8	880·8	+35
S	69·00	31·00	·5	70	12·68	12·28	+0·40	866·8	839·8	+27
E	75·225	24·775	.5	70	11·82	11·52	+0·30	807·9	787·9	+20
T	81·50	18·50	·5	70	11·16	10·92	+0·24	762·6	746·6	+16
V	90·25	9·75	·5	70	10·18	10·02	+0·16	695 5	684·5	+11
Copper	100	—	.86	99	7·00	—	—	604	—	—
Zinc	—	100	·38	90	16·60	—	—	1432	—	—

The experiments were made according to the method fully described in a paper by Dr. Galt, on "Heat of Combination of Metals," communicated to the Royal Society of Edinburgh, on March 7, 1898.[1] In each case of solution the nitrous products remained in the liquid, the vessel in which the solution took place being kept closed by a cork. The importance of this arrangement is illustrated by the following statement extracted from the paper just referred to :—

"If the method of pouring the acid on the filings or of dropping the filings into the acid had been adopted, a violent action would have occurred, and it would not have been possible to prevent the loss of heat due to escape of fumes. But the plan adopted effectually got rid of this difficulty by the almost instantaneous projection of the bulb containing the filings to the bottom of the acid.[2] It was very interesting to watch the scouring effect in the bulb due to the chemical action; the filings were almost instantaneously expelled from it by the rapid evolution of gas, the removal being facilitated by the existence of the two apertures already described. The gentle rotatory motion given to the acid was kept up while solution was going on, and when it was complete the thermometer reading was again noted. The time required to effect solution was 50 to 55 seconds, and it was observed that complete solution and maximum temperature were reached about the same time."

Addition by the Chairman.

The Committee has carefully considered an objection to the method of experiment which was suggested after the reading of the Report at the Dover meeting, to the effect that nitrous products evolved from the solution might be different in the cases of the solution of the mixture and the solution of the alloy. It seems not probable that even if gaseous products had been allowed to escape, they would have been different in these two cases; but as the whole nitrogenous products remained in the solution in each case, it seems scarcely possible that there can have been any final chemical difference in the solutions. As, however, the question has been suggested, a chemical investigation of the solutions in the two cases might be interesting. K.

Addition by Dr. Gladstone.

This suggestion of the Chairman seems to me most important, and one that ought to be carried out, as there is reason to believe that the chemical products in the two solutions would be different. J. H. G.

Addition by Professors FitzGerald and Lodge.

The above report was drawn up by Dr. Galt, and though we consider it most interesting, and have reason to believe that if the experiments were repeated the results would not be very different, yet, as it has been suggested that the chemical products resulting from actions on the mixed metals and on the alloy might be different, we do not feel justified in concluding that the heat of combination of the metals can be safely deduced from these results in the simple way suggested. G. F. F.-G., O. J. L.

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[1] *Proc. R.S.E.* vol. xxii., 1898, p. 137.

[2] Andrews's *Scientific Papers*, p. 214. Every chemist is familiar with the violent action of nitric acid on zinc and copper, and the abundant evolution of gas which accompanies it. But the facility with which the gases may be condensed by the acid solution is probably not so generally known, and when the experiment is made for the first time it cannot fail to excite surprise.

Meteorological Observations on Ben Nevis.—Report of the Committee, consisting of Lord McLAREN, Professor A. CRUM BROWN (*Secretary*), Sir JOHN MURRAY, Professor COPELAND, *and* Dr. ALEXANDER BUCHAN. (*Drawn up by* Dr. BUCHAN.)

THE Committee was appointed as in past years for the purpose of co-operating with the Scottish Meteorological Society in making meteorological observations at the two Ben Nevis Observatories.

The hourly eye observations, made by night as well as by day, which are a speciality of the Ben Nevis Observatory, being as yet not attempted at any other first-class meteorological observatory in the world, were made with complete regularity by Mr. Angus Rankin and his assistants.

The health of the staff at the high level Observatory continued good, and the heavy work of the Observations has been carried on without the loss of a single hour's observations. The Directors desire to express their very cordial thanks to Messrs. J. S. Begg, M.A., P. S. Hardie, W. A. Bartlett, Andrew Hunter, and T. Kilgour, for the invaluable assistance they rendered as volunteer observers, thus enabling them to give the members of the staff the relief they greatly stood in need of. Special thanks are due to Mr. Begg for the great service he rendered in taking at no small personal risk the place of observer at Fort William during the time of the influenza there, which was of an exceptionally severe character.

The observations at the intermediate station on Ben Nevis, 2,200 feet, were again undertaken by Mr. T. S. Muir, M.A., assisted by the late Mr. Campbell Irons. These observations, together with those made in 1897, are being discussed by Mr. Muir, under the superintendence of Mr. Omond. Arrangements were made for the resumption of these valuable observations during the current holiday season. The observations will be made on the lines indicated in your Committee's Report of last year.

The principal results of the observations of 1898 are detailed in Table I.

TABLE I.

1898	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mean Pressure in Inches.													
Ben Nevis Observatory	25·430	25·097	25·262	25·207	25·273	25·413	25·547	25·394	25·473	25·274	25·180	25·149	25·309
Fort William	30·049	29·720	29·896	29·770	29·830	29·914	30·063	29·866	29·958	29·779	29·735	29·716	29·858
Differences .	4·610	4·623	4·634	4·563	4·557	4·501	4·516	4·472	4·485	4·505	4·555	4·567	4·549
Mean Temperatures.													
Ben Nevis Observatory	29°·3	22°·4	23°·4	29°·8	31°·3	38°·8	41°·0	40°·9	42°·6	35°·7	28°·9	28°·2	32°·7
Fort William	41·2	39·5	40·1	47·1	48·2	55·1	56·5	57·0	55·2	50·6	42·7	43·8	48·4
Differences .	14·9	17·1	16·7	17·3	16·0	16·3	15·5	16·1	12·6	14·9	13·8	15·6	15·7
Extremes of Temperature, Maxima.													
Ben Nevis Observatory	39°·0	37°·9	37°·1	41°·3	51°·2	52°·1	55°·9	55°·3	62°·6	57°·	43°·9	39°·3	62°·6
Fort William	53·0	52·4	51·7	60·6	64·3	72·0	74·6	76·9	79·7	73·8	55·9	53·2	79·7
Differences .	14·0	14·5	14·6	19·3	13·1	19·9	18·7	21·6	17·1	16·6	12·0	13·9	17·1

TABLE I.—*continued.*

1898	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Extremes of Temperature, Minima.													
Ben Nevis Observatory	21°·2	9°·6	13°·1	15°·2	19°·3	26°·5	30°·1	29°·0	29°·0	23°·5	11°·1	16°·4	9°·6
Fort William	31·9	26·2	26·7	28·6	32·3	42·8	42·0	43·7	35·9	36·0	21·1	27·3	21·1
Differences .	10·7	16·6	13·6	13·4	13·0	16·3	11·9	14·7	6·9	12·5	10·0	10·9	11·5
Rainfall, in Inches.													
Ben Nevis Observatory	27·08	30·09	19·07	10·76	8·74	10·37	11·74	18·61	24·81	13·86	21·27	43·65	240·05
Fort William	14·22	11·36	7·41	6·77	2·91	4·27	2·84	7·30	10·60	6·83	7·99	24·01	106·51
Differences .	12·86	18·73	11·66	3·99	5·83	6·10	8·90	11·31	14·21	7·03	13·28	19·64	133·54
Number of Days 1 in. or more fell.													
Ben Nevis Observatory	12	15	6	2	1	3	6	6	7	4	6	18	86
Fort William	4	1	2	1	0	0	1	1	3	1	2	10	26
Differences .	8	14	4	1	1	3	5	5	4	3	4	8	60
Number of Days 0·01 in. or more fell.													
Ben Nevis Observatory	27	24	27	21	22	17	22	27	21	21	23	29	281
Fort William	28	23	25	23	19	15	16	24	20	9	23	30	265
Differences .	+1	1	4	0	3	0	1	3	1	0	3	+1	26
Mean Rainband (scale 0–8).													
Ben Nevis Observatory	2·5	2·3	1·5	2·8	2·3	1·9	3·0	2·9	2·3	2·0	2·1	2·1	2·3
Fort William	4·1	3·4	3·4	4·3	4·2	3·6	3·4	3·7	3·6	3·8	3·6	3·7	3·7
Differences .	1·6	1·1	1·9	1·5	1·9	1·7	·4	·8	1·3	1·8	1·5	1·6	1·4
Number of Hours of Bright Sunshine.													
Ben Nevis Observatory	11	19	43	33	149	116	141	44	88	76	33	12	765
Fort William	14	48	104	117	213	170	198	119	125	90	32	11	1,241
Differences .	3	29	61	84	64	54	57	75	37	14	+1	+1	476
Mean Hourly Velocity of Wind, in Miles.													
Ben Nevis Observatory	15	17	14	19	10	8	6	10	12	21	16	20	14
Percentage of Cloud.													
Ben Nevis Observatory	95	95	91	92	76	79	76	90	77	76	82	94	85
Fort William	86	79	74	76	65	69	68	77	64	67	72	81	73
Differences	9	16	17	16	11	10	8	13	13	9	10	13	12

Table I. shows for 1898 the mean monthly and extreme pressure and temperature ; amounts of rainfall, with the number of days of rain, and the days on which the amount equalled or exceeded one inch ; the hours of sunshine ; the mean percentage of cloud ; the mean velocity of the wind in miles per hour at the top of the mountain ; and the mean rainband at both Observatories. The mean barometric pressures at Fort William are reduced to 32° and sea-level, but those at the Ben Nevis Observatory only to 32°.

At Fort William the mean atmospheric pressure for the year was 29·858 inches, being 0·014 inch higher than the mean of the forty years from 1856 to 1895. The mean at the top was 25·309 inches, being 0·013 inch above the average of the Observatories made since the opening of the Observatory in 1883. The difference for the two Observatories was thus 4·549 inches for the year, being nearly the average difference of past years. At the top of the mountain the absolutely highest pressure for the year was 25·992 inches on June 10; and at Fort William 30·458 inches on January 23.

The differences from the mean monthly barometric pressure greatly exceeded the averages in January and July, the excesses being respectively for Fort William 0·231 inch and 0·196 inch, and at the top of Ben Nevis 0·227 inch and 0·183 inch. On the other hand the reverse held good in February and April, when the defects from the averages were respectively for Fort William 0·174 inch and 0·146 inch, and at the top of Ben Nevis 0·177 inch and 0·104 inch. The excesses occurred when the general type of weather was anticyclonic, and the defects from the pressure when it was cyclonic.

The following shows the deviations of the mean temperature of the months from their respective averages :—

	Fort William.	Top of Ben Nevis.	Difference.
	°	°	°
January	5·2	5·5	0·3
February	0·3	1·5	1·8
March	0·2	0·4	0·2
April	1·8	2·3	0·5
May	2·1	1·7	0·4
June	0·1	0·5	0·4
July	0·6	0·3	0·3
August	0·6	0·9	0·3
September	2·7	4·6	1·9
October	4·0	4·1	0·1
November	0·6	0·3	0·9
December	3·7	3·2	0·4
Year	1·2	1·4	0·2

The absolutely highest temperature for the year recorded for Fort William was 79°·7 on September 6, and at the top 62°·6 on the same date. The absolutely lowest temperature was 21°·1 on November 29 at Fort William, and 9°·6 on February 20 at the top of the mountain. A noticeable feature of these maximum temperatures in September, when the type of weather was strongly anticyclonic, was the lateness of the season when they occurred, and, besides, they far exceed any previously recorded in September at either of the Observatories.

In Table II. are given for each month the lowest observed hygrometric readings at the top of Ben Nevis :—

TABLE II.

—	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Dry Bulb	25°·0	19°·3	25°·0	38°·8	31°·0	45°·5	47°·2	34°·1	53°·0	57°·1	41°·4	20°·2
Wet Bulb	32·2	17·3	22·6	30·7	24·3	32·0	33·2	26·3	36·5	46·3	30·0	16·9
Dew-point	13·3	2·7	9·3	20·2	6·2	15·8	17·5	12·3	20·0	36·4	15·2	–6·5
Elastic Force	·079	·049	·065	·109	·057	·089	·096	·075	·108	·215	·086	·032
Relative Humidity (Sat.=100)	59	47	49	46	33	29	23	38	27	46	33	29
Day of Month	3	24	30	22	6	28	9	9	24	3	19	8
Hour of Day	6 a.m.	3 a.m.	8 a.m.	6 a.m.	11p.m.	7 a.m.	9 a.m.	4 a.m.	1 p.m.	5 p.m.	3 p.m.	9 a.m.

Of these lowest relative humidities, the lowest 23 occurred in July with a dew-point of 17°·5, and the highest 59 in January with a dew-point of

13°·3. It is to be noted that with these humidities the accompanying dew-point fell only once below zero, viz., to −6°·5 on December 8, being in this respect very different from the low humidities of previous years.

The registrations of the sunshine recorder at the top 765 hours out of a possible 4,470 hours, being 48 hours fewer than in 1897. This is 17 per cent. of the possible sunshine. The monthly maximum was 149 hours in May, and the minimum 11 hours in January and 12 hours in December. At Fort William the number of hours was 1,241, being the largest hitherto recorded. The maximum was 213 hours in May, and the minimum 11 hours in December. The annual number of hours, 1,241, is 36 per cent. of the possible sunshine at Fort William.

At the Ben Nevis Observatory the mean percentage of cloud was 85, which is nearly the average, the highest being 95 in January and February, and the minimum 76 in May, July, and October; and at Fort William, the mean was 73, the highest being 86 in January, and the lowest 64 in September.

The mean rainband observation (scale 0—8) was 2·3 at the top for the year; the maximum being 3·0 in July and the minimum 1·5 in March. At Fort William the mean for the year was 3·7, the maximum being 4·3 in April and the minimum 3·4 in February, March, and July.

The mean hourly velocity of the wind was at the top of the mountain 14 miles per hour, the maximum velocity being 21 miles in October, and the minimum 6 miles in July, being the lowest mean yet recorded on Ben Nevis. The means of 10 miles for May, 8 miles for June, 6 miles for July, and 10 miles for August, were the lowest means yet observed in four consecutive months, thus forming a striking feature of the meteorology of Ben Nevis during the summer months of 1898.

The rainfall for the year was 240·05 inches, which is by far the largest rainfall of any year yet observed on the top of Ben Nevis, being 59 per cent. above the average of the observations made since 1881. This high percentage above the average was approximated to at several stations in this part of the West Highlands. The largest monthly amount was 43·65 inches in December, and, as will be seen from Table I., the amount for six of the months was exceptionally large. Another singular circumstance is that the amounts for each of the months exceeded their average. The heaviest fall on any single day was 5·39 inches on November 2. At Fort William the amount for the year was 106·51 inches, the largest yet observed here, being 38 per cent. above the average. The largest monthly amount was 24·01 inches in December. The heaviest fall on any single day was 3·66 on December 4.

On the top of Ben Nevis rain fell on 281 days, and at Fort William on 265 days. At the top the maximum number of rainy days was 29 in December and the minimum 17 in June; the numbers for Fort William being 30 days in December and 15 in June.

During the year the number of days on which 1 inch of rain or more was collected was 86 at the top and 26 at Fort William, these being very greatly above the averages, the percentages excess being 80 and 69 respectively. In December, at the top, more than 1 inch of rain fell on eighteen days and in February on fifteen days. The prominent feature of the meteorology of Ben Nevis in 1898 was the unprecedented number of days characterised by heavy rainfalls, April and May being the only exceptions.

Auroras are reported to have been observed on the following dates:—

January 12 ; March 26 ; April 15 ; August 16, 17 ; September 16, 17, 22, 23, 24, 25 ; November 21, 22, or thirteen nights in all.

St. Elmo's Fire was seen on February 6, 7, 8, 12, 13, 26, 27, 28 ; March 14 ; July 2 ; September 18, 28 ; November 3, 4, 5 ; December 7, 9, —seventeen times in all.

Zodiacal Light, not observed.

Thunder and lightning were reported June 21 ; July 2 ; November 3 ; December 26. Lightning only, February 2 ; October 22.

Solar Halo, January 1, 3 ; February 5, 24 ; March 30 ; May 2, 7, 17, 24, 27 ; June 16, 17 ; July 9, 30 ; August 9, 11 ; September 23 ; November 22 ; December 8.

Lunar Halo, August 6, 7, 9 ; December 29, 30.

Much time continues to be given to the discussion of the hourly observations of the two Observatories. The work of reducing and entering these observations for every day, side by side, so as to present a direct and easy comparison of the two, is far advanced, being brought down to the end of 1897. The number of daily sheets finished is 2,710, and, as each sheet contains twenty-two columns, the laboriousness of the work may be in some degree appreciated.

As explained in previous Reports, the rainfall, fog, thunder, lightning, halos, aurora, and other phenomena observed at 120 stations on each day, are entered on a map of Scotland for that day. The whole of these maps are now completed down to December 1898, the number of the maps amounting to 2,922. A beginning has been made to enter on these maps the gales and storms which have occurred at the seventy lighthouses round the Scottish coasts. Care is taken to note the hour of commencement of each storm, so that a comparison may be made as to the commencement and violence of storms and the related forecasts issued by the Meteorological Office in London.

Storms which strike the Scottish coasts may be conveniently divided into these chief classes, viz. : storms which overspread the whole of Scotland ; storms over the west coast only ; storms over the east coast only ; and storms more restricted as to the area they overspread, such as only from the Tweed to the Tay, from the Tay to the Moray Firth, over the Hebrides, and those confined to Orkney and Shetland. As regards the intensity of storms, since this depends on the barometric gradients formed within the cyclones, these gradients will be specially examined in the relations they stand to the vertical gradients of pressure, temperature, and humidity formed in the stratum of the atmosphere between the top and foot of Ben Nevis.

The Ben Nevis observations indicate that the great majority of cyclones show the winds both at the top and bottom of the mountain blowing vorticosely inwards upon the central area of the cyclones. But no inconsiderable number of cyclones passing over Ben Nevis show that while the winds at sea level blow inwards upon the cyclone, the winds at the top of the Ben blow outwards from the cyclones. Now the vertical gradients of pressure, temperature, and humidity, as disclosed by the two Observatories, open up very important lines of inquiry in the investigation of these different types of cyclones.

Again, the frequent sudden changes of these vertical gradients suggest lines of inquiry of no less importance as to the relation of these changes to the manner of distribution over the stations of the rain accompanying the cyclones and many of the smaller barometric depressions. In several respects this remark applies also to the distribution of fogs.

Among the results indicated by the observations made during the past four summer seasons at the intermediate station compared with the observations made at the two Observatories, the more important referred to in our last year's Report is this : When the reduced barometer at the top of Ben Nevis, for a series of observations, comes higher than that of Fort William, the accompanying disturbance of temperature takes place in the lower half of the mountain, that is below the intermediate station, *and denotes the approach of an anti-cyclone.* Conversely, when the reduced barometer at the Ben Nevis Observatory reads lower than that of Fort William, then the disturbance of temperature takes place in the upper half of the mountain, *and denotes the approach of a cyclone.*

The hourly and other observations at the two Observatories from January 1888 to December 1896 are now in the press, together with a general discussion of the results, and other discussions of separate inquiries raised by observations, nearly all of which have been resumed in the successive annual reports of your Committee.

Arrangements have been made for the publication during the next three years, in the 'Transactions of the Royal Society of Edinburgh,' of the hourly observations made at the Observatories from 1888 to 1901, the time to which it is proposed by the Directors to continue the observations. The observations will fill three large quarto volumes, the cost of publishing which will be a little over 1,000*l.* Your Committee have much pleasure in adding that the Royal Society of London have agreed to give 500*l.*, being half of the whole expenditure, the balance being met by the Royal Society of Edinburgh ; and that Mr. Mackay Bernard of Dunsinnan has by another donation of 500*l.* enabled the Directors to continue the observations for another year. These handsome gifts, the first two by the two leading Scientific Societies of the country, and the third by a generous private person, are announced by your Committee with great satisfaction.

Water and Sewage Examination Results.—Report of the Committee, consisting of Professor W. RAMSAY (*Chairman*), Dr. S. RIDEAL (*Secretary*), Sir W. CROOKES, Professor F. CLOWES, Professor P. F. FRANKLAND, *and* Professor R. BOYCE, *appointed to establish a Uniform System of recording the Results of the Chemical and Bacterial Examination of Water and Sewage.*

The Committee beg to report as follows :—That it is desirable that results of analysis should be expressed in parts per 100,000, except in the case of dissolved gases, when these should be stated as cubic centimetres of gas at 0°C. and 760 mm. in 1 litre of water. This method of recording results is in accordance with that suggested by the Committee appointed in 1887 to confer with the Committee of the American Association for the Advancement of Science, with a view to forming a uniform system of recording the results of water analysis.[1]

2. The Committee suggest that in the case of all nitrogen compounds

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[1] *Brit. Assoc. Report*, 1889.

the results be expressed as parts of nitrogen over 100,000, including the ammonia expelled on boiling with alkaline permanganate, which should be termed albuminoid nitrogen. The nitrogen will, therefore, be returned as—

(1) Ammoniacal nitrogen from free and saline ammonia.
(2) Nitrous nitrogen from nitrites.
(3) Nitric nitrogen from nitrates.
(4) Organic nitrogen (either by Kjeldahl or by combustion, but the process used should be stated).
(5) Albuminoid nitrogen.

The total nitrogen of all kinds will be the sum of the first four determinations.

The Committee are of opinion that the percentage of nitrogen oxidised, that is, the ratio of (2) and (3) to (1) and (4), gives sometimes a useful measure of the stage of purification of a particular sample. The purification effected by a process will be measured by the amount of oxidised nitrogen as compared with the total amount of nitrogen existing in the crude sewage.

In raw sewage and in effluents containing suspended matter it is also desirable to determine how much of the organic nitrogen is present in the suspended matter.

In sampling, the Committee suggest that the bottles should be filled nearly completely with the liquid, only a small air-bubble being allowed to remain in the neck of the bottle. The time at which a sample is drawn, as well as the time at which its analysis is begun, should be noted. An effluent should be drawn to correspond as nearly as possible with the original sewage, and both it and the sewage should be taken in quantities proportional to the rate of flow when that varies (*e.g.* in the emptying of a filter bed).

In order to avoid the multiplication of analyses the attendant at a sewage works (or any other person who draws the samples) might be provided with sets of twelve or twenty-four stoppered $\frac{1}{4}$ Winchester bottles, one of which should be filled every hour or every two hours, and on the label of each bottle the rate of flow at the time should be written. When the bottles reach the laboratory quantities would be taken from each proportional to these rates of flow and mixed together, by which means a fair average sample for the twenty-four hours would be obtained.

The Committee at present are unable to suggest a method of reporting bacterial results, including incubator tests, which is likely to be acceptable to all workers.

Bibliography of Spectroscopy.—Interim Report of the Committee, consisting of Professor H. McLEOD, Professor Sir W. C. ROBERTS-AUSTEN, Mr. H. G. MADAN, *and* Mr. D. H. NAGEL.

THE collection and verification of titles of papers has been proceeded with, and the Committee hope to be able to continue the work until it can be taken up by the compilers of the International Catalogue of Scientific Papers.

The Committee therefore ask for reappointment.

On 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*), Sir J. N. Lockyer, Professor J. Dewar, Professor G. D. Liveing, Professor A. Schuster, Professor W. N. Hartley, Professor Wolcott Gibbs, *and* Captain Abney.

CHLORINE (VACUUM-TUBE).

Eder and Valenta: 'Denkschr. kais. Akad. Wissensch. Wien,' Bd. lxviii. 1899.
S. = Salet; P. = Plücker; T. = Thalén; H. = Hasselberg.

Pressure 10 to 20 mm.		Pressure 30 to 40 mm.		Pressure 70 to 100 mm.	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length (Rowland) (a)	Intensity and Character	Wave-length (Rowland) (b)	Intensity and Character	Intensity and Character		λ +	$\frac{1}{\lambda}-$	
		5672·2	½			1·55	4·8	17625
		35·1	1b			1·54	,,	741
		25·5	½			1·53	,,	71
		23·1	½			,,	,,	79
		5580·1	¼		5597·5 P., also T.	1·52	4·9	916
		70·4	½		73·7 P.	,,	,,	48
		—	n		38·0 P.	,,	,,	
5457·70	½s	57·70	½b^v	b	5457 8 H., also S.P.T.	1·49	,,	88·1a
57·28	3s	57·30	3b^v					89·5a
56·391	2s	56·49	2b^v					92·4a
45·12	1s	45·1	1n	b	45·0 H., also S.P.T.	,,	5·0	18029·0a
44·412	3s	44·52	4b^v					362·5a
43·587	5s	43·64	6b^v					65·2a
23·703	2s	23·7	4b^v	b	24·6 H., also S.P.T	1·48	,,	432·6a
23·441	6s	23·4	10b^v					33·5a
5392·300	4s	92·3	6b		5393·7 H., also S.P.T.	1·47	5·1	539·9a
		5285·8	½		5285·9 H., also P. T.	,,	,,	913
5221·48	4s	21·54	6b	b	20·8 H., also S.P.T.	1·44	5·2	19146·5a
18·07	3s	18·16	8b^v	b	17·0 H., also P. T.	1·43	,,	59·0a
		5193·6	½n		5195·6 P., also T.	1·42	5·3	249
		89·74	1b		89·8 H., also P. T.	,,	,,	63·5
		76·0	½		78·1 P., also T.	,,	,,	315
		73·4	1n		73·2 H., also P. T.	1·41	,,	24
		—			61·6 H., also P. T.	,,	,,	—
		62·50	1		63·7 P.	,,	,,	65·2
		58·9	½n			,,	,,	79
		13·3	1n		13·6 H., also P. T.	1·40	5·4	551
5103·18	2s	03·18	4b		03·0 H., also P. T.	,,	,,	90·2a
		5099·36	1b^v		5098·8 H., also S.P.T.	1·39	,,	604·9
		89·6	½n				,,	43
		83·59	1				,,	65·7
5078·361	4s	78·38	4b^v		78·3 H., also S.P.T.	1·38	,,	86·0a
		4995·7	1n		4998·7 H., also S.P.T	1·37	5·5	20012
		70·3	1n		73·3 H , also S.P.T	1·36	,,	114
		43·1	½		46·2 H., also P. T	1·35	5·6	225
		—			39 0 H., also P. T.	,,	,,	—

CHLORINE (VACUUM-TUBE)—*continued.*

Pressure 10 to 20 mm.		Pressure 30 to 40 mm.		Pressure 70 to 100 mm.	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length (Rowland) (a)	Intensity and Character	Wave-length (Rowland) (b)	Intensity and Character	Intensity and Character		$\lambda +$	$\frac{1}{\lambda} -$	
		4927 3	½				5·6	20289
		24·90	1n		4926·1 H., also S.P.T.	1·35	,,	99·4
4917·870	2s	17·84	3b		17·5 T., also P.	,,	,,	328·4a
04·905	4s	04·85	4b^v		05·4 H., also S.P.T.	1·34	,,	82·2a
4896·905	5s	4896·90	5b^v		4897·6 H., also S. T.	,,	,,	415·5a
19·628	9s	19·63	10b		20·3 H,, also S.P.T.	1·32	5·7	742·8a
10·194	9s	10·19	9b		10·5 H., also S.P.T.	,,	,,	85·1a
4794·665	10s	4794·63	10b		4794·5 H., also S.P.T.	1·31	,,	850·8a
85·41	½s	85·5	1n				,,	91·1a
81·49	5s	81·44	5s		83·4 P., also S.	,,	5·8	908·2a
79·06	3s	79·07	3s		81·8 H., also P. T.	,,	,,	18·8a
71·22	2s	71·19	2n		74·6 P.	,,	,,	53·2a
68·80	4s	68·76	4s		70·0 H., also S.P.T.	,,	,,	63·8a
		55·9	1n		54·0 P.	1·30	,,	21021
40·505	3s	40·52	3b^v		40·5 H., also S.P.T.	,,	,,	89·0a
		4661·38	1s		4660·9 T.	1·28	5·9	447·0
		54·3	1		48·8 T.	1·27	,,	80
		49·1	½		40·9 T., also P.	,,	,,	504
		24·23	3b		28·3 P.	,,	6·0	619·2
		01·19	4b^v		07·2 P., also T.	1·26	,,	727·5
		—			4595·8 P., also T.	,,	,,	—
		4585·05	1n		90·7 P., also S. T.	,,	,,	804·0
		72·79	5b		72·1 P.	1·25	,,	62·5
		70·16	3		66·5 P.	,,	,,	75·1
		37·0	½		37·0 P.	1·24	6·1	22035
		26·44	5b^v		26·0 P., also T.	,,	,,	86·3
		19·4	½				,,	121
		10·6	½				,,	64
		04·50	½		05·6 P.	1·23	,,	93·9
		4497·45	½		4497·2 P.	,,	,,	228·7
		91·25	3b				6·2	59·3
		90·16	3b		90·4 P.	,,	,,	64·7
		75·498	4s	b^v		,,	,,	337·7
		69·569	5s	s		,,	,,	67·3
4446·348	2s	46·30	2s	b		1·22	,,	484·2a
46·096	2s	46·10	2s	b		,,	,,	85·4
38·735	4s	38·72	2s	b^v		,,	,,	522·8a
		17·0	½n			1·21	6·3	634
03·210	5s	03·22	5s	b^v		,,	,,	704·4a
02·672	1s	02·79	4b			,,	,,	07·2a
		4399·765	1b			,,	,,	22·2
		99·373	2b			,,	,,	24·2
4391·12	½					1·20	,,	66·9
90·566	3s	90·572	3s	s		,,	,,	69·8a
89·949	8s	89·941	6s	b^v		,,	,,	73·0a
87·730	5s	87·791	2			,,	,,	84·5a
80·075	8s	80·097	5s	s		,,	,,	824·3a
73·119	6s	73·111	8s	b		,,	,,	60·7a
71·715	5s	71·740	2			,,	,,	68·0a
69·676	6s	69·690	6s	s		,,	,,	78·7a
63·457	8s	63·462	5s	b^v		,,	6·4	911·2a

CHLORINE (VACUUM-TUBE)—*continued.*

Pressure 10 to 20 mm.		Pressure 30 to 40 mm.		Pressure 70 to 100 mm.	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length (Rowland) (a)	Intensity and Character	Wave-length (Rowland) (b)	Intensity and Character	Intensity and Character		$\lambda +$	$\frac{1}{\lambda} -$	
4343·822	10s	4343·82	10sr		4347·1 P., also S.	1·19	6·4	23014 8
36·371	5s	36·39	5s	s	39·4 P.	,,	,,	54·4a
		33·125	1			,,	,,	71·7
23·523	6s	23·54	4s	b^v	13·7 P., also S.	1·18	,,	122·9a
09·189	3s	09·19	4b	b				99·8a
07·593	6s	07·627	8s	s		,,	6·5	208 3a
04·211	4s	04·20	6s	s		,,	,,	26·6a
4291·861	5s	4291·884	6s	s	4295·6 P.	,,	,,	93·4a
80·615	3s				82·6 P.	1·17	,,	354·7
76·628	4s	76·719	$3b^v$	b^v	78·8 P.	,,	,,	76·4a
70·725	3s	70·855	$2b^v$	b^v		,,	,,	408·7a
64·740	3s	64·769	2s	n		,,	,,	41·6a
61·350	3s	61·421	4b	b		,,	,,	60·2a
59·628	4s	59·640	5s	s	59·7 P., also S.	,,	,,	69·7a
53·532	9s	53·638	$10b^v$	b^v		,,	6·6	503·3a
41·435	8s	41·474	$8b^v$	b^v		1·16	,,	70·3a
35·608	3s	35·683	$4b^v$			,,	,,	602·8a
34·137	5s	34·198	$5b^v$			,,	,,	10·9a
26·580	7s	26·585	4s	s		,,	,,	53·2a
		25·139	1			,,	,,	61·3
09·866	5s	09·861	4s			,,	,,	747·1a
08·160	4s	08·209	$3b^v$	b		,,	,,	56·8a
		4189·379	1n			1·15	6·7	863·2
4158·021	4s	58·001	5b			1·14	,,	24043·2a
		49·631	1n			,,	,,	91·8
47·203	4s	47·356	$5b^v$	b^v		,,	6·8	105·9a
33·834	3s	33·955	3			,,	,,	83·8a
32·680	8s	32·719	$9b^v$	b^v	4130·8 S.	,,	,,	90·6a
30·991	4s	31·088	$4b^v$			1·13	,,	200·5a
30·34	1n	30·304	1n	b^v		,,	,,	04·3a
		24·153	1n			,,	,,	40 6
04·965	4s					,,	,,	354·0
		4054·242	2n			1 11	6·9	658·6
		40·710	2n			,,	7·0	741·1
4032·330	5s	32·368	3s			,,	,,	92·6a
		3991·625	1n			1·10	7·1	25045·4
		82·060	3n			,,	,,	105·5
		61·770	2n			1 09	,,	234·1
		55·582	3n			,,	7 2	73·5
3917·721	2s	17·762	4s	b^v		1·08	,,	517·9a
16·832	4s	16·870	5s	b^v		,,	,,	23·6a
14·055	5s	14·105	$6b^v$	b^v		,,	,,	41·7a
		3884·045	2b	b^v		1 07	7·3	739·1
		83·454	2*	s		,,	,,	43·0
		71·537	4b	b		,,	,,	822·2
		68·844	6s	b^v		,,	,,	40 2
		66·103	1s			,,	,,	58·6
		63·726	2b			,,	,,	74·4
3861·008	10s	61·006	10s	b^v		,,	,,	92·7

* Possibly not due to Chlorine.

CHLORINE (VACUUM-TUBE)—*continued.*

Pressure 10 to 20 mm.		Pressure 30 to 40 mm.		Pressure 70 to 100 mm.	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length (Rowland) (a)	Intensity and Character	Wave-length (Rowland) (b)	Intensity and Character	Intensity and Character		λ+	$\frac{1}{\lambda}-$	
		3858·83	½			1·07	7·3	25907·3
		55·738	2s	s		1·06	,,	28·1
		55·000	4b			,,	,,	33·0
		54·21	1n			,,	,,	38·4
		53·63	1n			,,	,,	42·3
51·751	1n	51·8	1n	b^{v}		,,	,,	54·9a
51·531	8s	51·536	8s			,,	,,	56·4a
51·165	10s	51·172	10s			,,	,,	58·8a
		49·299	2s			,,	,,	71·5
		48·034	2s			,,	,,	80·0
45·825	8s	45·83	8s	b^{v}		,,	,,	94·9a
45·545	8s	45·56	5s			,,	,,	96·8a
43·390	5s	43·398	5s			,,	,,	26011·4a
		38·482	3s			,,	,,	44·7
		36·658	2s			,,	,,	57·0
33·502	8s	33·510	$6b^{v}$	b^{v}		,,	,,	78·5a
		30·962	2n			,,	,,	95·8
		29·550	2n			,,	,,	105·4
		27·802	5			,,	,,	17·4
		21·850	1			,,	,,	58·0
		20·404	5			,,	,,	68·0
		18·577	3			,,	,,	80·4
		10·215	2b			1·05	7·4	237·9
		09·697	4			,,	,,	41·4
		05·384	6			,,	,,	71·2
		00·105	1			,,	,,	307·7
		3798·991	$5b^{v}$			,,	,,	15·4
		87·262	1n			,,	,,	96·9
		81 378	6s			,,	,,	438·0
		74·324	4			1·04	,,	87·4
		73·813	2			,,	,,	91·0
		69·187	1s			,,	7·5	523·4
		68 228	3s			,,	,,	30·2
		67·647	4s			,,	,,	34·2
		50·102	5s	s		,,	,,	658·5
		48·594	2s	b^{v}		,,	,,	69·2
		43·206	1			,,	,,	707·5
		26 688	3s	b		1·03	7·6	825·9
		25·912	3s			,,	,,	31·5
		22·4	1n			,,	,,	57
		20·4	1n			,,	,,	71
		07·4	1n			,,	,,	965
		05·5	1n			,,	,,	979
		3689·1	1n			1 02	,,	27099
		83 6	1n			,,	,,	140
		82·1	1n			,,	,,	51
		73·9	1n			,,	,,	211
		68·1	1n			,,	,,	54
		63·948	2s			,,	7·7	85·3
		59·913	2s			,,	,,	315 1
		58·499	3s			,,	,,	25·9

CHLORINE (VACUUM-TUBE)—*continued.*

Pressure 10 to 20 mm.		Pressure 30 to 40 mm.		Pressure 70 to 100 mm.	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length (Rowland) (a)	Intensity and Character	Wave-length (Rowland) (b)	Intensity and Character	Intensity and Character		λ+	$\frac{1}{\lambda}-$	
		3650·243	4s			1·01	7·7	27387·8
		24·3	½n			,,	,,	534
		22·7	½n			,,	7·8	96
		13·9	2n			,,	,,	663
		02 2	2s	b		,,	,,	753
		3577·211	1			,,	7·9	954·7
		68·08	3b			,,	,,	28018·4
		22·04	½			,,	8·0	384·6
		09·09	½			,,	8·1	489·3
		3479·82	1			,,	,,	729·0
		3353 45	5s			,,	8·5	29811·5
		33·74	2s			,,	,,	987·8
		29·14	5b			,,	,,	30029·3
		16·83	½			,,	8 6	140 7
		15·49	4b			,,	,,	52·9
		07·90	1b			,,	,,	222·1
		06·44	3b			,,	,,	35·4
		3276·79	1n			,,	,,	509·8

MOLYBDENUM.

Exner and Haschek: 'Sitzber. kais. Akad. Wissensch. Wien,' civ. 1895, cv. 1896.

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}-$	
5060 0	1n	1·38	5·4	19757
00·5	1b	1·37	5·5	992
4979·0	1n	1·36	,,	20079
64·0	1n	,,	,,	139
57·5	1n Fe	,,	,,	66
50·5	1n	1 35	,,	94
41·4	1n	,,	5·6	232
33·0	1n	,,	,,	66
26·2	1	,,	,,	94
09·0	1n	1·34	,,	365
07·0	1n	,,	,,	73
03·5	1n	,,	,,	88
4886·5	1n	,,	,,	459
84·5	1n	,,	,,	67
78·0	1n	1·33	,,	95
67·8	4	,,	,,	538
60·0	1n	,,	5·7	70
58·1	1n	,,	,,	78

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
4853·5	2n	1·33	5·7	20598
44·8	1n	,,	,,	635
43·7	1n	,,	,,	40
39·2	1n	1·32	,,	59
33·7	1	,,	,,	82
32·5	1n	,,	,,	87
30·4	4	,,	,,	96
19·0	4	,,	,,	745
10·9	2	,,	,,	80
07·8	1n	,,	,,	94
05·5	1n	,,	,,	804
02·8	1n	1·31	,,	15
4798·0	1n	,,	,,	36
96·3	1	,,	,,	44
93·2	1	,,	,,	57
92·6	1	,,	,,	60
88·0	1n	,,	,,	80
86·5	1n	,,	,,	86
85 0	1	,,	,,	93
82·8	1	,,	5·8	902
76·0	1	,,	,,	32
75·4	1	,,	,,	35
73·3	1	,,	,,	44
70·5	1n	,,	,,	56
69·3	1	,,	,,	62
63·3	1	1·30	,,	88
61·8	1	,,	,,	95
59·9	6	,,	,,	21003
54·0	3n	,,	,,	29
50·2	2	,,	,,	46
44·3	1	,,	,,	72
42·3	4	,,	,,	81
40·0	1n	,,	,,	91
35·2	1n	,,	,,	113
33·0	1	,,	,,	22
31·3	4	,,	,,	30
30·4	1	,,	,,	34
29·0	1	1·29	,,	40
28·1	1	,,	,,	44
25·0	1	,,	,,	58
23·0	1	,,	,,	67
18·8	1	,,	,,	86
17·8	2	,,	,,	90
16·8	1	,,	,,	95
14·3	1	,,	,,	206
12·7	1	,,	,,	13
08·2	1	,,	,,	34
07·3	4	,,	5·9	38
06·1	2	,,	,,	43
00·3	1	,,	,,	69
4699·1	1b	,,	,,	75
96·0	1	,,	,,	89
93·9	1	,,	,,	98
90 9	1	1·28	,,	312
90·1	1	,,	,,	16

MOLYBDENUM—*continued.*

Wave length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
4689·4	1	1·28	5·9	21319
88·2	2	,,	,,	24
87·3	1	,,	,,	28
85·8	1	,,	,,	35
83·8	1	,,	,,	44
81·8	1	,,	,,	53
80·6	1b	,,	,,	59
73·7	1	,,	,,	90
71·8	2	,,	,,	99
67·3	1n	,,	,,	420
62·9	2	,,	,,	40
61·7	1	,,	,,	45
60·8	1	,,	,,	50
59·9	1 W	,,	,,	54
57·7	1	,,	,,	64
56·3	1	,,	,,	70
53·2	1	1·27	,,	85
52·5	1	,,	,,	88
50·8	1	,,	,,	96
47·8	1	,,	,,	510
38·1	2	,,	,,	55
36·1	1	,,	,,	64
35·0	1	,,	6·0	69
34·4	1	,,	,,	72
33·2	1	,,	,,	77
27·9	1	,,	,,	602
26·7	2	,,	,,	08
23·8	1	,,	,,	21
23·1	1	,,	,,	24
22·7	1	,,	,,	26
21·3	1	,,	,,	33
21·0	1n	,,	,,	34
20·6	1n	,,	,,	36
19·5	1n	,,	,,	41
18·1	1	,,	,,	48
16·6	1	1·26	,,	55
14·7	1	,,	,,	64
13·4	1	,,	,,	70
12·9	1n	,,	,,	72
11·4	1n	,,	,,	79
10·8	1n	,,	,,	82
10·1	4	,,	,,	85
09·1	1n	,,	,,	90
04·6	1	,,	,,	711
03·8	1	,,	,,	15
4599·3	1	,,	,,	36
98·5	1	,,	,,	40
98·1	1	,,	,,	42
95·3	2	,,	,,	55
93·7	1	,,	,,	63
92·3	1	,,	,,	70
88·3	1	,,	,,	89
87·5	1n	,,	,,	92
87·0	1	,,	,,	95
86·8	1	,,	,,	96

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}$ −	
4586·3	1	1·26	6·0	21798
84·5	1n	,,	,,	807
82·7	1	,,	,,	15
81·1	1	,,	,,	23
80·1	1	1·25	,,	28
79·0	1	,,	,,	33
78·2	1	,,	,,	37
76·8	2	,,	,,	43
76·2	1n	,,	,,	46
75·6	1	,,	,,	49
74·8	1	,,	,,	53
70·2	1	,,	,,	75
69·2	1	,,	,,	80
67·9	1	,,	,,	86
66·1	1	,,	,,	94
64·9	1	,,	6·1	900
60·4	1	,,	,,	22
60·1	1	,,	,,	23
58·9	1	,,	,,	29
58·3	1	,,	,,	32
53·5	6	,,	,,	55
49·5	1b	,,	,,	74
48·1	1n	,,	,,	81
46·4	1b	,,	,,	89
43·8	1	,,	,,	92
41·8	1	1·24	,,	22012
41·0	1n	,,	,,	15
38·8	1	,,	,,	26
37·1	4	,,	,,	34
36·1	2	,,	,,	39
35·6	1	,,	,,	42
35·1	1	,,	,,	44
34·8	4	,,	,,	46
31·3	1	,,	,,	62
29·6	1	,,	,,	71
28·8	1	,,	,,	75
26·7	1	,,	,,	85
25·8	1	,,	,,	89
24·5	2	,,	,,	96
23·9	1	,,	,,	99
22·5	1	,,	,,	106
21·2	1n	,,	,,	12
19·8	1	,,	,,	19
18·6	1n	,,	,,	25
17·2	2	,,	,,	31
16·6	1	,,	,,	34
15·5	1	,,	,,	40
14·6	1	,,	,,	44
12·5	2	,,	,,	55
11·4	1	,,	,,	60
08·8	1n	,,	,,	73
06·9	1	,,	,,	82
06·1	2	,,	,,	86
05·5	1	1·23	,,	89
03·8	1	,,	,,	97

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}-$	
4501·5	1	1·23	6·1	22209
00·7	1	,,	,,	13
4499·8	1	,,	,,	17
98·5	1	,,	,,	23
94·7	1n	,,	6·2	42
94·2	1n	,,	,,	45
93·8	2n	,,	,,	47
91·9	1	,,	,,	56
91·6	4	,,	,,	58
90·6	1	,,	,,	62
89·6	1	,,	,,	67
89·2	1	,,	,,	69
87·3	1	,,	,,	79
85·3	2	,,	,,	89
84·4	1	,,	,,	93
81·7	1	,,	,,	307
79·1	1	,,	,,	20
75·9	1	,,	,,	36
74·9	6	,,	,,	41
73·5	2	,,	,,	48
72·3	2n	,,	,,	54
72·0	1	,,	,,	55
68·5	2	1·22	,,	73
67·8	1	,,	,,	76
65·6	1	,,	,,	87
65·2	1	,,	,,	89
64·2	1	,,	,,	94
62·1	1	,,	,,	405
60·8	1	,,	,,	11
58·8	1	,,	,,	21
57·7	4	,,	,,	27
56·3	1	,,	,,	34
55·5	1	,,	,,	38
54·3	1	,,	,,	44
52·9	2n	,,	,,	51
52·3	4	,,	,,	54
50·1	2	,,	,,	65
49·3	1	,,	,,	69
46·7	1	,,	,,	82
45·7	1n	,,	,,	87
44·4	1	,,	,,	94
43·3	1 Fe	,,	,,	500
42·4	2 Fe	,,	,,	04
41·8	1	,,	,,	07
41·1	1	,,	,,	11
40·3	1	,,	,,	15
39·2	1	,,	,,	20
37·2	2	,,	,,	30
35·2	4	,,	,,	41
34·5	1	,,	,,	44
33·7	4	,,	,,	48
30·8	1 Fe	1·21	6·3	63
28·5	1	,,	,,	75
26·9	2	,,	,,	83
23·9	2	,,	,,	98

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
4423·2	1n	1·21	6·3	22602
22·4	1n	"	"	06
21·0	1n	"	"	13
15·3	2	"	"	42
13·1	2	"	"	53
12·5	2	"	"	57
11·9	6	"	"	60
10·2	1	"	"	68
09·7	1	"	"	71
07·8	2	"	"	81
07·1	1	"	"	84
06·2	1n	"	"	89
04·8	2n Fe	"	"	96
04·1	1n	"	"	99
03·5	1	"	"	703
03·3	4n	"	"	04
02·8	1	"	"	06
01·4	1	"	"	14
4399·4	1	"	"	24
98·8	1	"	"	27
97·5	2	"	"	34
96·8	2	"	"	37
94·6	2	"	"	49
93·8	1	1·20	"	53
92·2	1	"	"	61
91·8	2	"	"	63
91·1	1	"	"	67
90·0	1	"	"	73
89·7	1	"	"	74
88·5	1	"	"	80
87·8	1	"	"	84
86·1	1	"	"	93
85·8	1	"	"	95
84·9	1	"	"	99
84·4	1	"	"	802
83·8	1 Fe	"	"	05
83·4	1	"	"	07
82·6	1	"	"	11
81·7	4	"	"	16
80·7	1	"	"	21
80·4	2	"	"	23
79·7	1	"	"	26
79·5	1	"	"	27
77·9	6	"	"	36
76·9	2	"	"	41
75·1	2	"	"	50
74·2	1	"	"	55
73·4	1	"	"	59
72·2	1	"	"	65
70·8	1	"	"	73
69·2	2	"	"	81
66·7	1n	"	6·4	94
64·6	1n	"	"	905
63·7	8	"	"	10
62·1	1	"	"	18

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}-$	
4359·8	1	1·20	6·4	22930
58·3	6	,,	,,	38
56·1	1	1·19	,,	50
55·4	1	,,	,,	54
53·4	1	,,	,,	64
51·6	1n	,,	,,	74
50·4	2	,,	,,	80
44·9	1	,,	,,	23009
41·6	2	,,	,,	27
40·9	1	,,	,,	30
40·0	1	,,	,,	35
39·4	1	,,	,,	38
38·8	1	,,	,,	41
36·8	1 W?	,,	,,	52
35·3	2 W?	,,	,,	60
34·9	1	,,	,,	62
33·4	1	,,	,,	70
32·7	1	,,	,,	74
29·9	1	,,	,,	89
29·6	1	,,	,,	90
28·3	1	,,	,,	97
27·1	2	,,	,,	104
26·3	4	,,	,,	08
26·1	1	,,	,,	09
25·6	1	,,	,,	12
24·7	1n	,,	,,	17
23·6	1	,,	,,	22
18·7	1	1·18	,,	49
18·1	2	,,	,,	52
17·4	1	,,	,,	56
15·4	1	,,	,,	66
13·7	1n	,,	,,	76
13·0	1	,,	,,	79
12·6	1	,,	,,	81
11·8	4	,,	,,	86
11·2	4	,,	,,	89
10·6	1	,,	,,	92
08·9	1	,,	6·5	201
08·3	1	,,	,,	04
05·1	1	,,	,,	22
04·2	1	,,	,,	27
02·8	1	,,	,,	34
02·2	1 W	,,	,,	37
01·5	1	,,	,,	41
00·9	1n	,,	,,	44
4299·4	1	,,	,,	53
99·2	1	,,	,,	54
98·2	1n	,,	,,	59
97·7	1n	,,	,,	62
96·8	1	,,	,,	67
96·4	1	,,	,,	69
94·9	2	,,	,,	77
94·2	2 W	,,	,,	81
93·4	4	,,	,,	85
92·4	2	,,	,,	92

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
4291·9	1	1·18	6·5	23293
91·4	1	,,	,,	96
90·4	1	,,	,,	301
89·9	1	,,	,,	04
89·7	1	,,	,,	05
88·9	4	,,	,,	10
87·2	1	,,	,,	19
85·9	1	,,	,,	26
84·9	1	,,	,,	31
82·0	1	,,	,,	47
80·7	1	1·17	,,	54
80·2	1	,,	,,	57
79·2	6	,,	,,	62
77·5	6	,,	,,	72
77·2	6	,,	,,	73
76·4	1	,,	,,	78
75·8	1	,,	,,	81
74·6	2	,,	,,	87
73·4	1	,,	,,	94
72·4	1	,,	,,	99
72·0	1	,,	,,	402
71·2	1	,,	,,	06
69·4	2 W	,,	,,	16
68·2	1	,,	,,	23
66·8	1	,,	,,	30
66·4	1	,,	,,	32
65·2	1	,,	,,	39
64·8	1	,,	,,	41
63·6	1n	,,	,,	48
62·6	1n	,,	,,	53
61·6	1	,,	,,	59
61·1	1	,,	,,	62
60·8	1	,,	,,	63
60·5	1 Fe	,,	,,	65
59·5	1n	,,	,,	70
58·9	1n	,,	,,	74
58·0	1n	,,	,,	79
56·9	1	,,	,,	85
55·2	2	,,	,,	94
54·6	1	,,	,,	97
53·6	1n	,,	6·6	503
52·6	1n	,,	,,	08
52·1	2	,,	,,	11
50·6	6 Fe	,,	,,	19
46·7	1	,,	,,	41
46·2	1	,,	,,	44
44·9	4	,,	,,	51
43·2	2	1·16	,,	60
40·9	1	,,	,,	73
40·4	1	,,	,,	76
40·3	1	,,	,,	77
39·2	1n	,,	,,	83
38·5	1n	,,	,,	87
37·4	1n	,,	,,	93
35·1	1	,,	,,	606

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
4233·6	1	1·16	6·6	23614
32·7	4	,,	,,	19
26 9	2 Ca	,,	,,	51
25·1	1	,,	,,	61
24·1	1n	,,	,,	67
23·1	1	,,	,,	73
22·6	1	,,	,,	75
21·1	1	,,	,,	84
19·6	1	,,	,,	92
19·1	1	,,	,,	95
16·9	1	,,	,,	707
14·6	1	,,	,,	20
14·2	1	,,	,,	23
12 9	1	,,	,,	30
11·1	1	,,	,,	40
09·8	6	,,	,,	47
07·4	1	,,	,,	61
05·9	1	1 15	,,	69
04·9	1	,,	,,	75
02 3	1n	,,	,,	90
01·5	1n	,,	,,	94
00 7	1	,,	,,	99
4199·1	1	,,	6 7	808
94·5	2	,,	,,	34
92 3	2	,,	,,	47
91·1	1	,,	,,	53
90·1	1	,,	,,	59
88·3	4	,,	,,	69
86·4	1	,,	,,	80
85·9	4	,,	,,	83
84·4	1	,,	,,	92
78·5	1	,,	,,	925
78·2	1	,,	,,	27
77·3	1	,,	,,	32
75·5	1n	,,	,,	42
74 3	1n	,,	,,	49
72·6	1	,,	,,	59
72·0	2	,,	,,	63
71 4	2n	,,	,,	66
70·0	1	,,	,,	74
69 2	1	,,	,,	79
68·7	1	1·14	,,	82
66·5	1	,,	,,	95
65·6	1	,,	,,	99
64·4	1	,,	,,	24006
63·0	2	,,	,,	14
61·5	2	,,	,,	23
58·2	1n	,,	,,	42
57·6	2	,,	,,	46
57·0	1	,,	,,	49
55·8	1	,,	,,	56
55·5	2	,,	,,	58
54·5	1	,,	,,	64
53·1	1	,,	,,	72
52·2	1	,,	,,	77

Molybdenum—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
4151·0	1n	1·14	6·7	24084
49·2	2	,,	,,	94
47·1	2	,,	6·8	106
46·3	2	,,	,,	11
43·9	6	,,	,,	25
41·6	2	,,	,,	38
40·0	2	,,	,,	48
38·8	1n	,,	,,	55
38·0	1	,,	,,	59
37·0	1	,,	,,	65
35·7	1	,,	,,	73
33·1	1n	,,	,,	88
32·4	1	,,	,,	92
32·2	1	,,	,,	93
31·1	1n	,,	,,	200
30·4	1n	1·13	,,	04
29·0	1	,,	,,	12
28·4	1	,,	,,	16
28·2	1	,,	,,	17
27·5	1n	,,	,,	21
26·7	1	,,	,,	26
26·5	1	,,	,,	27
25·7	1	,,	,,	31
24·8	1	,,	,,	37
23·7	1	,,	,,	43
22·4	4	,,	,,	51
20·3	4	,,	,,	63
19·9	4	,,	,,	66
19·1	2	,,	,,	70
18·7	1	,,	,,	73
16·9	1	,,	,,	83
16·1	1	,,	,,	88
15·2	1	,,	,,	94
14·6	1n	,,	,,	97
14·2	1n	,,	,,	99
11·9	1	,,	,,	313
10·9	1	,,	,,	19
10·4	1n	,,	,,	22
08·9	1	,,	,,	31
07·5	4	,,	,,	39
05·7	1	,,	,,	50
03·5	1	,,	,,	63
03·1	1	,,	,,	65
02·8	1 W	,,	,,	67
02·1	2	,,	,,	71
00·4	1	,,	,,	81
4098·9	1	,,	6·9	90
98·4	2n	,,	,,	93
97·0	1	,,	,,	401
95·7	1	,,	,,	09
94·9	1	,,	,,	14
94·5	1	,,	,,	16
92·9	1	1·12	,,	26
91·1	1b	,,	,,	36
88·9	1n	,,	,,	50

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}$−	
4087·3	1	1·12	6·9	24459
86·2	1	,,	,,	66
84·5	4	,,	,,	76
81·7	4	,,	,,	93
81·3	1	,,	,,	95
77·9	1	,,	,,	515
76·3	1	,,	,,	25
75·7	1	,,	,,	29
75·5	1	,,	,,	30
74·5	2 W	,,	,,	36
71·9	2	,,	,,	52
67·9	1	,,	,,	76
67·2	1n	,,	,,	80
66·4	1	,,	,,	85
64·8	1	,,	,,	95
64·6	1	,,	,,	96
63·8	1	,,	,,	601
62·3	4	,,	,,	10
59·8	1	,,	,,	25
58·7	1	,,	,,	31
57·6	2	,,	,,	38
56·4	1	,,	,,	45
56·0	2	,,	,,	48
51·4	1	1·11	7·0	76
50·2	1	,,	,,	83
49·8	1	,,	,,	86
47·6	1n	,,	,,	99
46·9	1	,,	,,	703
46·8	1	,,	,,	04
45·8	1 Fe	,,	,,	10
45·6	1	,,	,,	11
43·7	1	,,	,,	23
42·9	1	,,	,,	28
41·2	1b	,,	,,	38
38·9	1	,,	,,	52
38·2	1	,,	,,	56
37·9	1	,,	,,	58
36·6	1	,,	,,	66
35·7	2n	,,	,,	72
33·6	1	,,	,,	85
32·5	1n	,,	,,	92
31·4	1n	,,	,,	98
30·9	1n	,,	,,	801
28·7	1n	,,	,,	15
27·7	1n	,,	,,	21
27·0	1n	,,	,,	25
26·0	1n	,,	,,	32
25·6	1	,,	,,	34
24·2	1	,,	,,	43
23·6	1	,,	,,	46
20·9	1	,,	,,	63
20·5	1	,,	,,	66
17·8	1	,,	,,	82
17·3	1	,,	,,	85
16·1	1n	,,	,,	93

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
4015·2	1	1·10	7·0	24898
14·4	1	"	"	903
13·2	2	"	"	11
11·9	1n	"	"	19
10·3	1	"	"	29
09·4	1	"	"	34
08·7	2 (W)	"	"	39
08·0	1	"	"	43
06·8	1	"	"	51
06·5	1	"	"	52
06·0	1	"	"	56
05·0	1 (Fe)	"	"	62
02·9	1	"	7·1	75
00·5	1	"	"	90
00·0	1	"	"	93
3998·6	1	"	"	25002
98·4	1	"	"	03
94·0	1	"	"	31
93·1	1	"	"	36
91·8	1	"	"	44
91·4	1	"	"	47
90·9	2	"	"	50
89·9	1	"	"	56
89·5	1n	"	"	59
86·1	4	"	"	80
82·6	1n	"	"	102
82·1	1n	"	"	05
81·6	1	"	"	08
80·8	1	"	"	14
80·4	1	"	"	16
79·4	1	"	"	22
77·9	1	"	"	32
76·4	1	"	"	41
74·8	1	1·09	"	51
73·8	4	"	"	58
73·4	4	"	"	60
73·0	1n	"	"	63
71·5	1n	"	"	72
71·1	1n	"	"	75
68·6	8 Ca	"	"	94
67·9	1	"	"	95
66·3	1	"	"	205
65·8	1	"	"	09
64·1	1	"	"	19
63·6	1	"	"	22
62·9	2	"	"	27
61·4	10	"	"	36
60·1	1n	"	"	45
58·5	1	"	"	55
55·6	1	"	7·2	73
54·0	1	"	"	84
52·9	2	"	"	91
51·0	1	"	"	303
48·7	1	"	"	18
47·4	1	"	"	26

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3947·1	1	1·09	7·2	25328
47·0	1	,,	,,	29
45·3	1	,,	,,	39
45·1	1	,,	,,	41
44·1	2	,,	,,	47
43·6	1	,,	,,	50
43·1	2	,,	,,	54
42·9	4	,,	,,	55
41·5	6	,,	,,	64
38·7	1	,,	,,	82
37·6	1n	,,	,,	89
36·8	1	1·08	,,	94
35·1	1	,,	,,	405
35·0	2	,,	,,	06
33·7	8 (W)	,,	,,	14
31·4	1	,,	,,	29
30·9	1	,,	,,	32
30·4	1	,,	,,	36
29·7	1	,,	,,	40
28·8	1	,,	,,	46
27·7	1	,,	,,	53
27·1	1	,,	,,	57
26·4	1n	,,	,,	61
{ 25·9	2	,,	,,	65
{ 25·8	1	,,	,,	65
23·7	1	,,	,,	79
22·3	1	,,	,,	88
21·6	1	,,	,,	93
21·0	1	,,	,,	96
20·3	1n	,,	,,	501
17·9	1	,,	,,	17
17·6	1	,,	,,	19
17·1	1	,,	,,	22
16·5	1	,,	,,	26
15·4	4	,,	,,	33
13·7	1	,,	,,	44
11·1	1	,,	,,	61
10·1	1	,,	,,	68
09·5	1	,,	,,	72
08·6	2	,,	7·3	77
06·8	1	,,	,,	89
06·4	1	,,	,,	92
05·5	1	,,	,,	98
04·9	2n	,,	,,	601
03·0	1	,,	,,	14
01·9	2	,,	,,	21
3897·9	1	,,	,,	47
96·9	1	1·07	,,	54
96·5	1	,,	,,	57
94·1	1	,,	,,	73
94·0	1	,,	,,	73
93·5	1	,,	,,	77
92·4 }	1	,,	,,	84
92·0 }	1	,,	,,	86
91·4	1	,,	,,	90

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3891·2	1	1·07	7·3	25692
90·7	1	"	"	95
90·6	1	"	"	96
89·0	1	"	"	706
88·4	1n	"	"	10
88·1	1	"	"	12
87·8	1	"	"	14
87·1	1	"	"	19
85·7	1n	"	"	28
83·5	1	"	"	43
83·4	1	"	"	43
83·0	1	"	"	46
82·4	2	"	"	50
81·5	1	"	"	56
80·1	1	"	"	65
79·8	1	"	"	67
79·1	1	"	"	72
78·7	1	"	"	74
76·9	1	"	"	86
75·4	1	"	"	96
73·4	1	"	"	810
72·1	1	"	"	18
71·6	2	"	"	22
69·2	2	"	"	38
68·0	1	"	"	46
67·8	1	"	"	47
66·9	1	"	"	53
65·7	1	"	"	61
64·2	10	"	"	71
62·7	1	"	"	81
61·5	2	"	"	89
60·0	1	"	"	99
58·9	1	"	"	907
58·4	1	"	"	10
56·7	1n	1·06	"	22
56·1	1n	"	"	26
55·0	1	"	"	33
54·8	1	"	"	34
53·6	1	"	"	42
53·4	1	"	"	44
52·8	1	"	"	48
52·2	1	"	"	52
51·6	1	"	"	56
50·9	1	"	"	61
49·9	1	"	"	67
48·5	2	"	"	77
47·4	2	"	"	84
46·3	1	"	"	92
46·1	1	"	"	93
44·2	1	"	"	26006
43·2	1	"	"	13
42·8	1	"	"	15
42·1	1n	"	"	20
40·6	1	"	"	30
40·0	1n	"	"	34

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3839·7	1	1·06	7·3	26036
39·1	1	,,	,,	40
38·8	1	,,	,,	42
37·4	1	,,	,,	52
35·4	4	,,	,,	66
35·1	1	,,	,,	68
34·7	1	,,	,,	70
34·3	1	,,	,,	73
33·9	1	,,	,,	76
33·7	2	,,	,,	77
32·5	6	,,	,,	85
32·3	2	,,	,,	87
32·1	2	,,	,,	88
31·1	1	,,	,,	95
31·0	1	,,	,,	96
30·1	1	,,	,,	102
30·0	1	,,	,,	02
28·9	1	,,	,,	10
28·5	2	,,	,,	13
28·4	1	,,	,,	13
28·0	1	,,	,,	16
27·3	1	,,	,,	21
26·8	1	,,	,,	24
26·0	2	,,	,,	30
25·5	1	,,	,,	33
25·0	1	,,	,,	37
24·6	1	,,	,,	39
23·7	1	,,	,,	45
23·1	1	,,	,,	49
23·0	1	,,	,,	50
22·5	1	,,	,,	54
22·0	1	,,	,,	57
21·8	1	,,	,,	58
19·3	1	,,	,,	75
19·2	1	,,	,,	76
18·7	1	,,	,,	80
18·4	1	,,	,,	82
18·1	1	,,	7·4	84
17·5	1	,,	,,	88
17·2	1	,,	,,	90
16·7	1	1·05	,,	93
15·9	1	,,	,,	99
15·3	1	,,	,,	203
15·2	1	,,	,,	04
14·6	1	,,	,,	08
14·0	1	,,	,,	12
12·5	1	,,	,,	22
12·3	2	,,	,,	23
12·0	1	,,	,,	26
11·5	1	,,	,,	29
11·0	1	,,	,,	32
10·2	1	,,	,,	38
09·9	1	,,	,,	40
09·3	1	,,	,,	44
08·8	1	,,	,,	48

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3807·8	1n	1·05	7·4	26255
07·1	1	,,	,,	59
06·9	1	,,	,,	61
06·1	1	,,	,,	66
05·5	1n	,,	,,	70
04·6	1	,,	,,	77
03·5	1	,,	,,	84
02·5	1	,,	,,	91
02·2	1	,,	,,	93
01·8	2	,,	,,	96
01·1	1	,,	,,	301
00·4	1n	,,	,,	06
3798·3	10	,,	,,	20
97·4	1	,,	,,	26
97·2	1	,,	,,	28
96·7	2	,,	,,	29
96·2	1	,,	,,	35
95·7	1	,,	,,	38
95·4	1	,,	,,	40
95·1	1	,,	,,	42
94·5	1	,,	,,	47
93·8	1	,,	,,	51
92·3	1	,,	,,	62
92·1	1	,,	,,	63
91·8	1	,,	,,	65
91·5	1	,,	,,	67
90·5	1n	,,	,,	74
88·4	2	,,	,,	89
88·0	1	,,	,,	92
87·4	1	,,	,,	96
86·6	4	,,	,,	402
85·7	1	,,	,,	08
85·3	1	,,	,,	11
83·3	4	,,	,,	25
82·2	4	,,	,,	32
81·8	2	,,	,,	35
81·4	1	,,	,,	38
81·1	1	,,	,,	40
81·0	1	,,	,,	41
79·8	2	,,	,,	49
78·1	1	,,	,,	61
77·8	1	,,	,,	63
77·0	1	1·04	,,	69
76·8	1	,,	,,	70
76·3	1	,,	,,	74
75·8	1	,,	,,	77
74·8	1	,,	,,	84
73·9	1	,,	,,	90
73·1	1	,,	7·5	96
72·2	2	,,	,,	502
71·7	1	,,	,,	06
70·7	2	,,	,,	13
70·2	1	,,	,,	16
69·3	1	,,	,,	23
68·8	1	,,	,,	26

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}-$	
3768·0	2	1·04	7·5	26532
67·4	1	,,	,,	36
66·5	1	,,	,,	42
65·9	1	,,	,,	47
65·5	1	,,	,,	49
65·3	1	,,	,,	51
64·7	1	,,	,,	55
64·2	1	,,	,,	59
64·1	1	,,	,,	59
63·1	1	,,	,,	66
62·4	2	,,	,,	71
62·1	2	,,	,,	73
61·4	1	,,	,,	78
61·0	1	,,	,,	81
60·9	1	,,	,,	82
60·3	1	,,	,,	86
59·5*	1	,,	,,	92
58·7	2	,,	,,	97
58·3	2	,,	,,	600
57·0	1	,,	,,	09
56·5	1	,,	,,	13
55·6	4	,,	,,	19
55·4	1	,,	,,	23
54·9	2	,,	,,	24
54·0	1	,,	,,	31
53·9	1	,,	,,	32
53·5	2	,,	,,	34
52·3	1	,,	,,	43
51·7	1	,,	,,	47
51·1	2	,,	,,	51
50·4	1	,,	,,	56
48·6	2	,,	,,	69
48·2	2	,,	,,	72
47·6	1	,,	,,	76
47·3	1	,,	,,	78
47·2	1	,,	,,	79
46·5	2	,,	,,	84
46·0	1	,,	,,	88
45·6	1	,,	,,	90
45·5	1	,,	,,	91
45·0	1	,,	,,	95
44·5	4	,,	,,	98
43·9	1	,,	,,	703
43·5	1	,,	,,	06
43·1	1	,,	,,	08
42·4	6	,,	,,	13
41·9	1	,,	,,	17
39·0	1	,,	,,	38
37·9	1	1·03	,,	45
37·2	2	,,	,,	50
36·5	2	,,	,,	56
36·3	2	,,	,,	57
36·1	1	,,	,,	58

*Double.

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3735·8	1	1·03	7·5	26761
34·8	1	,,	,,	68
34·4	1	,,	,,	71
34·0	1	,,	,,	73
33·5	1	,,	,,	77
33·1	1	,,	,,	80
32·8	2	,,	,,	82
30·6	1	,,	,,	98
30·1	1	,,	,,	801
29·1	1	,,	,,	09
28·5	1	,,	,,	13
28·4	1	,,	7·6	14
27·8	2	,,	,,	18
26·6	1	,,	,,	27
25·7	2	,,	,,	33
25·1	1	,,	,,	37
24·5	1	,,	,,	42
23·9	1	,,	,,	46
23·6	1	,,	,,	48
23·1	1	,,	,,	52
22·6	1	,,	,,	55
22·4	1	,,	,,	57
22·1	1	,,	,,	59
20·4	2	,,	,,	71
19·9	2	,,	,,	75
19·7	1	,,	,,	76
19·1	2	,,	,,	81
18·5	1	,,	,,	85
17·0	4	,,	,,	96
16·1	2	,,	,,	902
15·7	2	,,	,,	05
15·3	1	,,	,,	08
14·6	1	,,	,,	13
14·0	2	,,	,,	18
13·5	1	,,	,,	21
13·1	1n	,,	,,	24
12·0	1	,,	,,	32
11·8	1	,,	,,	33
11·6	1	,,	,,	35
10·6	1	,,	,,	42
10·3	1	,,	,,	44
09·6	1	,,	,,	49
08·6	1	,,	,,	57
08·0	1	,,	,,	61
07·7	2	,,	,,	63
07·2	6	,,	,,	67
06·1	1n	,,	,,	75
05·6	1	,,	,,	79
05·5	1	,,	,,	79
04·2	2	,,	,,	89
02·5	8	,,	,,	27001
02·1	1	,,	,,	04
01·4	1	,,	,,	09
01·1	1	,,	,,	11
00·0	2n	,,	,,	19

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3698·7	1	1·03	7·6	27029
97·8	1	1·02	,,	35
97·5	1	,,	,,	38
97·1	1	,,	,,	41
96·0	1	,,	,,	49
95·1	2	,,	,,	55
94·6	1	,,	,,	59
93·8	2	,,	,,	65
92·7	6	,,	,,	73
92·2	1	,,	,,	76
91·7	1	,,	,,	80
90·7	1	,,	,,	87
90·5	2	,,	,,	89
90·0	1	,,	,,	93
89·0	1	,,	,,	100
88·3	10	,,	,,	05
87·6	2	,,	,,	10
87·1	1	,,	,,	14
86·7	1	,,	,,	17
86·1	1	,,	,,	21
85·8	1	,,	,,	24
85·2	1	,,	,,	28
84·3	4	,,	,,	35
83·1	1	,,	7·7	43
82·7	1	,,	,,	46
81·6	1	,,	,,	54
80·6	4	,,	,,	62
80·4	1	,,	,,	63
80·1	1	,,	,,	65
79·4	1	,,	,,	71
79·2	1	,,	,,	72
78·8	1	,,	,,	75
78·1	1	,,	,,	80
77·9	1	,,	,,	82
76·4	1	,,	,,	93
75·5	1	,,	,,	99
73·9	1n	,,	,,	211
72·1	1n	,,	,,	25
71·9	2	,,	,,	26
70·9	1	,,	,,	34
70·7	1	,,	,,	35
70·6	4	,,	,,	36
70·0	1	,,	,,	40
†69·5	2	,,	,,	44
68·5	1	,,	,,	51
68·4	1	,,	,,	52
68·1	1	,,	,,	54
67·8	1	,,	,,	57
67·5	1	,,	,,	59
67·0	1	,,	,,	63
66·7	1	,,	,,	65
65·8	1n	,,	,,	71
65·0	2	,,	,,	77

† Coincident with an iron line of the comparison spectrum.

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3664·5	1	1·02	7·7	27281
64·1	1	,,	,,	84
63·8	1	,,	,,	86
63·4	1	,,	,,	89
63·0	1	,,	,,	92
62·3	1	,,	,,	98
61·8	1	,,	,,	301
61·1	1	,,	,,	06
59·6	2	,,	,,	18
59·0	4	,,	,,	22
58·4	4	,,	,,	27
57·5	5 (W)	1·01	,,	33
56·2	1	,,	,,	43
55·9	1	,,	,,	45
55·1	1	,,	,,	51
54·6	1	,,	,,	55
54·4	1	,,	,,	57
53·9	1	,,	,,	60
53·7	1	,,	,,	62
52·5	6	,,	,,	71
51·3	6	,,	,,	80
50·2	2	,,	,,	88
49·6	1	,,	,,	93
48·6	1	,,	,,	400
48·0	1	,,	,,	05
†47·6	1	,,	,,	08
47·1	1	,,	,,	11
47·0	1	,,	,,	12
46·3	1n (W)	,,	,,	17
45·9	1	,,	,,	20
43·7	2	,,	,,	37
43·1	1	,,	,,	41
42·9	1	,,	,,	43
41·6	1	,,	,,	53
41·2	1	,,	,,	56
40·8	1	,,	,,	59
40·5	1	,,	,,	61
39·9	2	,,	,,	66
38·5	1	,,	7·8	76
38·3	1	,,	,,	78
37·9	1	,,	,,	81
37·7	1	,,	,,	82
36·8	1	,,	,,	89
35·4	2	,,	,,	99
35·2	1	,,	,,	501
34·5	1	,,	,,	06
33·5	2	,,	,,	14
31·6	1	,,	,,	28
†31·3	1	,,	,,	31
29·5	1	,,	,,	44
28·8	1	,,	,,	50
28·6	1	,,	,,	51
27·5	2	,,	,,	59

† Coincident with an iron line of the comparison spectrum.

Molybdenum—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3626·4	2	1·01	7·8	27568
25·8	2	,,	,,	72
24·7	2	,,	,,	81
23·9	2	,,	,,	87
23·4	2	,,	,,	91
23·1	2	,,	,,	93
22·6	1n	,,	,,	97
20·4	1n	,,	,,	613
19·6	1n	,,	,,	20
19·0	1	,,	,,	24
18·6	1	,,	,,	27
17·7	2	1·00	,,	34
17·0	1	,,	,,	39
16·9	1	,,	,,	40
16·2	1	,,	,,	46
15·9	1	,,	,,	48
15·3	1	,,	,,	52
14·9	2	,,	,,	55
14·4	4	,,	,,	59
13·8	1	,,	,,	64
13·6	1 (W)	,,	,,	65
12·4	1	,,	,,	75
12·1	4	,,	,,	77
11·2	1	,,	,,	84
10·7	1	,,	,,	88
09·7	1	,,	,,	95
09·4	1	,,	,,	98
09·1	1	,,	,,	700
08·8	1	,,	,,	02
08·5	1	,,	,,	05
07·0	2	,,	,,	16
06·9	2	,,	,,	17
05·5	1	,,	,,	28
05·2	1	,,	,,	30
04·8	1	,,	,,	33
04·1	1	,,	,,	38
03·8	1	,,	,,	41
03·7	1	,,	,,	41
03·3	1	,,	,,	45
03·1	2	,,	,,	46
02·5	1n	,,	,,	51
02·0	1	,,	,,	55
01·8	1	,,	,,	56
01·5	1	,,	,,	58
01·0	1n	,,	,,	62
00·4	1	,,	,,	67
00·0	1	,,	,,	70
3599·0	2	,,	,,	78
97·7	1	,,	,,	88
96·4	4	,,	,,	98
95·6	1	,,	,,	804
95·4	1	,,	,,	06
94·0	1	,,	7·9	16
93·2	1	,,	,,	22
92·6	1	,,	,,	27

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3592·3	1 (W)	1·00	7·9	27829
92·0	1	,,	,,	32
91·7	2	,,	,,	34
91·6	1	,,	,,	35
90·8	2	,,	,,	41
90·1	2	,,	,,	46
89·4	2	,,	,,	52
89·0	1	,,	,,	55
88·1	1	,,	,,	62
86·8	1	,,	,,	72
85·9	2	,,	,,	79
85·6	4	,,	,,	81
84·2	1	,,	,,	92
83·1	1	,,	,,	901
82·7	1	,,	,,	04
82·5	1	,,	,,	06
81·9	1	,,	,,	10
81·3	1	,,	,,	15
80·7	1	,,	,,	20
80·3	1	,,	,,	23
79·0	1	,,	,,	33
77·5	1	0·99	,,	45
77·0	1	,,	,,	48
76·2	1	,,	,,	55
75·7	1	,,	,,	59
74·5	1	,,	,,	68
74·1	1	,,	,,	71
73·8	1	,,	,,	74
72·5	1 (W)	,,	,,	84
71·3	1	,,	,,	93
70·7	2	,,	,,	98
70·1	1	,,	,,	28003
69·6	1	,,	,,	06
68·7	1	,,	,,	14
68·1	1n	,,	,,	18
67·1	1	,,	,,	26
66·8	1	,,	,,	28
66·3	1	,,	,,	32
66·0	1	,,	,,	35
65·4	1	,,	,,	39
64·5	1	,,	,,	47
64·3	1	,,	,,	48
63·9	1	,,	,,	51
63·2	2	,,	,,	57
62·1	1	,,	,,	65
61·9	1	,,	,,	67
61·3	2	,,	,,	72
60·0	1	,,	,,	82
59·7	1	,,	,,	84
59·2	1	,,	,,	88
58·8	1	,,	,,	91
58·6	1	,,	,,	93
58·1	2	,,	,,	97
57·0	2	,,	,,	106
56·3	2	,,	,,	11

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3555·5	1	0·99	7·9	28118
54·2	1	,,	,,	28
53·8	1	,,	,,	31
53·2	1	,,	,,	36
52·7	1	,,	,,	40
52·5	1	,,	,,	41
52·1	1	,,	,,	44
51·5	1n	,,	8·0	49
51·0	1	,,	,,	53
49·1	1	,,	,,	68
48·8	1	,,	,,	71
48·0	2	,,	,,	77
47·5	1	,,	,,	81
47·1	1	,,	,,	84
45·9	4	,,	,,	94
43·8	1n	,,	,,	210
43·3	1	,,	,,	14
42·4	2	,,	,,	21
42·1	4	,,	,,	24
41·1	1n	,,	,,	32
40·8	1n	,,	,,	37
40·4	1n	,,	,,	40
39·6	1n	,,	,,	44
38·9	1n	,,	,,	49
37·1	4	0·98	,,	64
36·5	1	,,	,,	69
35·2	1	,,	,,	79
34·7	2	,,	,,	83
33·1	2	,,	,,	96
32·5	1n	,,	,,	301
31·5	1	,,	,,	09
31·3	1	,,	,,	10
30·9	1	,,	,,	13
29·8	1	,,	,,	22
29·5	2	,,	,,	25
28·8	1	,,	,,	30
28·0	2	,,	,,	37
26·6	1	,,	,,	48
26·4	1	,,	,,	50
26·0	1	,,	,,	53
24·9	1	,,	,,	62
24·6	6	,,	,,	64
24·0	1	,,	,,	69
22·5	1	,,	,,	81
22·2	2	,,	,,	83
21·6	2	,,	,,	88
20·2	2	,,	,,	99
19·8	1	,,	,,	403
18·6	1	,,	,,	12
18·3	1	,,	,,	15
17·5	1	,,	,,	21
16·7	1	,,	,,	28
15·8	2	,,	,,	35
15·1	2	,,	,,	41
14·9	1	,,	,,	42

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3513·8	1	0·98	8·0	28451
13·1	1	,,	,,	57
11·8	1n	,,	,,	67
10·8	1	,,	,,	76
10·2	1	,,	8·1	80
10·0	1	,,	,,	82
09·3	1	,,	,,	88
08·5	1	,,	,,	94
08·1	2	,,	,,	97
07·3	1	,,	,,	504
06·6	1	,,	,,	10
05·4	2	,,	,,	19
04·5	2	,,	,,	27
02·7	1	,,	,,	39
01·9	4	,,	,,	48
01·0	1	,,	,,	55
00·0	2	,,	,,	63
3499·0	2	0·97	,,	71
98·4	1	,,	,,	76
98·1	1	,,	,,	79
97·1	1	,,	,,	87
96·8	1	,,	,,	89
95·1	1n	,,	,,	603
94·3	1	,,	,,	10
93·4	1	,,	,,	17
92·0	1	,,	,,	29
91·3	1n	,,	,,	35
90·6	1	,,	,,	40
90·4	1	,,	,,	42
89·5	1	,,	,,	49
88·7	1	,,	,,	56
88·2	2	,,	,,	60
87·9	2	,,	,,	62
85·9	1	,,	,,	79
85·8	2	,,	,,	80
84·4	2	,,	,,	91
83·9	1	,,	,,	95
83·8	1	,,	,,	96
82·8	1	,,	,,	704
82·5	1n	,,	,,	07
81·8	1	,,	,,	13
81·1	1n	,,	,,	18
80·2	1	,,	,,	26
79·5	1n	,,	,,	32
77·6	1n	,,	,,	47
75·6	1	,,	,,	64
75·1	2	,,	,,	68
74·8	1n	,,	,,	71
74·1	1n	,,	,,	76
73·3	1n	,,	,,	83
71·7	1	,,	,,	96
71·0	2	,,	8·2	802
70·8	1n	,,	,,	04
69·7	1	,,	,,	13
69·3	2	,,	,,	16

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}-$	
3468·5	1	0·97	8·2	28823
68·3	1	,,	,,	24
68·0	2	,,	,,	27
67·0	1	,,	,,	35
66·8	1	,,	,,	37
66·3	1	,,	,,	41
65·9	1	,,	,,	44
65·8	1	,,	,,	45
65·0	1n	,,	,,	52
64·5	1n	,,	,,	56
63·9	1	,,	,,	61
63·7	1	,,	,,	63
63·3	2	,,	,,	66
62·2	2	,,	,,	75
60·9	2	,,	,,	86
60·3	1	,,	,,	91
60·1	1	,,	,,	93
58·9	1	0·96	,,	903
58·2	1	,,	,,	09
57·7	1	,,	,,	13
57·5	1	,,	,,	14
56·5	2	,,	,,	23
56·3	2	,,	,,	24
55·9	1	,,	,,	28
55·5	1	,,	,,	31
55·2	1	,,	,,	34
54·3	1	,,	,,	41
53·5	1	,,	,,	48
53·0	2	,,	,,	52
52·8	2	,,	,,	54
51·8	1	,,	,,	62
50·9	1	,,	,,	70
50·6	1	,,	,,	72
50·0	1	,,	,,	77
49·1	2	,,	,,	85
48·6	2	,,	,,	89
48·1	1	,,	,,	93
47·1	2	,,	,,	29002
46·1	4	,,	,,	10
45·5	2	,,	,,	15
45·4	1	,,	,,	16
45·2	1	,,	,,	18
44·4	1n	,,	,,	24
44·0	1n	,,	,,	28
43·3	1	,,	,,	34
42·7	1	,,	,,	39
42·6	1	,,	,,	40
42·0	1	,,	,,	45
41·5	2	,,	,,	49
41·1	1n	,,	,,	52
40·7	1	,,	,,	56
40·6	1	,,	,,	57
40·2	1n	,,	,,	60
39·9	1	,,	,,	62
39·6	1	,,	,,	65

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3439·1	1n	0·96	8·2	29069
38·9	2	,,	,,	71
38·0	1n	,,	,,	78
36·7	1	,,	,,	89
35·5	4	,,	,,	100
34·8	2	,,	,,	06
34·6	1	,,	,,	07
34·1	1	,,	,,	12
33·4	1	,,	,,	17
33·1	1n	,,	8·3	20
32·2	2	,,	,,	28
30·7	1	,,	,,	40
30·4	1n	,,	,,	43
29·6	1	,,	,,	50
28·9	1	,,	,,	56
28·1	1	,,	,,	62
28·0	1	,,	,,	63
27·6	1	,,	,,	67
27·1	2	,,	,,	71
26·9	1	,,	,,	73
26·0	1	,,	,,	80
25·6	1	,,	,,	84
25·3	1	,,	,,	86
24·9	1	,,	,,	90
24·8	1	,,	,,	90
24·3	1	,,	,,	95
†22·8	4	,,	,,	208
22·3	2	,,	,,	12
21·3	2	,,	,,	20
20·1	2	,,	,,	31
19·0	2	,,	,,	40
18·5	2	,,	,,	44
18·4	1	,,	,,	45
18·1	1	,,	,,	48
17·6	1	0·95	,,	52
17·1	1	,,	,,	56
16·7	1	,,	,,	60
16·1	1	,,	,,	65
15·7	1	,,	,,	68
15·4	1	,,	,,	71
14·5	1	,,	,,	79
13·8	1	,,	,,	85
13·5	1	,,	,,	87
12·4	1	,,	,,	97
12·1	1	,,	,,	99
10·6	1	,,	,,	312
08·7	2	,,	,,	28
07·6	2	,,	,,	38
07·3	2	,,	,,	40
†06·0	2	,,	,,	52
05·8	2	,,	,,	53
05·2	1	,,	,,	59
04·3	2	,,	,,	66
02·8	2	,,	,,	79
01·6	1	,,	,,	90

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}-$	
3400·3	1	0·95	8·3	29401
3399·2	1	,,	,,	10
98·3	2	,,	,,	18
97·9	1	,,	,,	22
97·0	1	,,	,,	29
96·8	1	,,	,,	31
95·5	2	,,	8·4	42
95·0	1	,,	,,	47
93·8	1	,,	,,	57
93·3	1	,,	,,	61
93·1	1	,,	,,	63
92·0	4	,,	,,	73
90·3	1	,,	,,	88
89·8	1	,,	,,	92
88·9	1n	,,	,,	500
88·0	1	,,	,,	08
87·3	1	,,	,,	14
87·2	1	,,	,,	15
86·4	1	,,	,,	21
86·0	1	,,	,,	25
84·7	2	,,	,,	36
84·0	2	,,	,,	42
82·7	2	,,	,,	54
82·6	1	,,	,,	55
82·0	1	,,	,,	60
80·5	4	,,	,,	73
79·9	4	,,	,,	78
78·7	1	,,	,,	89
78·4	1	,,	,,	91
76·8	1	0·94	,,	605
75·7	1	,,	,,	15
75·3	1	,,	,,	19
75·0	1	,,	,,	21
74·8	1	,,	,,	23
73·1	1	,,	,,	38
72·8	1	,,	,,	41
71·8	2	,,	,,	49
70·7	1	,,	,,	59
70·1	1	,,	,,	64
69·8	1	,,	,,	67
69·5	1	,,	,,	70
68·0	4	,,	,,	83
66·3	1	,,	,,	98
65·5	1	,,	,,	705
65·2	1	,,	,,	08
63·9	2	,,	,,	19
63·8	1	,,	,,	20
63·0	2	,,	,,	27
62·6	1	,,	,,	30
61·3	1	,,	,,	42
60·3	2	,,	8·5	51
58·5	1	,,	,,	67
58·3	2	,,	,,	68
58·1	1	,,	,,	70
57·1	1	,,	,,	79

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}$ −	
3355·6	1	0·94	8·5	29792
55·1	1	,,	,,	97
53·8	1	,,	,,	808
52·9	1	,,	,,	16
51·9	1	,,	,,	25
51·0	1	,,	,,	33
50·7	1	,,	,,	36
50·3	1	,,	,,	40
49·5	1	,,	,,	47
49·1	2	,,	,,	50
48·0	1n	,,	,,	60
47·3	2	,,	,,	66
47·1	1	,,	,,	68
46·4	4	,,	,,	74
46·1	2	,,	,,	77
44·8	1	,,	,,	89
42·6	2 (W)	,,	,,	908
41·9	2	,,	,,	15
41·7	1	,,	,,	16
41·3	1	,,	,,	20
40·6	1	,,	,,	26
40·2	1	,,	,,	30
38·3	1n	0·93	,,	47
37·1	1n	,,	,,	58
36·5	1	,,	,,	63
36·1	1	,,	,,	67
35·5	1	,,	,,	72
35·1	2	,,	,,	76
33·9	1	,,	,,	86
32·5	2	,,	,,	99
30·9	1	,,	,,	30013
30·8	2	,,	,,	14
30·3	2	,,	,,	19
†29·3	4	,,	,,	28
28·6	1	,,	,,	34
28·1	1	,,	,,	39
27·3	2	,,	,,	46
25·7	2	,,	,,	60
25·3	1	,,	,,	64
24·8	1	,,	8·6	68
24·0	1	,,	,,	76
22·1	2	,,	,,	93
20·9	6	,,	,,	104
19·6	1n	,,	,,	16
18·2	1	,,	,,	28
17·5	1	,,	,,	35
17·1	1	,,	,,	38
16·8	1	,,	,,	41
16·3	1	,,	,,	45
14·5	1	,,	,,	62
13·6	4	,,	,,	70
12·9	4	,,	,,	76
10·8	1	,,	,,	96
10·1	1	,,	,,	202
09·4	1	,,	,,	08

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3309·0	1	0·93	8·6	30212
08·3	1	,,	,,	18
07·0	2	,,	,,	30
05·8	1	,,	,,	41
05·5	2	,,	,,	44
05·2	1	,,	,,	47
04·5	1	,,	,,	53
04·3	1	,,	,,	55
04·0	1	,,	,,	58
03·5	1	,,	,,	62
02·6	1	,,	,,	71
02·4	1n	,,	,,	72
01·0	1n	,,	,,	85
00·4	1	,,	,,	91
3299·5	1	0·92	,,	99
98·8	1	,,	,,	305
97·5	2	,,	,,	17
96·4	2	,,	,,	28
96·2	4	,,	,,	29
95·7	1	,,	,,	34
95·4	1n	,,	,,	37
94·9	1	,,	,,	41
93·7	1	,,	,,	52
93·6	1	,,	,,	53
92·4	3b	,,	,,	64
90·8	4	,,	,,	79
90·0	1	,,	,,	87
89·2	2	,,	,,	94
88·0	2	,,	8·7	405
87·4	2	,,	,,	10
86·7	1	,,	,,	17
86·4	1	,,	,,	20
85·6	1	,,	,,	27
85·5	1	,,	,,	28
85·2	1	,,	,,	31
84·6	2	,,	,,	36
83·6	1	,,	,,	46
83·1	4	,,	,,	50
81·7	1	,,	,,	63
81·2	2	,,	,,	68
80·3	1	,,	,,	76
79·9	1	,,	,,	80
79·3	1	,,	,,	86
79·0	4	,,	,,	88
78·2	2	,,	,,	96
77·2	1n	,,	,,	505
76·3	4	,,	,,	14
74·8	1	,,	,,	28
74·3	1n	,,	,,	32
73·7	1	,,	,,	38
72·4	1	,,	,,	50
71·6	4	,,	,,	57
71·1	2	,,	,,	62
70·3	1n	,,	,,	70
69·2	2	,,	,,	80

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3267·7	2	0·92	8·7	30594
66·9	2	,,	,,	601
66·3	1n	,,	,,	07
65·2	2	,,	,,	17
64·7	1n	,,	,,	22
64·5	1	,,	,,	24
64·1	1	,,	,,	28
63·3	1n	,,	,,	35
62·7	1	,,	,,	41
62·5	1	,,	,,	43
62·2	2	,,	,,	45
60·6	1	,,	,,	61
59·8	1n	0·91	,,	68
59·1	1	,,	,,	75
59·0	1	,,	,,	76
58·7	2	,,	,,	78
58·3	1	,,	,,	82
57·4	1	,,	,,	91
56·2	1	,,	,,	702
55·2	2	,,	,,	11
54·7	2	,,	,,	16
53·8	4	,,	,,	25
52·8	1	,,	8·8	34
52·2	1	,,	,,	40
51·7	1	,,	,,	44
51·4	1	,,	,,	47
50·7	2	,,	,,	54
50·1	2n	,,	,,	59
49·3	1	,,	,,	67
48·2	1	,,	,,	77
47·7	2	,,	,,	82
47·4	1	,,	,,	85
46·3	1	,,	,,	96
46·0	1	,,	,,	98
45·9	1	,,	,,	99
45·4	1	,,	,,	804
44·7	1	,,	,,	11
43·2	1	,,	,,	25
42·5	1	,,	,,	32
42·1	1	,,	,,	35
41·5	1	,,	,,	41
40·8	4	,,	,,	48
38·4	1	,,	,,	71
38·0	1	,,	,,	74
37·1	1	,,	,,	83
37·0	1	,,	,,	84
36·3	1n	,,	,,	91
35·4	2	,,	,,	99
35·0	2	,,	,,	903
34·6	1	,,	,,	07
34·3	1	,,	,,	10
33·8	2	,,	,,	15
33·3	1	,,	,,	19
32·7	1n	,,	,,	25
31·0	2	,,	,,	41

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}-$	
3230·6	1	0·91	8·8	30945
30·1	1	,,	,,	50
29·6	4	,,	,,	55
28·8	1	,,	,,	62
28·4	1	,,	,,	66
27·5	1	,,	,,	75
27·3	1	,,	,,	77
26·6	1	,,	,,	84
25·8	1	,,	,,	91
25·3	1	,,	,,	96
24·7	2	,,	,,	31002
23·9	1	,,	,,	10
23·6	1	,,	,,	12
22·9	1	,,	,,	19
22·4	1	,,	,,	24
21·8	1	,,	,,	30
21·4	1	,,	,,	34
21·0	1	0·90	,,	37
20·7	1	,,	,,	40
20·2	1	,,	,,	45
19·4	1	,,	,,	53
19·0	1	,,	,,	57
18·5	2n	,,	,,	62
16·9	1	,,	,,	77
16·0	2	,,	8·9	86
15·2	2	,,	,,	93
14·3	2	,,	,,	102
13·2	2	,,	,,	13
12·6	1	,,	,,	19
12·0	2	,,	,,	24
11·7	1n	,,	,,	27
11·0	2	,,	,,	34
10·5	2n	,,	,,	39
09·8	2	,,	,,	46
09·0	2	,,	,,	53
07·4	1n	,,	,,	69
07·2	1	,,	,,	71
06·8	1	,,	,,	75
06·3	1	,,	,,	80
05·9	1	,,	,,	84
05·6	1	,,	,,	87
05·3	1	,,	,,	89
04·9	2	,,	,,	93
03·8	1	,,	,,	204
03·4	1	,,	,,	08
02·8	1	,,	,,	14
02·1	1n	,,	,,	21
01·6	2	,,	,,	25
†00·3	2	,,	,,	38
3199·4	1	,,	,,	47
98·9	1	,,	,,	52
98·5	2	,,	,,	56
97·5	1	,,	,,	66
97·2	1	,,	,,	68
96·5	1	,,	,,	75

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3195·9	2	0·90	8·9	31281
95·2	2	„	„	88
94·9	1	„	„	91
94·1	2	„	„	99
93·1	1	„	„	309
92·8	1	„	„	12
92·1	2	„	„	18
91·5	1	„	„	23
90·8	2n	„	„	31
89·4	1	„	„	45
88·1	1	„	„	58
87·6	2	„	„	63
86·4	1	„	„	74
85·6	1	„	„	82
85·5	2	„	„	83
85·1	2	„	„	86
84·6	1	„	„	92
84·0	1	„	„	98
83·3	4	„	„	405
82·9	4	„	„	09
82·5	1	„	„	13
82·0	1	0·89	„	18
81·3	1	„	„	25
80·9	2	„	9·0	29
79·9	1	„	„	39
79·4	1	„	„	43
79·0	1	„	„	47
78·6	1	„	„	51
78·0	1	„	„	57
77·2	1	„	„	65
76·7	1	„	„	70
76·3	4	„	„	74
75·7	1	„	„	80
75·2	4	„	„	85
74·3	2	„	„	94
73·7	2	„	„	500
72·8	4	„	„	09
72·3	2	„	„	14
72·0	2	„	„	17
71·4	1	„	„	23
70·3	2n	„	„	34
69·9	2	„	„	38
69·7	1n	„	„	40
68·7	1	„	„	50
68·4	1	„	„	53
67·9	1	„	„	58
†67·8	1	„	„	59
67·1	1	„	„	66
66·2	1n	„	„	75
65·6	1	„	„	81
64·6	1	„	„	91
64·0	2	„	„	97
63·7	1	„	„	600
63·4	1	„	„	03
62·7	2	„	„	10

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3161·8	1	0·89	9·0	31619
61·4	1	"	"	23
60·2	1	"	"	35
59·2	2	"	"	45
58·9	2	"	"	48
58·2	2	"	"	55
57·3	2	"	"	64
56·9	2	"	"	68
55·7	4	"	"	80
55·2	1	"	"	85
54·7	1	"	"	90
54·0	1	"	"	97
52·8	4	"	"	709
52·3	1	"	"	14
51·7	2	"	"	20
50·6	1	"	"	31
50·3	1	"	"	34
49·0	1	"	"	47
48·5	1n	"	"	52
48·0	2	"	"	57
47·4	2	"	"	63
46·1	1	"	9·1	76
45·7	2	"	"	80
45·3	1	"	"	84
44·7	1	"	"	90
44·5	1	"	"	92
44·1	1	"	"	97
43·2	2	"	"	806
41·8	4	0·88	"	20
41·3	4	"	"	25
40·8	1	"	"	30
40·3	1	"	"	35
39·9	1	"	"	39
39·3	1	"	"	45
38·7	4	"	"	51
38·4	2	"	"	54
37·3	1	"	"	65
37·1	1	"	"	67
36·5	4	"	"	74
35·9	1	"	"	80
35·7	1	"	"	82
34·8	1	"	"	91
34·4	2	"	"	95
33·8	1	"	"	901
32·6	4	"	"	13
31·3	1	"	"	27
30·5	1	"	"	35
30·2	2	"	"	38
28·6	2	"	"	54
27·9	1	"	"	61
26·8	2	"	"	72
26·4	1n	"	"	77
26·0	2	"	"	81
25·7	2	"	"	84
24·9	1	"	"	92

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
3124·1	1	0·88	9·1	32000
24·0	2	”	”	01
23·3	2	”	”	08
21·9	6	”	”	23
21·2	2	”	”	30
20·4	1	”	”	38
19·9	1	”	”	43
19·4	2	”	”	48
18·8	1	”	”	55
18·3	1n	”	”	60
17·6	1	”	”	67
17·4	1	”	”	69
16·1	2	”	”	82
15·1	1	”	”	93
14·2	1	”	”	103
13·5	2	”	9·2	09
12·9	1n	”	”	15
12·1	1	”	”	23
11·7	2	”	”	28
11·1	1	”	”	34
10·7	4	”	”	38
08·9	2	”	”	57
07·4	1n	”	”	72
06·9	2	”	”	77
06·6	1	”	”	80
06·3	2	”	”	83
05·7	1	”	”	90
05·4	1	”	”	93
04·7	1	”	”	200
04·3	1	”	”	04
03·4	2	”	”	14
01·3	2	0·87	”	35
01·1	2	”	”	37
01·0	1	”	”	38
00·6	2	”	”	43
00·1	2	”	”	48
3099·4	1	”	”	55
98·6	2	”	”	63
98·2	1	”	”	68
97·8	1	”	”	72
97·3	1	”	”	77
97·0	1	”	”	80
96·6	2	”	”	84
95·8	1	”	”	93
95·3	1	”	”	98
95·0	1	”	”	301
94·7	1	”	”	04
94·3	1	”	”	08
93·8	1	”	”	14
93·5	1	”	”	17
93·1	2	”	”	21
92·2	4	”	”	30
91·6	1	”	”	37
90·8	1	”	”	45
90·6	1	”	”	47

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}-$	
3089·9	1n	0·87	9·2	32354
89·7	1	,,	,,	56
89·2	1	,,	,,	62
88·8	1	,,	,,	66
88·2	1	,,	,,	72
87·7	6	,,	,,	77
86·6	1	,,	,,	89
86·3	1	,,	,,	92
85·7	2	,,	,,	98
85·0	1	,,	,,	407
84·5	2	,,	,,	11
84·3	1	,,	,,	13
83·3	2	,,	,,	24
83·0	1	,,	9·3	27
82·3	4	,,	,,	34
82·0	1	,,	,,	37
81·7	2	,,	,,	40
80·5	2	,,	,,	53
80·0	2n	,,	,,	58
78·7	2	,,	,,	72
78·1	2	,,	,,	78
77·7	6	,,	,,	83
76·6	1	,,	,,	94
76·3	1	,,	,,	97
75·6	1	,,	,,	505
75·3	1	,,	,,	08
74·6	1	,,	,,	15
74·3	2	,,	,,	18
73·4	1	,,	,,	28
73·3	1	,,	,,	29
73·0	1	,,	,,	32
72·5	1n	,,	,,	37
72·0	1	,,	,,	43
71·5	1n	,,	,,	48
71·0	1	,,	,,	53
70·7	1	,,	,,	57
70·1	1	,,	,,	63
70·0	1	,,	,,	64
69·2	1	,,	,,	72
69·0	1	,,	,,	75
68·9	1	,,	,,	76
68·6	1	,,	,,	79
68·1	1	,,	,,	84
67·7	1	,,	,,	88
67·3	1	,,	,,	94
66·7	1	,,	,,	99
66·4	1	,,	,,	602
65·9	1	,,	,,	08
65·7	1	,,	,,	10
65·2	2	,,	,,	15
64·7	1n	,,	,,	21
64·4	2	,,	,,	24
63·9	1	,,	,,	29
63·5	1	,,	,,	33
62·1	1	0·86	,,	48

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}-$	
3061·6	1	0·86	9·3	32654
61·3	1	,,	,,	57
60·9	2	,,	,,	61
60·1	2	,,	,,	70
59·2	1	,,	,,	79
58·7	2	,,	,,	85
58·0	2	,,	,,	92
56·9	1	,,	,,	703
56·7	1	,,	,,	14
55·7	1	,,	,,	17
55·6	1	,,	,,	18
55·3	1	,,	,,	21
54·9	1	,,	,,	25
54·8	1	,,	,,	27
53·6	2	,,	,,	39
52·3	2	,,	9·4	53
51·3	1	,,	,,	63
50·4	1	,,	,,	73
50·2	1	,,	,,	75
49·7	1	,,	,,	80
49·2	1	,,	,,	86
49·0	2	,,	,,	88
48·2	2	,,	,,	97
47·4	1	,,	,,	805
46·8	1	,,	,,	12
46·4	2	,,	,,	16
45·7	2	,,	,,	24
44·8	1n	,,	,,	33
44·0	2	,,	,,	42
43·5	1	,,	,,	50
43·0	1	,,	,,	53
42·1	2	,,	,,	63
41·8	2	,,	,,	66
41·2	2	,,	,,	72
39·9	1	,,	,,	86
39·2	1	,,	,,	94
38·8	1	,,	,,	99
37·5	1	,,	,,	913
37·1	1	,,	,,	17
36·3	1	,,	,,	25
35·5	1	,,	,,	34
35·4	1	,,	,,	35
35·0	2	,,	,,	40
34·3	1	,,	,,	47
33·9	1	,,	,,	51
33·4	2	,,	,,	52
32·0	1	,,	,,	72
30·8	1	,,	,,	85
30·3	2	,,	,,	91
30·0	1	,,	,,	94
29·9	1	,,	,,	95
29·2	1	,,	,,	33003
28·3	1	,,	,,	12
28·0	1	,,	,,	16
27·7	1n	,,	,,	19

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
3026·8	2	0·86	9·4	33029
†25·9	2	,,	,,	39
25·0	1	,,	,,	48
24·9	1	,,	,,	49
23·3	4	,,	9·5	67
22·8	2	0·85	,,	72
21·7	4	,,	,,	84
20·8	2	,,	,,	94
19·8	1	,,	,,	105
19·1	1	,,	,,	13
18·5	4	,,	,,	20
17·4	2	,,	,,	32
16·9	2	,,	,,	37
16·3	1	,,	,,	44
16·0	1	,,	,,	47
15·4	2	,,	,,	54
14·7	1	,,	,,	61
14·3	2	,,	,,	64
13·4	1	,,	,,	76
12·8	1	,,	,,	82
12·2	1	,,	,,	89
12·0	2	,,	,,	91
11·2	1	,,	,,	200
11·0	2	,,	,,	02
10·0	1	,,	,,	13
09·8	1	,,	,,	15
09·5	1	,,	,,	19
08·8	1	,,	,,	26
08·2	4	,,	,,	32
07·8	1	,,	,,	37
07·4	2	,,	,,	42
07·0	1	,,	,,	46
06·8	1	,,	,,	48
05·5	2	,,	,,	63
05·1	1	,,	,,	69
04·5	4	,,	,,	74
04·0	1	,,	,,	79
03·8	2	,,	,,	82
03·3	1	,,	,,	87
02·8	1	,,	,,	93
02·2	1	,,	,,	99
01·9	1	,,	,,	303
01·5	1	,,	,,	07
00·9	1	,,	,,	13
00·4	4	,,	,,	19
2999·8	1	,,	,,	26
98·9	1	,,	,,	36
98·3	1	,,	,,	43
98·0	1	,,	,,	46
97·7	1	,,	,,	49
97·3	2	,,	9·6	54
97·2	1	,,	,,	55
96·7	1	,,	,,	60
96·3	2	,,	,,	65
95·6	1	,,	,,	73

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
2995·4	1	0·85	9·6	33375
95·0	1	,,	,,	79
94·8	1	,,	,,	82
93·9	1	,,	,,	92
93·6	2	,,	,,	95
92·9	2	,,	,,	403
92·8	2	,,	,,	04
92·3	2	,,	,,	08
91·7	1n	,,	,,	16
91·1	1	,,	,,	23
90·8	1	,,	,,	26
90·3	1	,,	,,	31
89·9	2	,,	,,	36
89·5	1	,,	,,	41
88·8	1	,,	,,	49
88·6	2	,,	,,	51
88·0	1	,,	,,	58
87·4	1	,,	,,	64
87·0	2	,,	,,	69
86·2	2	,,	,,	78
86·0	1n	,,	,,	80
85·2	1	,,	,,	89
84·9	1	,,	,,	92
83·9	2	,,	,,	504
83·6	2	,,	,,	07
82·7	1	0·84	,,	17
82·4	1	,,	,,	20
82·0	1	,,	,,	25
81·5	1	,,	,,	31
81·2	1	,,	,,	34
80·8	1	,,	,,	38
80·5	1	,,	,,	42
79·8	2	,,	,,	50
79·6	1	,,	,,	52
78·7	2	,,	,,	62
77·8	2	,,	,,	72
77·0	2	,,	,,	81
76·0	1	,,	,,	93
75·6	2	,,	,,	97
75·4	4	,,	,,	99
74·8	1	,,	,,	606
74·3	1	,,	,,	12
74·0	1	,,	,,	15
72·6	4	,,	,,	31
71·8	4	,,	,,	40
71·1	2	,,	,,	48
70·4	1	,,	9·7	56
69·7	1	,,	,,	64
69·3	2	,,	,,	68
68·7	2	,,	,,	75
68·5	1	,,	,,	77
67·3	1	,,	,,	91
67·0	2	,,	,,	94
66·7	2	,,	,,	98
65·3	2	,,	,,	714

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2965·1	1	0·84	9·7	33716
64·5	1	,,	,,	23
63·8	2	,,	,,	31
63·0	1	,,	,,	40
62·4	1	,,	,,	47
61·4	2	,,	,,	58
61·2	1	,,	,,	60
60·4	1	,,	,,	70
60·3	2	,,	,,	71
58·7	1	,,	,,	89
58·1	1	,,	,,	96
57·7	1	,,	,,	800
57·1	2	,,	,,	07
56·0	2	,,	,,	20
55·9	2	,,	,,	21
55·2	2	,,	,,	29
†54·5	1	,,	,,	37
53·9	2	,,	,,	44
53·7	1	,,	,,	46
52·8	2	,,	,,	56
52·0	2	,,	,,	66
51·6	1	,,	,,	71
50·9	1	,,	,,	78
50·1	1	,,	,,	87
49·4	1	,,	,,	95
48·9	1	,,	,,	902
48·8	1	,,	,,	03
48·2	1	,,	,,	09
47·3	2	,,	,,	19
46·9	2	,,	,,	24
46·7	1	,,	,,	26
46·1	4	,,	,,	33
44·8	2	,,	9·8	48
44·1	1	,,	,,	56
43·4	2	,,	,,	64
42·7	1	0·83	,,	72
42·6	1	,,	,,	74
42·4	1	,,	,,	76
41·9	1	,,	,,	82
41·3	4	,,	,,	89
40·8	1	,,	,,	94
40·2	1	,,	,,	34001
39·3	1	,,	,,	11
38·3	4n	,,	,,	23
37·8	1n	,,	,,	29
36·9	2	,,	,,	40
35·7	1	,,	,,	54
35·2	2	,,	,,	60
34·2	2	,,	,,	73
33·2	1	,,	,,	84
32·2	2	,,	,,	96
31·6	1	,,	,,	103
30·5	4	,,	,,	14
30·1	2	,,	,,	18
29·5	1	,,	,,	25

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2928·5	2	0·83	9·8	34137
27·6	2	"	"	48
26·9	1	"	"	56
26·2	1	"	"	64
25·5	1	"	"	73
24·5	1	"	"	84
23·4	4	"	"	98
22·8	2	"	"	205
22·2	1	"	"	12
22·0	1	"	"	13
21·5	1	"	"	19
20·2	1	"	9·9	34
19·3	2	"	"	45
18·9	4	"	"	50
17·9	1	"	"	62
17·2	2	"	"	70
16·5	1	"	"	78
16·0	2	"	"	84
15·4	1	"	"	91
14·9	1	"	"	97
14·3	2	"	"	304
13·3	1n	"	"	16
12·5	1	"	"	25
11·7	2	"	"	35
10·9	1	"	"	44
09·9	1	"	"	56
09·2	2	"	"	64
08·2	1	"	"	75
08·0	1	"	"	78
07·2	2	"	"	87
06·0	2	"	"	92
05·4	1	"	"	409
05·3	1	"	"	10
05·0	1	"	"	14
04·5	1	"	"	19
04·3	1	"	"	22
03·2	6	0·82	"	30
02·0	2	"	"	49
01·0	2	"	"	61
00·7	2	"	"	64
2899·2	2	"	"	82
98·7	1	"	"	88
97·8	2	"	"	99
97·6	1	"	"	501
96·9	1	"	10·0	10
96·5	1	"	"	14
95·1	1	"	"	31
95·0	1	"	"	32
94·7	2	"	"	36
93·9	1	"	"	45
93·0	4	"	"	56
92·3	1	"	"	64
91·4	2	"	"	75
91·2	4	"	"	78
89·7	1n	"	"	96

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}$−	
2888·8	1	0·82	10·0	34606
88·2	1	”	”	13
87·2	2	”	”	26
86·2	1	”	”	38
85·8	1	”	”	43
84·9	1	”	”	54
84·3	1	”	”	61
84·1	1	”	”	63
83·4	1	”	”	71
82·6	2	”	”	81
82·2	2n	”	”	86
81·7	1	”	”	92
81·6	2	”	”	93
80·0	2	”	”	712
79·2	2	”	”	22
77·7	1	”	”	40
77·0	2	”	”	48
75·8	1n	”	”	63
75·0	2	”	”	73
73·8	1	”	”	87
73·1	2	”	10·1	96
71·7	6	”	”	812
70·0	1n	”	”	33
69·8	1	”	”	35
69·3	1	”	”	41
69·0	1	”	”	45
68·5	2	”	”	51
68·3	2	”	”	53
67·8	1n	”	”	59
66·8	2	”	”	72
65·9	1	”	”	83
65·7	1	”	”	85
65·4	1	0·81	”	89
64·9	1	”	”	95
64·6	1	”	”	99
63·4	4	”	”	913
62·0	1	”	”	30
60·9	1	”	”	44
60·0	2	”	”	55
59·0	1	”	”	67
58·2	1	”	”	77
57·3	1	”	”	88
57·1	1	”	”	90
56·1	2	”	”	35003
56·0	2	”	”	04
54·8	1	”	”	18
54·2	1	”	”	25
53·7	2	”	”	31
53·3	6	”	”	37
51·3	1	”	”	61
50·7	1	”	”	69
49·8	1	”	”	80
49·4	1	”	”	85
48·3	8	”	10·2	98
46·7	1	”	”	118

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2846·3	1	0·81	10·2	35123
45·7	1	”	”	30
45·0	1	”	”	39
44·5	1n	”	”	46
44·0	1	”	”	52
43·4	1	”	”	58
42·7	2	”	”	67
42·4	4	”	”	71
42·0	2	”	”	76
39·2	1	”	”	210
38·6	1	”	”	18
38·4	1	”	”	21
37·4	1	”	”	33
36·7	1	”	”	42
36·5	1	”	”	45
35·4	1	”	”	58
35·0	2	”	”	63
34·5	2	”	”	69
33·5	1	”	”	82
32·8	2	”	”	91
32·3	2	”	”	97
31·7	2	”	”	304
30·7	1	”	”	17
30·1	1	”	”	24
29·2	1	”	”	35
29·0	1	”	”	38
27·9	4	”	”	52
27·3	1	”	”	59
26·7	1	”	”	67
26·1	1	”	”	73
25·9	1	”	”	77
25·4	1	”	”	83
25·2	1	”	”	85
24·3	1	0·80	”	97
24·0	1	”	”	401
23·4	2	”	10·3	09
23·1	1	”	”	12
22·4	1	”	”	21
22·1	1	”	”	24
21·9	2	”	”	26
20·2	2n	”	”	48
19·9	1	”	”	52
17·6	2	”	”	81
16·2	3	”	”	99
14·8	2	”	”	516
14·2	1	”	”	24
13·7	1	”	”	30
13·3	1	”	”	35
12·7	1	”	”	43
11·2	2	”	”	62
10·5	2n	”	”	71
09·0	1	”	”	90
08·7	1	”	”	93
08·5	1	”	”	96
07·8	6	”	”	605

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
2807·2	2	0·80	10·3	35612
06·3	2	,,	,,	24
05·1	1	,,	,,	39
04·6	1	,,	,,	45
04·2	1	,,	,,	50
03·3	1	,,	,,	63
02·5	1	,,	,,	72
01·4	2	,,	,,	86
01·2	1	,,	,,	89
01·0	1	,,	,,	91
00·6	2	,,	,,	96
00·4	1	,,	,,	99
2799·2	2	,,	10·4	714
99·0	1	,,	,,	17
98·2	1	,,	,,	27
97·2	2n	,,	,,	40
96·8	1	,,	,,	45
95·6	1	,,	,,	60
94·8	1	,,	,,	70
94·2	1	,,	,,	78
93·2	1	,,	,,	91
92·6	1	,,	,,	99
91·7	1	,,	,,	810
90·5	1	,,	,,	26
89·0	1n	,,	,,	45
87·9	1	,,	,,	59
87·5	1	,,	,,	64
85·1	4	,,	,,	95
84·2	2n	0·79	,,	907
83·3	1	,,	,,	19
82·0	1	,,	,,	35
81·5	1	,,	,,	41
80·2	6	,,	,,	58
79·4	2	,,	,,	68
78·4	1	,,	,,	81
77·9	1	,,	,,	88
76·7	1	,,	,,	36003
75·4	6	,,	10·5	20
74·5	2	,,	,,	32
73·8	2n	,,	,,	41
71·9	1	,,	,,	66
70·7	1	,,	,,	82
69·7	2	,,	,,	94
68·8	1n	,,	,,	106
67·7	1	,,	,,	20
67·0	1	,,	,,	30
66·3	1	,,	,,	39
66·1	1	,,	,,	42
65·2	1	,,	,,	53
64·5	1	,,	,,	63
63·8	2	,,	,,	72
63·5	4	,,	,,	75
62·9	2	,,	,,	83
62·6	1	,,	,,	90
61·6	1	,,	,,	200

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
2760·7	2	0·79	10·5	36212
60·0	1	,,	,,	21
59·6	1	,,	,,	26
59·2	1	,,	,,	32
58·7	2	,,	,,	38
57·3	2	,,	,,	57
56·0	4	,,	,,	74
55·5	1	,,	,,	81
54·7	1n	,,	,,	91
54·0	1	,,	,,	300
52·4	1	,,	,,	21
51·6	1	,,	,,	32
50·0	2	,,	10·6	53
49·3	1	,,	,,	62
48·5	1	,,	,,	73
47·7	1	,,	,,	83
47·1	1	,,	,,	91
47·0	1	,,	,,	93
46·2	4	,,	,,	403
45·2	1	,,	,,	17
44·2	1	,,	,,	30
43·1	2	,,	,,	44
42·9	2	,,	,,	47
41·6	2	0·78	,,	64
41·5	2	,,	,,	65
40·2	1n	,,	,,	83
39·5	1	,,	,,	92
38·7	1	,,	,,	503
37·9	1	,,	,,	14
37·0	1	,,	,,	26
36·5	1	,,	,,	33
35·9	1	,,	,,	40
35·4	1	,,	,,	47
35·0	1	,,	,,	52
34·0	1	,,	,,	66
33·2	2	,,	,,	78
32·8	4	,,	,,	81
31·5	1	,,	,,	99
30·8	1	,,	,,	608
30·2	2	,,	,,	17
29·8	2	,,	,,	21
28·8	2	,,	,,	35
26·9	1	,,	10·7	61
26·0	1	,,	,,	73
25·1	1n	,,	,,	85
24·0	2	,,	,,	700
23·3	1	,,	,,	10
22·5	1	,,	,,	21
21·8	1	,,	,,	30
21·2	1	,,	,,	38
20·2	1	,,	,,	51
19·8	1n	,,	,,	57
19·0	1	,,	,,	68
18·1	1n	,,	,,	80
17·3	4	,,	,,	91

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2716·2	1	0·78	10·7	36805
15·5	1n	”	”	15
14·5	1	”	”	29
13·5	1	”	”	43
13·0	1	”	”	49
12·3	2	”	”	58
11·5	2	”	”	70
10·9	2	”	”	77
10·2	1	”	”	87
09·8	2	”	”	92
08·6	1	”	”	908
07·8	1	”	”	20
07·0	1	”	”	31
06·2	1	”	”	42
05·0	1	”	”	58
04·2	1	”	”	69
03·9	1	”	”	73
03·0	1	”	10·8	85
02·4	1	”	”	93
01·8	1	”	”	37001
01·3	4	”	”	08
00·6	1	”	”	17
2699·5	1	”	”	33
98·3	1	0·77	”	49
97·8	1	”	”	56
97·3	1	”	”	63
96·9	2	”	”	69
95·9	1	”	”	83
95·2	2	”	”	92
93·9	2	”	”	110
93·2	2	”	”	19
93·0	1	”	”	23
92·7	2	”	”	27
91·8	2n	”	”	40
91·1	1	”	”	49
90·1	1	”	”	63
89·7	1	”	”	69
88·9	1	”	”	78
88·0	4	”	”	92
87·1	1	”	”	205
85·9	2	”	”	21
85·2	1	”	”	31
84·2	2	”	”	45
83·2	2	”	”	59
82·5	1	”	”	68
81·5	4	”	”	82
80·6	1n	”	”	95
80·0	1	”	”	303
79·8	1	”	”	06
78·6	1	”	10·9	22
77·8	1	”	”	33
77·1	2	”	”	43
76·5	4	”	”	55
75·7	1	”	”	62
74·9	1	”	”	74

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2672·9	4	0·77	10·9	37401
72·0	4	,,	,,	14
71·1	2	,,	,,	27
70·1	2	,,	,,	41
69·7	2	,,	,,	46
69·3	2	,,	,,	52
68·2	1	,,	,,	68
67·5	2	,,	,,	77
66·8	2	,,	,,	87
66·4	1	,,	,,	93
65·1	2	,,	,,	511
63·9	1	,,	,,	28
63·1	1	,,	,,	39
62·7	1	,,	,,	45
61·9	1	,,	,,	56
61·2	1	,,	,,	66
60·6	4	,,	,,	75
59·7	1n	,,	,,	87
59·3	1	,,	,,	93
59·0	1	,,	,,	97
58·1	1	,,	,,	610
57·0	1	,,	,,	26
55·9	1	,,	,,	41
55·6	1	,,	,,	45
55·2	1	,,	11·0	51
55·0	1	0·76	,,	54
53·8	1	,,	,,	71
53·2	4	,,	,,	79
52·2	2n	,,	,,	94
51·7	2	,,	,,	701
51·0	1	,,	,,	11
50·7	1	,,	,,	15
50·0	1	,,	,,	25
49·5	1n	,,	,,	32
48·1	1	,,	,,	52
48·0	1	,,	,,	53
47·6	1	,,	,,	59
47·1	1	,,	,,	66
46·3	4	,,	,,	78
44·2	4	,,	,,	808
42·8	1	,,	,,	28
42·3	2	,,	,,	35
42·1	1	,,	,,	38
41·0	4	,,	,,	53
39·7	1	,,	,,	72
39·4	1	,,	,,	76
38·8	4	,,	,,	85
38·7	4	,,	,,	86
38·3	2n	,,	,,	92
37·1	1	,,	,,	909
36·7	2	,,	,,	15
35·4	1	,,	,,	34
35·1	1	,,	,,	38
34·7	1	,,	,,	43
34·0	1	,,	,,	54

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2633·5	2	0·76	11·0	37961
33·1	1n	,,	,,	67
31·6	1	,,	11·1	89
31·2	1	,,	,,	94
31·0	1	,,	,,	97
30·7	2	,,	,,	38001
30·3	1	,,	,,	07
29·9	1	,,	,,	13
29·7	1	,,	,,	16
29·3	1	,,	,,	22
28·8	1	,,	,,	29
28·4	1	,,	,,	35
28·0	1	,,	,,	41
27·5	1	,,	,,	48
27·2	1	,,	,,	53
26·2	2	,,	,,	67
25·9	2n	,,	,,	71
25·5	1	,,	,,	77
25·3	1	,,	,,	80
24·8	1	,,	,,	87
24·4	1	,,	,,	93
23·4	1	,,	,,	107
22·5	1	,,	,,	20
22·0	1	,,	,,	28
21·7	1	,,	,,	32
20·8	1	,,	,,	46
20·1	1	,,	,,	56
19·8	1	,,	,,	60
18·0	1	,,	,,	86
17·6	1	,,	,,	92
17·2	1	,,	,,	97
16·9	1	,,	,,	202
16·7	1	,,	,,	04
15·7	1	,,	,,	19
15·5	1	,,	,,	22
15·2	1	,,	,,	26
14·5	1	,,	,,	37
13·8	1	,,	,,	47
13·2	1	,,	,,	56
12·2	1	,,	,,	70
11·9	1	,,	,,	75
11·2	1	,,	,,	85
10·9	1	,,	11·2	90
10·2	1	,,	,,	300
09·4	2	0·75	,,	12
09·0	2	,,	,,	18
08·5	1	,,	,,	26
07·9	1	,,	,,	34
07·4	1	,,	,,	41
07·2	1	,,	,,	44
06·7	1	,,	,,	52
05·9	2	,,	,,	63
05·7	1	,,	,,	66
05·2	2	,,	,,	74
04·7	1	,,	,,	81

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2604·6	1	0·75	11·2	38383
03·8	1	,,	,,	94
03·4	1	,,	,,	400
02·9	2	,,	,,	07
02·7	2	,,	,,	11
02·0	2	,,	,,	21
01·6	1	,,	,,	27
01·2	1	,,	,,	33
00·9	1	,,	,,	37
00·2	1	,,	,,	47
2599·6	1	,,	,,	56
99·4	1	,,	,,	59
98·5	1	,,	,,	73
97·4	2	,,	,,	88
97·2	2	,,	,,	92
96·7	1	,,	,,	99
95·3	4	,,	,,	520
93·7	2	,,	,,	44
93·4	4	,,	,,	49
92·8	1	,,	,,	57
91·8	2	,,	,,	72
91·0	1n	,,	,,	84
90·2	1	,,	,,	96
89·8	1n	,,	,,	602
88·9	2	,,	,,	15
88·0	1	,,	11·3	28
87·5	2	,,	,,	36
87·2	2	,,	,,	41
†86·1	2	,,	,,	57
85·2	1	,,	,,	70
84·2	1	,,	,,	85
84·0	1	,,	,,	88
82·5	1n	,,	,,	711
81·2	1	,,	,,	30
80·5	1n	,,	,,	40
79·5	2	,,	,,	56
79·0	2	,,	,,	63
78·4	2	,,	,,	72
76·2	1	,,	,,	806
75·9	1	,,	,,	10
75·5	1	,,	,,	16
74·5	2	,,	,,	31
73·8	1	,,	,,	42
73·0	1n	,,	,,	54
72·3	2	,,	,,	64
71·4	2	,,	,,	78
71·3	2	,,	,,	80
71·0	2n	,,	,,	84
68·2	1	,,	11·4	926
67·6	1	,,	,,	35
67·2	1n	,,	,,	42
66·3	1	,,	,,	55
65·7	1n	,,	,,	64
65·2	1	,,	,,	72
64·9	1	0·74	,,	76

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2564·4	2	0·74	11·4	38984
63·6	1	,,	,,	96
63·3	1	,,	,,	39001
62·7	1	,,	,,	10
62·3	1	,,	,,	16
60·7	1	,,	,,	40
60·3	1n	,,	,,	47
59·7	2	,,	,,	56
59·2	2	,,	,,	63
58·9	2	,,	,,	68
58·2	1	,,	,,	79
57·9	1	,,	,,	83
57·4	2	,,	,,	91
56·8	1	,,	,,	100
56·5	1	,,	,,	15
55·6	1	,,	,,	20
55·0	1n	,,	,,	28
53·8	1n	,,	,,	46
53·2	1n	,,	,,	55
52·8	1n	,,	,,	61
52·6	1	,,	,,	64
52·4	1	,,	,,	67
52·2	1	,,	,,	70
52·0	1	,,	,,	74
50·8	2	,,	,,	92
49·3	1	,,	,,	215
49·1	1	,,	11·5	18
48·2	1n	,,	,,	32
47·6	2	,,	,,	41
47·5	2	,,	,,	43
45·8	1	,,	,,	69
45·1	1	,,	,,	80
44·5	1	,,	,,	89
44·3	2	,,	,,	92
43·6	1	,,	,,	303
42·9	2	,,	,,	14
41·5	1n	,,	,,	85
41·1	1	,,	,,	42
40·7	1	,,	,,	48
40·3	1	,,	,,	54
39·5	1	,,	,,	66
38·5	6	,,	,,	82
37·6	1	,,	,,	96
36·9	1	,,	,,	407
36·8	1	,,	,,	08
35·7	1	,,	,,	25
35·5	1n	,,	,,	28
35·0	1	,,	,,	36
34·6	1	,,	,,	42
33·8	1	,,	,,	55
32·8	1	,,	,,	70
32·5	1	,,	,,	75
31·5	1	,,	,,	91
31·0	1	,,	,,	99
30·9	1	,,	,,	500

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2529·9	2	0·74	11·6	39516
29·0	1	,,	,,	30
28·5	1	,,	,,	38
27·3	2	,,	,,	56
26·8	1n	,,	,,	64
26·5	1n	,,	,,	69
25·5	1	,,	,,	85
24·8	2	,,	,,	95
23·9	2n	,,	,,	610
23·3	2	,,	,,	19
23·0	1	,,	,,	24
22·8	2	,,	,,	27
22·0	1	,,	,,	39
21·3	1	,,	,,	50
20·7	1	,,	,,	60
19·8	1	,,	,,	74
19·3	1	,,	,,	82
19·2	1	,,	,,	84
18·8	2	,,	,,	90
18·7	2	,,	,,	91
17·7	1n	0·73	,,	707
16·3	1	,,	,,	29
15·7	1	,,	,,	39
15·3	1	,,	,,	45
14·3	1	,,	,,	61
14·1	1	,,	,,	64
13·3	1	,,	,,	77
12·7	1	,,	,,	86
12·5	1	,,	,,	89
12·2	1	,,	,,	94
11·8	1n (C)	,,	11·7	800
11·3	1	,,	,,	08
10·6	1	,,	,,	19
09·3	1	,,	,,	40
08·3	1 (C) (?)	,,	,,	56
07·3	1	,,	,,	72
06·8	1	,,	,,	80
†06·3	1	,,	,,	87
05·8	1	,,	,,	96
04·6	1	,,	,,	915
04·4	1	,,	,,	17
04·0	1	,,	,,	24
03·8	2	,,	,,	27
03·4	1	,,	,,	35
02·3	1	,,	,,	51
01·8	1	,,	,,	59
01·5	1	,,	,,	64
00·8	1n	,,	,,	75
2499·8	1	,,	,,	91
99·4	1	,,	,,	97
99·1	1	,,	,,	40003
98·3	1	,,	,,	16
98·2	2	,,	,,	17
98·0	2	,,	,,	20
97·5	2	,,	,,	28

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2497·2	1	0·73	11·7	40033
96·6	1	,,	,,	42
96·3	1	,,	,,	47
96·2	1	,,	,,	49
95·6	1	,,	,,	59
94·8	1	,,	,,	71
94·5	1	,,	,,	76
94·3	1	,,	,,	80
94·1	1	,,	11·8	82
93·3	1	,,	,,	96
93·1	1n	,,	,,	100
92·8	1	,,	,,	04
91·8	2	,,	,,	20
91·4	1	,,	,,	27
90·9	1	,,	,,	34
90·1	2	,,	,,	48
89·3	1	,,	,,	60
89·0	1	,,	,,	65
88·3	1	,,	,,	76
87·8	2	,,	,,	84
87·2	1	,,	,,	94
86·7	2n	,,	,,	202
86·3	1	,,	,,	09
84·9	2	,,	,,	31
84·7	2	,,	,,	34
84·3	1	,,	,,	41
83·9	1	,,	,,	47
83·5	1	,,	,,	54
83·2	1	,,	,,	58
82·7	2	,,	,,	66
82·2	1	,,	,,	75
81·3	2	,,	,,	89
80·4	1	,,	,,	303
79·5	2	,,	,,	19
78·8	1C	,,	,,	30
78·5	1	,,	,,	35
78·2	1	,,	,,	40
78·0	1	,,	,,	43
77·8	4	,,	,,	46
76·2	1n	,,	11·9	72
74·3	2	,,	,,	403
72·0	1	,,	,,	41
70·3	1	,,	,,	69
69·3	2	0·72	,,	85
69·0	2	,,	,,	90
68·6	1	,,	,,	97
68·1	2	,,	,,	505
67·5	2	,,	,,	14
67·1	2	,,	,,	21
66·8	4	,,	,,	26
66·2	1	,,	,,	35
63·8	1	,,	,,	75
63·4	1	,,	,,	82
62·7	2	,,	,,	94
62·1	2	,,	,,	604

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
2461·4	1	0·72	11·9	40615
61·2	1	"	"	18
60·0	1	"	12·0	42
58·8	1	"	"	58
57·9	4	"	"	73
57·2	1	"	"	85
57·0	1	"	"	88
56·5	1	"	"	96
55·6	4	"	"	711
53·9	1	"	"	39
53·5	1	"	"	46
53·3	2	"	"	50
52·3	1	"	"	66
51·5	1	"	"	79
51·0	1	"	"	88
50·5	1	"	"	96
49·9	1	"	"	806
48·6	1	"	"	28
47·5	1	"	"	46
47·2	1n	"	"	51
46·5	2n	"	"	63
44·9	1	"	"	99
44·8	1	"	"	91
43·3	2	"	12·1	918
41·2	1	"	"	53
40·3	2	"	"	67
40·2	1	"	"	68
39·3	2	"	"	84
38·6	1	"	"	95
38·4	2	"	"	99
37·8	4	"	"	41009
36·1	4	"	"	37
34·4	1	"	"	66
33·0	1n	"	"	90
30·4	1	"	"	134
30·2	1	"	"	37
29·6	1	"	"	47
28·9	2	"	"	59
28·3	1	"	"	69
27·6	1	"	12·2	81
25·8	1n	"	"	211
25·2	1	"	"	21
24·3	1n	"	"	36
†24·1	2	"	"	40
22·2	4	"	"	72
21·7	1	0·71	"	81
21·3	1	"	"	88
20·9	1	"	"	95
20·3	1	"	"	305
19·0	2	"	"	27
18·7	1	"	"	33
18·1	1	"	"	43
17·4	1	"	"	55
16·2	1	"	"	75
15·7	1	"	"	84

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$	
2414·8	1	0·71	12·2	41399
13·5	1	,,	,,	422
13·2	2	,,	,,	27
12·8	4	,,	12·3	33
11·9	2	,,	,,	49
11·3	1	,,	,,	58
11·0	2	,,	,,	64
10·6	1	,,	,,	74
10·3	2	,,	,,	76
08·8	2n	,,	,,	502
07·2	1	,,	,,	30
06·8	2	,,	,,	37
05·0	1	,,	,,	68
†04·8	1	,,	,,	72
03·7	2	,,	,,	91
02·8	1	,,	,,	606
02·0	2	,,	,,	20
00·4	1	,,	,,	48
†2399·5	1	,,	,,	63
98·1	1	,,	,,	87
97·3	1	,,	12·4	721
96·0	1	,,	,,	24
95·8	1	,,	,,	27
95·2	1	,,	,,	38
94·7	1	,,	,,	46
93·6	1	,,	,,	66
92·7	2	,,	,,	81
91·9	2	,,	,,	95
91·0	2	,,	,,	811
90·6	2	,,	,,	18
90·3	1	,,	,,	23
90·0	1	,,	,,	29
89·3	2	,,	,,	41
89·1	2	,,	,,	45
88·8	2	,,	,,	50
88·2	1	,,	,,	60
87·1	2	,,	,,	80
86·2	1	,,	,,	95
84·8	1	,,	,,	920
84·1	1	,,	,,	32
83·5	1	,,	,,	43
82·5	1	,,	12·5	60
81·7	1	,,	,,	74
81·3	2	,,	,,	80
80·3	1	,,	,,	98
79·0	1n	,,	,,	42022
78·1	1	,,	,,	38
77·3	4	,,	,,	51
75·0	1	,,	,,	93
74·5	1	,,	,,	102
73·1	2	0·70	,,	27
72·5	1	,,	,,	37
72·1	1	,,	,,	44
71·8	1	,,	,,	50
70·6	1	,,	,,	71

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
2370·5	1	0·70	12·5	42173
70·4	2	"	"	74
69·2	1	"	"	96
68·9	1	"	"	201
67·9	2	"	12·6	19
67·2	2	"	"	31
66·3	4	"	"	47
65·3	1	"	"	65
63·9	1	"	"	90
63·2	2	"	"	303
62·6	1	"	"	14
60·0	2	"	"	60
57·9	1	"	"	98
57·8	1	"	"	400
57·3	2	"	"	09
56·6	1	"	"	21
55·6	1	"	"	39
54·1	1	"	12·7	66
50·1	2	"	"	539
49·0	1	"	"	59
48·8	1	"	"	62
48·2	1	"	"	73
47·8	2	"	"	80
47·6	1	"	"	84
46·8	1	"	"	99
44·8	1	"	"	635
44·3	1n	"	"	44
43·1	2	"	"	66
41·8	2	"	"	89
40·5	4	"	12·8	713
39·8	1	"	"	26
39·4	1	"	"	33
39·0	1	"	"	41
38·5	1	"	"	50
38·2	1	"	"	55
37·4	1	"	"	70
36·6	1n	"	"	84
34·9	1	"	"	816
34·4	1	"	"	25
34·3	1	"	"	27
32·8	1	"	"	54
32·3	1	"	"	63
31·0	4	"	"	87
30·1	1	"	"	904
29·8	2	"	"	09
28·8	1n	"	"	28
27·0	1n	"	12·9	61
26·8	1	"	"	65
25·6	4	0·69	"	87
24·9	1	"	"	43000
24·1	1	"	"	15
23·2	1n	"	"	31
22·4	1n	"	"	46
20·3	1	"	"	85
20·2	1	"	"	87

MOLYBDENUM—*continued.*

Wave-length Spark Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
2318·0	2	0·69	12·9	43128
16·6	1	,,	,,	54
16·4	1	,,	,,	58
14·3	1n	,,	13·0	97
10·0	1	,,	,,	277
09·5	1	,,	,,	86
08·0	2n	,,	,,	315
07·0	1	,,	,,	33
06·5	2	,,	,,	43
04·3	1	,,	,,	84
02·9	1	,,	,,	411
2298·3	2n	,,	13·1	97
97·0	1	,,	,,	522
96·6	1	,,	,,	30
95·1	2	,,	,,	58
91·8	1	,,	,,	621
91·0	1	,,	,,	36
90·3	1	,,	,,	49
90·1	1	,,	,,	53
89·2	2	,,	,,	70
86·5	1	,,	13·2	722
86·0	1	,,	,,	31
81·3	1	,,	,,	821
80·8	2	0·68	,,	31
76·4	2	,,	,,	916
75·8	4n	,,	13·3	27
75·1	2	,,	,,	41
73·2	1	,,	,,	78
69·8	1	,,	,,	44043
68·8	1	,,	,,	63
64·8	1n	,,	,,	141
57·2	2	,,	13·4	289
53·4	1	,,	,,	364
52·6	1	,,	,,	80
51·5	1	,,	,,	401
50·3	1	,,	13·5	25
49·2	1n	,,	,,	47
47·8	1	,,	,,	74
42·3	1	,,	,,	584
41·2	1	,,	,,	605
40·8	1	,,	,,	13
39·4	2	,,	,,	41
36·3	1n	0·67	13·6	703
31·0	1	,,	,,	809
27·1	1	,,	,,	88
23·3	1	,,	13·7	965
21·3	1	,,	,,	45005
18·3	1	,,	,,	66
14·3	1n	,,	13·8	147
10·7	1	,,	,,	220

Absorption Spectra and Chemical Constitution of Organic Substances. —Interim Report of the Committee, consisting of Professor W. NOEL HARTLEY (*Chairman and Secretary*), Professor F. R. JAPP, and Professor J. J. DOBBIE, *appointed to investigate the Relation between the Absorption Spectra and Chemical Constitution of Organic Substances.*

Introduction.

IN presenting an interim report on the subject of the relation between the Absorption Spectra and Chemical Constitution of Organic Substances, it will be convenient to refer briefly to the report made to the British Association which was drawn up by Professor Huntington and presented at the Swansea Meeting in 1880.[1] It will there be noticed that the work originated in the discoveries of Sir George Gabriel Stokes in 1852 and 1853, and of the late Dr. William Allen Miller in 1862. Next M. L. Soret and MM. Soret and Rilliet advanced this line of research by showing that by the increased molecular mass of the alkyl radical there was increased absorption of the ultra-violet rays, though no absorption bands were observed in nitrates and nitrites of these substances. W. N. Hartley, in 1874, from a consideration that all the characteristic physical properties of organic substances are dependent on their molecular constitution, inferred that if a large number of substances of a similar constitution were examined, such as the ethereal salts of the organic acids and homologous series of the normal alcohols and acids, evidence would be obtained of the influence of impurities and of the variations in the absorption of the invisible rays caused by each increment of CH_2 in the molecule. The work was found impracticable without the aid of photography, and a form of camera was therefore constructed which admitted of metallic spectra being taken with all lines in focus on a flat plate from wave-lengths 5,400 to 2,000. It was also found necessary to employ dry-plates, and all the known makes were tried, some of which proved to be quite unsuitable. For the first time in spectrum work gelatino-bromide plates were used with success. The method of experimenting at the present time, except for a few modifications, is that described in the 'Phil. Trans.,' Part I., 1879., Hartley and Huntington.[2]

After the examination of a large number of specially purified carbon compounds the following generalisations were arrived at :—

1. The normal alcohols of the series $C_nH_{2n+1}OH$ are remarkable for transparency to the ultra-violet rays, pure methylic alcohol being nearly as much so as water.

2. The normal fatty acids exhibit a greater absorption of the more refrangible rays than the normal alcohols containing the same number of carbon atoms.

3. There is an increased absorption of the more refrangible rays

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[1] Report of the Fiftieth Meeting. (See p. 303.)

[2] *Proc. Roy. Soc.*, 1879, pts. i. and ii., vol. xxviii., p. 233. *Scientific Proceedings of the Roy. Dublin Soc.*, vol. iii., p. 93 (new series). 'Description of the Instruments and Processes employed in Photographing Ultra-Violet Spectra,' 1881, Hartley.

corresponding to each increment of CH_2 in the molecule of the alcohols and acids.

4. Like the alcohols and acids the ethereal salts (esters) derived from them are highly transparent to the ultra-violet rays, and do not exhibit absorption bands.

At a later date it was shown incidentally in the examination of other substances that the various secondary alcohols, isopropylic, isobutylic, and the different amylic alcohols showed no absorption bands. The same properties were shared by various polyhydric alcohols, such as glycol, glycerine, mannite, cane sugar, and dextrose.

In fact *no open chain carbon compound causes selective absorption.*

All substances derived from a closed chain of carbon atoms of the benzene type were found to be strongly adiactinic. It had been shown by Sir George Stokes that one of these substances, salicine, developed an absorption band when the solution was diluted. This matter was followed up by the examination of allied substances such as phenol, salicylic acid, and other derivatives of benzene, to ascertain whether they also exhibit absorption spectra characterised by bands.

The facts elicited were the following :—

5. Benzene and the hydrocarbons derived therefrom by the replacement of hydrogen, phenols, aromatic acids and amines, are remarkable—first, for their powerful absorption of the most refrangible rays ; secondly, for the absorption bands made visible by dissolving them in water or alcohol ; and thirdly, for the extraordinary intensity of these absorption bands even in very dilute solutions.

6. Isomeric substances containing the benzene nucleus exhibit widely different spectra, inasmuch as their absorption bands vary in position and intensity.

7. The photographic absorption spectra can be employed as a means of identifying organic substances, and as a most delicate test of their purity. The curves obtained by co-ordinating the extent of dilution, or in other words the quantity of substance, with the position of the rays of the spectrum transmitted by the solution, form a strongly marked and highly characteristic feature of very many substances.

Observations were extended to the essential oils, because they are known to consist for the most part of hydrocarbons which are physically isomeric, and which differ therefore in constitution from benzenoid hydrocarbons and their derivatives, though in a manner closely related to benzene. A large number of specimens were thoroughly examined.[1]

According to the classification employed at that time there were three groups, the second and third being polymers of the first, as shown by their formulæ,

$$C_{10}H_{16}, \quad C_{15}H_{24}, \quad \text{and } C_{20}H_{32}.$$

No absorption bands were discovered in any of the following specified substances or in the hydrocarbons derived from them by distillation ; but the extent of the absorption of the ultra-violet rays was found to be greater the larger the number of carbon atoms in the molecules ; such increase in the number of carbon atoms being due to the side chains when the nucleus of the compound was of the ring-form :—Terebene

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[1] *Proc. Roy. Soc.* vol. xxxi. pp. 1-26, 1881, Hartley and Huntington.

or pinene (which was shown subsequently to be camphene chiefly),[1] australene, terebenthene, hesperidene, cajeputene dihydrate; the oils of lign-aloe, Indian geranium, santal wood, cedrat, birch bark, juniper, rosemary, rosewood, lavender, vitivert, turpentine, cubebs, patchouli, citronella, elder, *Melaleuca ericifolia,* and cedar wood oil; the hydrocarbons extracted from cedrat, nutmeg, caraway, otto of rose, and otto of citron and menthol.

The presence of cymene, a benzene derivative, in some small proportion, in the hydrocarbons from thyme, lemon, and nutmeg, in the blue oil from patchouli, and also in one specimen of the caraway hydrocarbon, was proved by the absorption bands characteristic of that substance.

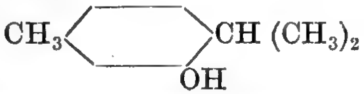
It was not within the scope of the Report of 1880 to treat especially of the relations between the absorption spectra and chemical constitution of organic compounds, but the conclusions just quoted must necessarily be taken into account, first in connection with the researches of Wallach and others on essential oils, and subsequently in the accounts of other investigations of absorption spectra which have since been published.

ESSENTIAL OILS AND THEIR CONSTITUENTS.

That essential oils of the terpene class are related in a certain manner to benzene was indicated in a general way by their powerful absorption, though their spectra are free from bands. Chemical researches have since thrown much light upon their constitution, and shown the nature of their relations to benzene, the hydrocarbons being hydrogen-addition products of cymene or some other benzenoid derivative.

It is now known that cymene is p. methyl-isopropyl benzene. By fractional distillation cymene had been separated from orange oil, French turpentine, and Russian turpentine; it was believed that these substances were largely composed of cymene, that it was in fact one of their constituents. It was shown, however, by their spectra that no cymene was contained in the first two and but 4 per cent. in the last. The inference was distinct and clear that the cymene found was the product of the chemical treatment to which these terpenes had been subjected while under investigation,[2] and in connection with the most recently made investigations of this nature it is a point of some importance.

But there were substances in essential oils characterised by very powerful absorption bands, and it was concluded that they were composed largely of true benzene derivatives or benzenoid hydrocarbons. These were the oils of bay, thyme, peppermint, bergamot, cloves, aniseed, cassia, carvone, myristicol, and otto of pimento. It was, however, generally admitted that eugenol with the constitution $C_6H_3(OCH_3)(C_3H_5)\cdot OH$ is contained in the oils of bay, pimento, and cloves; that anethol, $C_6H_4(OCH_3)(C_3H_5)$, is contained in aniseed, and that thymol, $C_6H_3(CH_3)(C_3H_7)\cdot OH$, is a constituent of oil of thyme (1 : 4 : 3 hydroxy-cymene) and may thus be represented :—



The constitutions of the oils of bergamot and peppermint were unknown,

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[1] *J. Chem. Soc.* vol. xxxv. p. 758, 1879.

[2] *Ibid.* vol. xxxvii. p. 676, 1880, Hartley.

as likewise those of the substances menthol, carvone, and myristicol, but the latter three were said to be isomeric.[1]

From the character of its spectrum it was shown that the nucleus of menthol was a terpene, while carvone and myristicol were concluded to be strictly benzenoid derivatives. Furthermore, a close examination of the absorption spectrum of myristicol led to the conclusion that it was a mixture of two substances, one only of which was capable of causing selective absorption. It was concluded that carvone was really a benzenoid derivative, oil of peppermint almost entirely so, while bergamot was shown to be a mixture of a terpene with a benzenoid derivative. Shortly these deductions were arrived at by considering that if a substance which shows absorption bands is not a mixture, no repeated fractional distillation will show any variations in the intensity of the absorption, or variations in the position of the bands in several fractions.

It was also pointed out that the refraction equivalents, as determined by Dr. Gladstone, are abnormal in carvone and myristicol, like those of substances derived from the aromatic nucleus.

The conclusions which were drawn at the time as to the constitution of those carbon groupings which can alone give rise to absorption bands have been fully justified, not only by purely chemical investigations, but also by more recent research into the absorption spectra of closed chain carbon compounds of different characters.

For instance, it was shown by Hartley[2] that camphor and benzene hexachloride exhibited merely a continuous absorption and no absorption band, furthermore that tetra-hydrobenzenes and tetra-hydropyridine or their derivatives possessed the same character.[3] Referring more particularly to the substances in essential oils we have the following classification:—

Terpenes, $C_{10}H_{16}$ or $(C_5H_8)_n$. Hydrocarbons, of which there are some 8 or 10 only as parent substances in essential oils.[4] The terpenes appear all to be nearly related by constitution to benzene, being, in fact, dihydrocymenes, $C_{10}H_{14}(H_2)$.

Pinene and Camphene Group.

Pinene, $C_{10}H_{16}$ liquid. Camphene, $C_{10}H_{16}$ solid. Pinene is the chief constituent of turpentine oil from different varieties of pine, eucalyptus oil, juniper oil, sage, terebenthene, sylvestrene, and australene. Camphenes from different sources differ from one another in rotary power; terecamphene is derived from terebenthene, austracamphene from australene.

Limonene and Dipentene Group, $C_{10}H_{16}$.

Dextro-limonene, $C_{10}H_{16}$, citrene, hesperidene, carvene, the chief constituent of cedar oil, cumin and dill oils. In oil of lemons it occurs along with pinene. Lævo-limonene is obtained from *Pinus sylvestris*.

Limonene from its reactions is probably a normal dihydro-para-

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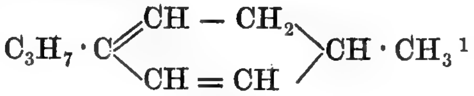
[1] *J. Chem. Soc.* vol. xxv. p. 1, Gladstone.

[2] 'Researches on the Relation between the Molecular Structure of Carbon Compounds and their Absorption Spectra,' *Trans. Chem. Soc.* vol. xxxix. p. 153.

[3] 'Absorption Spectra of the Alkaloids,' *Phil. Trans.* vol. clxxvi. pt. ii. p. 471, 1885.

[4] Wallach, *Ann. der Chemie*, vol. ccxxx. p. 225; vol. ccxxxix. p. 1; vol. ccxlv. p. 241; vol. cclii. p. 106, &c.; *Ann. der Chemie*, vol. ccxlvi. p. 236.

cymene. Its relation to carvone shows the position of the divalent unions, corresponding to the formula,



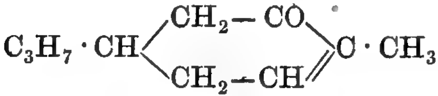
$$C_3H_7\cdot C\begin{cases}CH - CH_2\\ CH = CH\end{cases}CH\cdot CH_3$$ [1]

Dipentene, cinene, $C_{10}H_{16}$, inactive limonene.

Sesquiterpenes are widely distributed in the essential oils. The substances with high boiling point 274°–275° in oils of cubebs, patchouli, galbanum, and sabine oil are of this class.

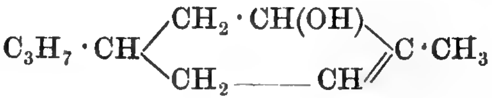
Camphor.

Japanese camphor, $C_{10}H_{16}O$, is a ketonic derivative of borneol, $C_{10}H_{18}O$, which is a hydroxy-tetrahydro-cymene. Their constitutional formulæ were formerly given thus :



$$C_3H_7\cdot CH\begin{cases}CH_2 - CO\\ CH_2 - CH\end{cases}C\cdot CH_3$$

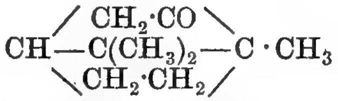
(Japanese Camphor.)



$$C_3H_7\cdot CH\begin{cases}CH_2\cdot CH(OH)\\ CH_2 —— CH\end{cases}C\cdot CH_3$$

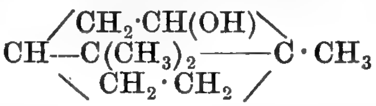
(Borneol.)

Bredt gives the following for camphor :—[2]



$$CH\begin{cases}CH_2\cdot CO\\ -C(CH_3)_2-\\ CH_2\cdot CH_2\end{cases}C\cdot CH_3$$

Consequently, the formula for borneol should be written thus :—



$$CH\begin{cases}CH_2\cdot CH(OH)\\ -C(CH_3)_2 ——\\ CH_2\cdot CH_2\end{cases}C\cdot CH_3$$

So far as we know at present, there is nothing in the absorption spectra of camphene and camphor which gives support to the one formula rather than to the other.

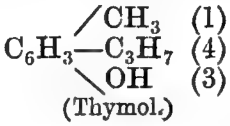
Cineol and terpineol are isomers of borneol. The former is a constituent of oils of cajeput and eucalyptus. It boils at 176°.

Menthol, or peppermint camphor, is a hydroxy-hexa-hydro-cymene. It can be crystallised from oil of peppermint after careful distillation. $C_{10}H_{19}.OH$. It yields a hydrocarbon menthene, $C_{10}H_{18}$. Myristicol, $C_{10}H_{16}O$, is the camphor from oil of nutmeg.

Patchouli camphor, from oil of patchouli, $C_{15}H_{28}O$, is a sesqui-camphor.

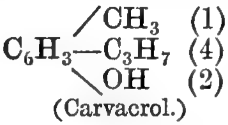
Phenols in Essential Oils.

Thymol and carvacrol are both methyl-iso-propyl phenols, and are derivatives of ordinary para-cymene containing the iso-propyl group.[3]



$$C_6H_3\begin{cases}CH_3 & (1)\\ C_3H_7 & (4)\\ OH & (3)\end{cases}$$

(Thymol.)



$$C_6H_3\begin{cases}CH_3 & (1)\\ C_3H_7 & (4)\\ OH & (2)\end{cases}$$

(Carvacrol.)

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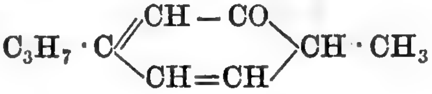
[1] Goldschmidt, *Berichte der deutsch. Chem. Ges.* vol. xviii. p. 1733.

[2] *Berichte der deutsch. Chem. Ges.* vol. xxvi. p. 3047, 1893.

[3] *Ibid.* vol. xix. p. 245.

Carvone, $C_{10}H_{14}O$ (formerly carvol), is isomeric with carvacrol, but it is a ketonic derivative of a dihydro-cymene.



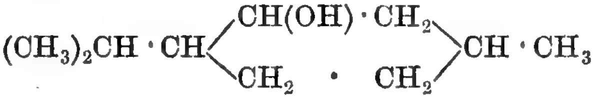
It will thus be seen that a marked distinction is to be drawn between the constitution of those substances in essential oils which are characterised by a continuous absorption, and those which exhibit the peculiarity of absorption bands; while the former belong to what has been termed the hydro-aromatic group, the latter are true derivatives of the aromatic series. The original conclusions have thus been confirmed.

Without entering into details of their structural formulæ in each case, it may be stated that none of the hydroxy-derivatives, or other oxy-derivatives, of the hydro-aromatic group exhibits absorption bands. Of substances which were examined the following examples may be referred to:

Citronellol,

$$(CH_3)_2C : CH \cdot CH_2 \cdot CH_2 \cdot CH(CH_3) \cdot CH_2 \cdot CH_2 \cdot OH$$

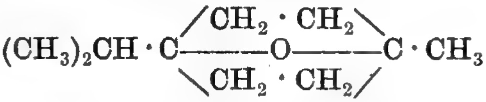
in rose, pelargonium, and geranium oils, and menthol, which has already been referred to,



both belong to the group of camphors with the general formula $C_nH_{2n}O$.

We have next the substances occurring in the oils of cajeput, eucalyptus, citronella, geranium, lemon, lign-aloe, and neroli.

Cineol,



Citronellal occurs in rose, pelargonium, and geranium oils.

$$(CH_3)_2C : CH \cdot CH_2 \cdot CH_2 \cdot CH(CH_3) \cdot CH_2 \cdot CHO$$

Geraniol (lemonol),

$$(CH_3)_2C : CH \cdot CH_2 \cdot CH_2 \cdot C(CH_3) : CH \cdot CH_2 \cdot OH$$

Lign-alöol,

$$(CH_3)_2C : CH \cdot CH_2 \cdot CH_2 \cdot C(CH_3)(OH) \cdot CH : CH_2$$

Nerolol, from oil of neroli, is believed to be identical with geraniol These belong to the class of camphors with the formula $C_nH_{2n-2}O$.

Note.—The absorption spectra of stereo-isomeric compounds have not up to the present yielded any indications which serve to distinguish between those which are lævo- and those which are dextro-rotatory, or, on the other hand, those which are inactive. In this respect there is a great difference between position isomerism and stereo-isomerism. The reason of this will possibly be evident from a consideration of the theory which accounts for the occurrence of absorption bands.

Two most distinct advances were made at this period which connect the molecular structure of organic substances with their absorption spectra. The first is the work of Russell and Lapraik and the second that of Abney and Festing. Both of these memoirs show what change is caused in the spectra of substances when alkyl radicals and hydroxyl are substituted for hydrogen. About this period the following work was also published. J. L. Schönn[1] examined the absorption spectra of methyl, ethyl, and amyl alcohol in layers from 1·6 to 3·7 metres in thickness, and observed narrow absorption bands in their spectra. Krüss, from Schönn's measurements, calculated their wave-lengths. They lie in the red, orange, and yellow.

	I.	II.	III.
Methyl alcohol	λ 643·0	632·8.	
Ethyl alcohol	λ 651·5	632·8	559·1.
Amyl alcohol	λ 659·1	636·2	562·7.

ON ABSORPTION-BANDS IN THE VISIBLE SPECTRUM PRODUCED BY CERTAIN COLOURLESS LIQUIDS.[2] *By* W. J. RUSSELL, *Ph.D., F.R.S., and* W. LAPRAIK, *F.C.S.*

These observations were made on long columns of liquid from 2 to 8 feet in length, and the substances examined were water, methylic, ethylic, propylic, and amylic alcohols. Amylic iodide, amylene, ether, ethyl iodide, aldehyde, acetic acid, benzene, toluene, xylene, phenol, monochlor-benzene, diclor-benzene, ammonia in water and in ether, methylamine in a 6-foot tube and in a 4-foot tube, ethylamine, diethylamine, triethylamine, aniline, toluidine, di-methyl aniline, turpentine, nitric acid, chloroform and naphthalene. All these substances in the thicknesses mentioned give very well defined but rather narrow absorption bands between λ 600 and λ 740. Toluidine gave a general absorption extending to λ 480. The bands of the different substances, it must be understood, differ altogether from those peculiar to water. All the alcohols give a similar band, but with different alcohols it has in each case a different position. *The higher the alcohol stands in the series, the nearer is the band to the red end of the spectrum.* The illustrations in the 'Jour. Chem. Soc.' (figs. 2, 3, 4, and 5) show these bands, p. 168. The esters gave interesting results; for in all cases a very similar band to that of alcohol was observed, but always in a position slightly nearer the blue end of the spectrum. In the case of ethyl iodide another band was visible, extending from λ 716 to 724. It is stated that probably this band is characteristic of all ethereal salts, but in other cases is hidden by the general absorption. Fig. 9 shows the spectrum of the iodide. In the amylic series the nitrate, acetate, and iodide were examined. They behave exactly in the same way as the compound ethylic ethers, viz., they all give bands similar to the alcohol band (fig. 5), but slightly nearer the blue. The same band running through each alcoholic series shows that the band-producing body is unaffected by the acid radical.

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[1] *Wiedemann's Ann.* vol. vi. p. 267, 1879.

[2] *Trans. Chem. Soc.* vol. xxxix. p. 168, 1881.

One of the most interesting points in this work of Russell and Lapraik is the observations on substituted benzenes and ammonias: for every CH_3 group introduced either into the C_6H_6 or the NH_3 molecule there is a shifting of the bands of absorption towards the red end of the spectrum. This is quite definitely established. In the ultra-violet a similar result was found by Hartley and Huntington for tri-ethylamine, di-ethylamine and ethylamine: for each ethyl group introduced there was a shortening of the spectrum.[1]

ON THE INFLUENCE OF THE ATOMIC GROUPING IN THE MOLECULES OF ORGANIC BODIES ON THEIR ABSORPTION IN THE INFRA-RED REGION OF THE SPECTRUM.[2] *By* Captain ABNEY, *R.E.*, *F.R.S.*, and Lieutenant-Colonel FESTING, *R.E.*

Abney and Festing have photographed rays extending down to λ 12000; the visible region ends about λ 7600. They studied the absorption spectra of water, hydrochloric acid, chloroform, carbon tetrachloride, cyanogen, and a number of hydrocarbons and their hydroxyl, haloid, and carboxyl derivatives.

Those carbon compounds which contain hydrogen show a characteristic group of lines, which, however, are absent from compounds containing no hydrogen. They do not all appear in some of the hydrogen compounds, and it is inferred that they belong to hydrogen.

When oxygen is present as hydroxyl, it obliterates the rays between two of the lines, which are due to hydrogen. When it forms part of the carbon nucleus of a compound, as it does in aldehyde, the spectrum is inclined to be linear, or the bands are bounded by well-defined lines. These appear to be characteristic bands which indicate the carbon nucleus of a series of substances.

There are some radicals which exhibit a distinctive absorption spectrum, in some cases lying near λ 7000, in others about λ 9000. In benzene, aniline, and ethylaniline, the following coincident bands are probably due to the benzene nucleus; a line at λ 8670 is the principal one, λ 8670 to 8720, λ 8720 to 8880, and a fourth band about λ 9300, a fifth being about λ 10400 to 10660.

In benzene and ethyl-aniline there occurs a band also at λ 10970 to 11050. If the line λ 8670 is associated with a band, it is almost certain to be caused by the benzene nucleus.

Ethyl compounds are indicated by absorption at λ 7410, 8950 to 9030, 9040 to 9070, 9130 to 9180, 9270 to 9300·5, and 9320 to 9420.

It is remarkable that the solar spectrum shows an absorption band at λ 8660, and, with the exception of the line at 7410, the absorptions observed are coincident with bands or lines in the solar spectrum.

It is also a remarkable fact that the halogens are not recognisable by any band or lines; for instance, the lines of hydrochloric acid are really the lines of hydrogen.

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[1] *Phil. Trans.* 1879, Plate 22.

[2] *Phil. Trans.* Part III. 1881, by Captain Abney, R.E., F.R.S., and Lieut.-Col. Festing, R.E.

THE MEASUREMENT OF THE ULTRA-VIOLET SPECTRA.

Up to this period 1883–84, the only wave-lengths of lines available for reference in the region of the ultra-violet were those of the metal cadmium, measured by M. Mascart, and these were found insufficient. To obviate the difficulty in accurately describing spectra, the spark-spectra of twenty-two elements had been photographed,[1] and the absolute wave-lengths of lines belonging to sixteen elements were determined by Hartley and Adeney.[2] A selection from these had been utilised for the investigation of absorption spectra. Liveing and Dewar [3] published the arc and spark spectra of iron and some other metals, but it had been previously found [4] that the spark spectrum of iron was unsuitable for such work. By the use of electrodes containing the metals lead, tin, and cadmium, and occasionally for special purposes copper and bismuth, a large number of reference lines of known wave-length were available, and a greater degree of accuracy was now attainable in the measurement of absorption bands.

It became more convenient to describe the absorption spectra in terms of the oscillation frequencies of the absorbed rays than in wave-lengths. As, however, the actual oscillation frequencies per second of time were inconveniently large numbers, the inverse wave-lengths were employed, their accuracy being even greater than the measurements of absorption spectra will admit of, and they answer the purpose though the unit of time is but a small fraction of the second.

ON THE VARIOUS COMBINATIONS WHICH SHOW CONTINUOUS ABSORPTION SPECTRA ONLY.

It had been shown by Hartley [5] (1) *that neither the olefines, acetylene, nor amyl-alcohol show absorption bands;* (2) *that in all cases where the carbon atoms are supposed to be arranged in an open chain, no absorption bands are seen;* (3) *that the replacement of* H *in any compound by the radicals of the formula* C_nH_{2n+1}, or C_nH_{2n-1}, *by* NH_2, OH, COOH, *or by* SO_3H, *has no influence on the production of absorption bands;* (4) *when halogens are substituted for* H *in a compound, and the result is a colourless body, no bands are caused to appear in its spectrum.* It was then pointed out [6] that when an atom of carbon is united to an atom of nitrogen, no absorption bands are seen in the ultra-violet spectrum transmitted by such a combination. This conclusion was drawn in the first instance from the results of Dr. W. A. Miller and of M. L. Soret, but independent observations were made on hydrocyanic acid and potassium cyanide, using very strong solutions and greater thicknesses of liquid. The results furnished the following conclusion:

The simple union of carbon to nitrogen does not cause selective absorption of the ultra-violet rays.

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[1] *Scientific Trans. of the Royal Dublin Soc.* vol. i. p. 231 (New Series, 1881); *J. Chem. Soc.* 'Notes on Certain Photographs of the Ultra-violet Spectra of Elementary Bodies,' vol. xli. p. 84, 1882.

[2] *Phil. Trans.* vol. clxxv. p. 63, pt. i. 1884.

[3] *Phil. Trans.* vol. clxxiv. pp. 187–222, 1884.

[4] *Phil. Trans.* vol. clxx. pt. i. p. 257, 1879, Hartley and Huntington.

[5] *Trans. Chem. Soc.* 1881.

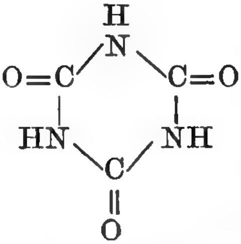
[6] *Trans. Chem. Soc.* 1882.

A conclusion regarding cyanuric acid was formed which has since been found to be erroneous. The examination of a very fine specimen gave an absorption band of a character indicating that the substance was intermediate in compactness of structure between benzene and benzene-hexachloride.[1]

Recent experiments have proved from the examination of several newly made preparations, and of a portion of the original specimen, that it has no absorption band in its spectrum.[2]

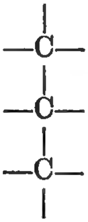
Special difficulties are encountered in the examination of the spectrum of cyanuric acid, owing to its slight solubility in cold water or even in water which is warm. Thicknesses of a warm solution of 100 and 200 mm. were examined. It contained 2·5 grains of the substance in 500 c.c. With 100 mm. of solution the spectrum was found to be cut off sharply at $^1/\lambda$ 4027. With a thickness of 200 mm. it terminated sharply about $^1/\lambda$ 3888, but the spectrum was weakened from about $^1/\lambda$ 3000. The band originally described was situated between $^1/\lambda$ 3640 and 3888, and was therefore in the weakened part of the spectrum.

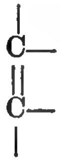
The formula previously assigned to this substance should probably be altered to the following :

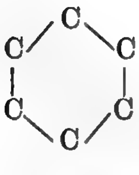


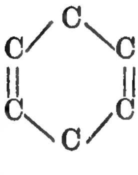
as being more consistent with the recently ascertained facts than that advanced in 1882.

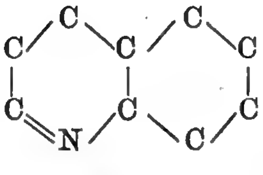
The absorption spectra of substances containing the following typical carbon groupings show no absorption bands even through the very wide range of the foregoing investigations :











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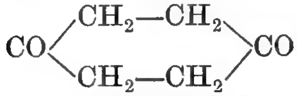
[1] *Trans. Chem. Soc.* vol. xli. pp. 4, 5, 1882, Hartley.

[2] *Proc. Chem. Soc.* vol. xv. (204), p. 46, 1899.

Latterly the following substances have been examined with a like result:

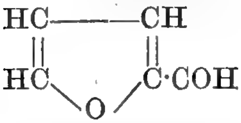
Typical Closed Chain Compounds which show no Absorption Bands, but transmit Continuous Spectra.[1]



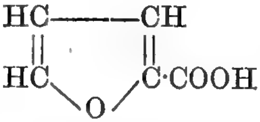
Diketo-hexa-methylene

$C_4H_3O{\cdot}CH(N : CH{\cdot}C_4H_3O)_2$

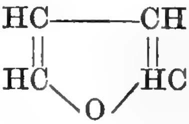
Furfuramide



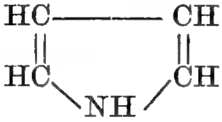
Furfuraldehyde



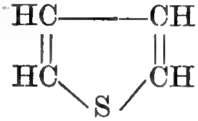
Pyromucic Acid



Furfurane



Pyrrole



Thiophene

The absorption of the ultra-violet rays by solutions of some of these substances, and particularly thiophene, is very intense, but in no case is there any selective absorption.

It is necessary now to refer back to a series of papers included under the heading 'Researches on the Relation between the Molecular Structure of Carbon Compounds and their Absorption Spectra.'[2]

ON MOLECULAR AND INTRAMOLECULAR VIBRATIONS.

In the 'Chem. Soc. Trans.,' vol. xxxix. p. 161, 1881, the spectra of condensed benzene nuclei were examined, such as are obtained from naphthalene, anthracene, and phenanthrene. The diagrams of the absorption spectra of these substances were drawn to scale, and they show enormous differences in the intensity of the absorption bands in these different hydrocarbons as well as differences in the positions of the bands. For instance, six bands were measured in the spectrum of benzene, and four of these are visible when one part is diluted with 2,400 of alcohol; then in naphthalene with a dilution of 1 in 100,000 parts, one in phenanthrene with 1 in 500,000 parts, and one in anthracene with 1 in 5,000,000 parts, the thickness of the layer of liquid in each case being only 15 millimetres. In February, 1881,[3] it was stated that the mean wave-length of the rays intercepted by ozone is 2,560 tenth-metres. From this the mean rate of vibration of the molecule of ozone can be calculated. When perfect absorption occurs, the molecule of the absorbing medium must be vibrating synchronously, and in the same plane with the ray absorbed, from which it follows, if the velocity of light be taken as 315,364,000 metres per second (Fizeau), the mean rate of vibration per second of time of the molecule of ozone must amount to 1,231,000,000,000,000 vibrations.

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[1] 'The Ultra-violet Absorption Spectra of some Closed Chain Carbon Compounds,' *Trans. Chem. Soc.* 1898, p. 598, W. N. Hartley and James J. Dobbie.

[2] *Trans. Chem. Soc.* 1881, W. N. Hartley.

[3] *Trans. Chem. Soc.* vol. xxxix. p. 60, 'On the Absorption Spectrum of Ozone,' Hartley.

On the Cause of Absorption Bands in the Spectra transmitted by Benzene and its Derivatives.[1]

It was pointed out that in the absorption of ultra-violet rays by hydrocarbons of the aromatic series we have two kinds of absorption made manifest, namely, a general and a selective absorption. It is the selective absorption which distinguishes these from all other compounds of whatever class, so far as our knowledge at present extends.

While the absorption spectrum of alcohols and fatty acids and amines depends upon and varies with the molecular weight of the compounds, or, more strictly expressed, with the number of carbon atoms in the molecule, in aromatic compounds it depends entirely on *the structure* of *the molecule.*

For instance, a terpene, $C_{10}H_{16}$, is much more strongly diactinic than naphthalene, $C_{10}H_8$, and benzene hexachloride, $C_6H_6Cl_6$, than benzene, C_6H_6. Cymene, $C_{10}H_{14}$, or $CH_3{\cdot}C_6H_4{\cdot}CH(CH_3)_2$, p. methyl-isopropylbenzene, if compared with naphthalene, $C_{10}H_8$, is found to possess only one-fifth the absorptive power of the latter, and it gives a very different spectrum. There is a similar difference between anthracene and phenanthrene, both with the composition $C_{14}H_{10}$. Such a difference is quite usual with isomerides of the aromatic series.

When the molecule of a substance is capable of vibrating synchronously with a radiation, the ray received on this substance is absorbed. The absorption is complete if the *direction* of the vibration of the ray and of the molecule is the same, but the *phase* opposite. It is evident that general actinic absorption, exerted by carbon compounds, is due to the vibrations of the molecules, since absorption increases in extent with the number of carbon atoms in the molecule, or, in other words, in any homologous series the greater the molecular mass the lower the rate of vibration of the molecule. Selective absorption appears to be caused by the vibration of atoms or atomic groupings within the molecule.

When a substance such as benzene absorbs all rays more refrangible than λ 2743, it is because the molecules are vibrating synchronously with these rays, and the number of molecules within the path of the rays is sufficient to damp all vibrations. When the liquid is diluted the number of molecules present is not sufficient to damp all the vibrations, and some rays are transmitted.

If, however, certain carbon atoms within the molecule are vibrating synchronously with certain rays, we shall have selective absorption of these rays after the general absorption has been so weakened by dilution as to allow them to pass. It was not found possible to associate any of the absorption bands of the substances examined with any particular carbon atoms; furthermore, it was shown that the intra-molecular vibrations were dependent upon the vibrations of the molecules.

From numbers representing approximately the mean wave-lengths of the four chief bands of rays absorbed by benzene, naphthalene, and anthracene, and from the velocity of light, the mean rate of vibration of the molecules of benzene, naphthalene, and anthracene were calculated. The following are the numbers given:—

Mean λ		Vibrations per second of time
Benzene, 2526	=	1,248 10^{12}
Naphthalene, 2687	=	1,177 ,,
Anthracene, 3439	=	910 ,,

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[1] *Trans. Chem. Soc.* vol. xxxix, p. 165, 1881.

The mean rate of vibration of the rays absorbed by naphthalene is less than that absorbed by benzene, and those of anthracene less than those of naphthalene. It follows from this that the vibrations within the molecules are not independent of but are a consequence of the fundamental molecular vibrations, like the harmonics of a stretched string, or a bell. When the rate of the vibration is reduced by the increase in mass of the molecule, the rate of vibrations of the carbon atoms is reduced in a similar ratio.

In the case of a vibrating string or tuning-fork, greater amplitude of vibration means a louder note; in the case of a luminous vibration it means a brighter light; consequently the converse of this should hold good, that a greater intensity of absorption is caused by a greater amplitude of vibration in the molecules of the absorbing medium, the number of molecules remaining constant. Hence it follows that as the absorbing power of anthracene and naphthalene is, molecule for molecule, greater than that of benzene, the amplitude of vibration of the molecules of these substances is greater. Now, the mean rate of vibration of the rays absorbed by naphthalene and anthracene is less than that of the rays absorbed by benzene, though the character of the absorption is the same in each case. Hence we may conclude that though the wave-form is similar, the *amplitude* of the vibrations is greater, and the *rate* of vibrations is slower.

From the foregoing views it will be observed that where λ is the wave-length, $^1/\lambda$ is the oscillation frequency in a small unit of time; omitting the correction for the refraction of air, which is a very small amount, and in representing absorption bands by inverse wave-lengths, we refer them directly to the oscillation frequencies of the absorbed rays, $^1/\lambda$, a very convenient mode of representing them.

It will be seen in dealing with coloured substances that Gerard Krüss, seven years later, in 1888,[1] also [2] gives expression to similar views, which are thus stated in his papers.

Although the kinetic energy of gases gives some account of the translation of molecules through space, yet no satisfactory hypothesis has been brought forward to illustrate either the rotation of the molecules about their own axes, or the interatomic movements within the molecules. These two last the author terms 'inner molecular movements.' From the undulatory theory of light, deductions may be drawn regarding these inner molecular movements, inasmuch as the vibrations of the ether, which fills the intramolecular space, are a resultant within that space of the velocity and amplitude of the molecular vibrations.

Thus, if λ be the wave-length of a ray emitted by a substance, v the velocity of light, the number of vibrations, n, which a molecule sends forth by movements of it as a whole and of its parts, can be determined by the equation, $n = \frac{v}{\lambda}$. The phenomena of emission and of absorption spectra thus throw some light on the least and most extensive form of this inner molecular movement. The latter point is discussed, together with relation to the interatomic attraction, which is subject to the chemical constitution of the molecule; inasmuch as the vibrations of the particles of a body are capable of being excited only by vibrations of a like period

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[1] *Ber.* vol. xviii. pp. 2586–2591.

[2] *Zeitschrift für physikalische Chemie*, vol. ii. pp. 312–337, 1888.

in the external ether, so from the wave-lengths of those rays of light which are absorbed to the greatest degree by the solution of any substance, the number of the vibrations of the molecules within the liquid can be calculated from the equation given. The number of vibrations for billionths of a second were calculated for indigo, rosolic acid, fluoresceïn, and their various derivatives, the absorption spectra of which had been examined. These will be referred to later on.

The Spectra of Tertiary Bases.

These substances are of particular interest, owing to their connection with the natural alkaloids.[1]

Cinchomeronic acid, the pyridine dicarboxylic acid obtained by the oxidation of quinine, &c. with potassium permanganate, has a strong absorption band between λ 2743 and λ 2574.

Picoline.—An alcoholic solution containing $\frac{1}{15000}$th of the substance shows a strong absorption band lying beyond λ 2743, but a broad band of rays is fully transmitted further on. Solutions containing $\frac{1}{50000}$th show a strong absorption band lying between λ 2743 and λ 2574. The absorption band is narrowed but is not destroyed by dilution to $\frac{1}{100000}$th.

Since picoline is a methyl-pyridine it follows that

The substitution of nitrogen for carbon in the benzene nucleus does not destroy or impair the power of selective absorption possessed by the original molecule.

The substitution of nitrogen for carbon in the benzene ring really removes an atom of hydrogen. This action greatly increases the absorptive power of the substance, as will be seen by comparing methyl-benzene (toluene)[2] with picoline or methyl-pyridine. There is a striking resemblance between the two spectra, but the narrow band characteristic of the homologues of benzene is absent.

Quinoline.—A solution of this substance in alcohol containing $\frac{1}{10000}$th shows one narrow band a little beyond λ 3076. Two narrow bands and a broad one are seen in solutions containing $\frac{1}{15000}$th, and a trace of absorption continues until the dilution has reached $\frac{1}{50000}$th. This spectrum is a remarkable one.

Comparing picoline with toluene, and quinoline with naphthalene, the chief difference to be noted in their absorption spectra is the increased intensity of absorption in the case of the nitrogen compounds.

Ultra-violet Spectra of Derivatives of the Paraffins.
By J. L. SORET *and* A. A. RILLIET.[3]

There is considerable difficulty in obtaining compounds of sufficient purity for observations on the ultra-violet rays. The alcohols were found to show great transparency to the ultra-violet, and any apparent exceptions were probably due to impurities. In the rectification and prolonged desiccation of the alcohols there is often slight oxidation, which leads to the production of impurities which affect the results of an examination. Hartley and Huntington concluded that in the series of alcohols

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[1] 'Researches on the Relation of the Molecular Structure of Carbon Compounds to their Absorption Spectra,' pt. vi. *Trans. Chem. Soc.*, February 1882.

[2] *Phil. Trans.* 1879, Pl. 25.

[3] *Comptes Rendus*, vol. cx. pp. 137–139, 1890.

the absorption of the ultra-violet increased as the complexity of the molecules increases in any homologous series. It was found, however, by Soret and Rilliet that when the process of drying was rapidly executed, ethyl alcohol is not appreciably less diactinic than methyl alcohol. Ketones, it was found, are strongly adiactinic, but any differences which were perceived were not greater than might be attributed to small quantities of impurities which it is difficult to exclude. Pure ether is almost as transparent as pure water, to the ultra-violet spectrum. In dealing with haloid derivatives it was found that the substitution of one alkyl for another has very little effect upon their transparency, and this is particularly well marked in iodides.

It is concluded that the action on the ultra-violet rays constitutes a very delicate test of the purity of an organic substance.

Note on Soret and Rilliet's Observations.—The difficulty in obtaining compounds derived from the paraffins of sufficient purity was found by Hartley and Huntington to be so great, in the case of hydrocarbons, that after repeated trials all hope of obtaining a sufficient number of pure homologues was abandoned. As a rule, substances were examined immediately after they had been submitted to a final distillation and their boiling points taken. In the case of ethyl alcohol, it was difficult to obtain it quite free from traces of other substances, which affected its spectrum. Samples were dehydrated finally by standing over freshly burnt lime for twelve hours, and then submitted to distillation. This process was recommended by Dupré. Haloid derivatives are remarkable for their transparency, particularly those of chlorine.

With the organic acids of the fatty series great difficulty was experienced, and this is mentioned in the original memoir. In place of the acids themselves salts were taken, but such anomalous results were obtained with the same substance that a careful examination led to the discovery of such substances as formates being oxidised to oxalates by the process of evaporation and crystallisation. To obviate the difficulties which were thus encountered barium or calcium salts were crystallised, by which means any oxalate formed remained insoluble.

Measured in terms of wave-lengths, the actual difference between ethyl alcohol, methylic alcohol, and pure water is very small. In fact, methylic alcohol is very slightly different in this respect from water. This is shown on Plate 1 in the 'Phil. Trans.' 1879.

CURVES OF MOLECULAR VIBRATIONS.

Researches on the Relation between the Molecular Structure of Carbon Compounds and their Absorption Spectra. Part VII. (HARTLEY).[1]

In this paper the results of the examination of the absorption spectra of the following substances are given :

(1) Aromatic hydrocarbons : benzene and naphthalene.

(2) Aromatic tertiary bases and their salts : pyridine, dipyridine, picoline, quinoline, and their hydrochlorides.

(3) Addition products of tertiary bases and salts : piperidine, tetrahydro-quinoline, and its hydrochloride.

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[1] *Trans. Chem. Soc.* vol. xlvii. p. 685, 1885.

(4) Primary and secondary aromatic bases or amido-derivatives and salts thereof : ortho- and para-toluidine and their hydrochlorides.

(5) Isomeric bodies : the three xylenes.

The Preparation of Solutions and Method of Examination.—In dealing with a variety of nearly related substances from which similar solutions have to be prepared, it is necessary that the solution of the least soluble substance (largest solution) shall, as far as possible, serve as a standard for the preparation of the other solutions. It was found most convenient to take a molecular weight in milligrams and dissolve it in 20 c.c. of absolute alcohol or any other menstruum better suited to the particular substance. In this way molecular weights were distributed through—that is to say, made to occupy equal volumes. The solutions, instead of being repeatedly diluted and examined in cells of the same thickness, were placed in a series of cells varying in thickness from 25 to 1 mm. ; if with a thickness of 1 mm. absorption bands were still visible, the liquid was diluted to five times its original volume, and another series of photographs taken ranging from 5 mm. downwards.

The wave-lengths in tenth-metres have been converted into reciprocal numbers, which have the advantage of representing oscillation frequencies per unit of time.

When a series of photographs had been secured which gave sufficient information from which a curve could be drawn indicating both the general and the selective absorption, the oscillation frequencies of the absorbed rays were taken as abscissæ and the proportional thicknesses in mm. of the weakest solution as ordinates. The curves are made continuous, and a careful description of the spectra obtained by transmitting rays through varying thicknesses of the solutions is intended to supplement the curves and serve the purpose of the shaded diagrams which had hitherto been employed.[1]

It will be convenient here to introduce some recent measurements of the bands in the spectrum of benzene.

(1) *Aromatic hydrocarbons.*—The absorption spectrum of benzene shows six absorption bands, while that of naphthalene shows four.

(2) *Aromatic tertiary bases and their salts.*—In the case of the bases and their hydrochlorides, the method of examination consisted in photographing the spectra, transmitted by the base contained in one series, and the molecule of hydrochloric acid contained in another, the rays from the spark passing through both. The contents of the two series of cells being then mixed and returned to their original vessels, a second series of photographs was taken. As the hydrochloric acid proved perfectly diactinic, the first spectra represent the absorption caused by the base alone, the second that caused by the salt. The difference in the mode of vibration of the base, the acid, and the salt, is very striking ; the amplitude of the vibrations within the molecule of the salt being much less, as one would imagine, than in that of the base. The absorption spectra of pyridine and its hydrochloride, of dipyridine, and picoline, show one absorption band each. Two specimens of quinoline were examined ; one prepared from coal-tar, and the other synthetically by Skraup's reaction. The absorption spectra of the two specimens were identical, and showed three absorption bands.

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[1] *Trans. Chem. Soc.* vol. xlvii. p. 687, 1885.

(3) *Addition products of tertiary bases and salts.*—Piperidine has no power of selective absorption; this was predicted from the behaviour of benzene hexachloride, which also has no power of selective absorption. Tetra-hydro-quinoline, on the other hand, has still the power of selective absorption, and its spectrum shows one absorption band.

(4) *Primary and secondary aromatic bases or amido-derivatives and their salts.*—Both ortho- and para-toluidine and their hydrochlorides show an absorption band.

(5) The absorption spectra of ortho- and meta-xylene both show an absorption band; that of para-xylene shows two absorption bands.

These substances being, unlike other isomeric bodies formerly examined, free from oxygen, afford a means of estimating the differences in molecular absorption which is due to nothing more than the so-called relative functions of the compound radicals.

The area enclosed by the curve of metaxylene appears to be the least, that of orthoxylene stands next, while that of paraxylene is the greatest.

The following deductions were drawn from the investigations:

1. *When an atom of nitrogen is substituted for an atom of carbon in the benzene or naphthalene nucleus, the property of selective absorption is still retained.*

This had already been inferred from an examination of picoline.[1]

2. *When the condensation of the carbon and nitrogen in the molecule of a benzenoïd compound or tertiary base is modified by the addition thereto of an atom of hydrogen to each atom of carbon and nitrogen, the power of selective absorption is destroyed.*

3. *When the condensation of the carbon atoms in quinoline is modified by the combination therewith of four atoms of hydrogen, the intensity of the selective absorption is reduced but is not destroyed.*

4. *Molecules of compounds—that is to say, molecules composed of dissimilar atoms—vibrate as wholes or units, and the fundamental vibrations give rise to secondary vibrations which stand in no visible relation to the chemical constituents of the molecule, whether these be atoms or smaller molecules.*

THE SPECTRA OF VARIOUS AROMATIC HYDROCARBONS AND SUBSTANCES DERIVED THEREFROM.

Note on the Absorption Bands in the Spectrum of Benzene.
(HARTLEY *and* DOBBIE).[2]

When benzene is examined with a wide slit, lenses of long focus, and a powerful spark, a remarkable feature is noticeable in the spectra photographed. The absorption bands are seen to be degraded in the direction of the least refrangible rays, suggesting that the bands consist of groups of lines stronger and closer together on the more refrangible side; weaker and wider apart on the less refrangible. Such were the conditions under which the first photographs were taken. By using a very powerful spark, but with an instrument of short focus and a narrow slit, the rays emitted by cadmium electrodes may be rendered sufficiently continuous to show

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[1] *Trans. Chem. Soc.* vol. xli. p. 47, 1882.

[2] *Trans. Chem. Soc.* p. 695, 1898.

these bands, and at the same time to render the lines sharp enough to serve as a scale of wave-length measurements.

The series of independent measurements obtained from photographs taken under the latter conditions, when compared with those obtained by Pauer by examining the vapour of benzene,[1] show that his weak line λ 2670 is identical with the first absorption band, and his weak band λ 2390–2360 with the sixth absorption band observed in solutions of benzene in alcohol. The result of Pauer's work was to show that the constitution of the absorption bands in benzene, when the substance is vaporised, is that of lines, or groups of closely adjacent lines. The action of a solvent is to cause the lines to be dispersed or merged into bands.

Benzene.

0·078 gram, or 1 milligram molecule, in 20 c.c. of alcohol.
Strong absorption bands to the number of six.

Thickness of layer of liquid in millimetres	Description of spectrum	$\frac{1}{\lambda}$
25	One band, absorption beyond complete	3691—3727
20	One band	3691—3727
10	Two bands, not very distinct.	
	First from	3691—3730
	Second from	3755—3883
5	The first absorption band is barely visible.	
	The second absorption band from	3802—3854
	Absorption band, third from	3886—3947
	„ „ fourth from	3979—4043
	„ „ fifth from	4075—4128
	„ „ sixth from	4170—4189
4	Absorption band, second from	3802—3847·5
	„ „ third from	3883—3947
	„ „ fourth from	3979—4040
	„ „ fifth from	4075—4122·5
	„ „ sixth from	4170—4215
3 2	The description applies to both these spectra.	
	Absorption band, second from	3812—3847·5
	„ „ third from	3915—3937
	„ „ fourth from	3995—4030
	„ „ fifth from	4100—4120
	„ „ sixth from	4190—4210
1	Absorption band, second from	3819—3847·5
	„ „ third from	3915—3934
	„ „ fourth from	4004—4024
	„ „ fifth from	4103—4116
	„ „ sixth from	4202—4208·5
	Continuous spectrum to	4555

It is perhaps worth while to draw attention to a slight mistake on p. 364 of Herr Pauer's paper; he credits Müller with work on the ultra-violet rays, but the author referred to is undoubtedly the late Dr. William Allen Miller. It has been explained also by Professor W. R. Dunstan,

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[1] *Wied. Ann.* vol. lxi. p. 362, 1897.

whom he mentions as having investigated ultra-violet absorption spectra, that certain work by Hartley and Huntington was in error attributed to him.[1]

Naphthalene.

·128 gram, or 1 milligram molecule, in 20 c.c. of alcohol.

With 5, 4, and 3 mm. the spectrum is continuous to $^1/\lambda$ 3151. With 3 mm. an absorption band (1) appears from $^1/\lambda$ 3194 to 3228, and a second absorption band (2) from $^1/\lambda$ 3249 to 3297; with 2 mm. both bands are still seen. With 1 mm the band (1) has narrowed somewhat, and the second band (2) has disappeared.

1 mill. mol. in 100 c.c. alcohol.

With 5, 4, and 3 mm. the band (1) is still seen from $^1/\lambda$ 3204 to 3228.

A third absorption band (3) also appears from $^1/\lambda$ 3359 to 3379.

With 2 mm. the band (3) still persists, while a fourth band (4) from $^1/\lambda$ 3439 to 4259 appears.

With 1 mm. only the band (4) is seen, band (3) having disappeared.

1 mill. mol. in 500 c.c. alcohol.

With 5, 4, 3, and 2 mm. the absorption band (4) is still seen; it gradually narrows as the thickness of the layer is diminished. With 1 mm. the absorption band (4) has disappeared.

Ortho-xylene.

1 mill. mol. in 20 c.c. alcohol.

With 25 and 20 mm. the spectrum is continuous $^1/\lambda$ 3611, but weak towards the violet end. With 15 mm. an absorption band appears from $^1/\lambda$ 3611 to 4331, and persists until the layer is only 2 mm. thick. With 1 mm. the absorption band has disappeared and the spectrum is continuous to $^1/\lambda$ 4426·7.

Meta-xylene.

1 mill. mol. in 20 c.c. alcohol.

With 25, 20, and 15 mm. the spectrum is continuous to $^1/\lambda$ 3580. With 15 mm. there is a faint prolongation to $^1/\lambda$ 3611. With 10 mm. an absorption band appears from $^1/\lambda$ 3611 to 4331. This band persists until a thickness of 2 mm. is reached. With 1 mm. the band has disappeared.

Para-xylene.

1 mill. mol. in 20 c.c. alcohol.

With 25, 20, and 15 mm. the spectrum is continuous to $^1/\lambda$ 3537. With 15 mm. there is a faint prolongation to $^1/\lambda$ 3580. With 10 mm. an absorption band (1) appears from $^1/\lambda$ 3580 to 4331. This band is still seen when the layer is 1 mm. in thickness. With 1 mm. a second absorption band (2) also appears from $^1/\lambda$ 3701 to 3890.

1 mill. mol. in 100 c.c. alcohol.

With 5, 4, 3, and 2 mm. the two absorption bands are still seen: (1) from $^1/\lambda$ 3611 to 3701; (2) from $^1/\lambda$ 3701 to 3890. With 1 mm. both bands have disappeared and the spectrum is continuous to $^1/\lambda$ 4426·7.

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[1] *Chem. News*, 1891, vol. lxiii. p. 309; 1891, vol. lxiv. pp. 10 and 212.

Pyridine.

1 mill. mol. in 20 c.c. alcohol.

With 5, 4, 3, 2, and 1 mm. there is complete absorption beyond $^1/\lambda$ 3647.

1 mill. mol. in 100 c.c. alcohol.

With 5, 4, 3, 2, and 1 mm. an absorption band appears from $^1/\lambda$ 3707 to 4426·7.

1 mill. mol. in 500 c.c. alcohol.

With 5, 4 and 3 mm. the absorption band appears from $^1/\lambda$ 3768 to 4253. With 2 and 1 mm. the absorption band disappears and the spectrum is continuous to $^1/\lambda$ 4566, but weak towards the violet end.

Pyridine and HCl.

·1155 gram hydrochloride in 40 c.c. alcohol.

Double thicknesses of cells taken. With 10, 8, and 6 mm. the spectrum was continuous to $^1/\lambda$ 3611. With 4 and 2 mm. an absorption band appeared from $^1/\lambda$ 3647 to 4426·7.

·1155 gram hydrochloride in 200 c.c. alcohol.

With 10 mm. the absorption band appears from $^1/\lambda$ 3467 to λ 4426·7. With 8, 6, 4, and 2 mm. the absorption band is still seen, but it gets narrower as the thickness of the layer of liquid is diminished.

·1155 gram hydrochloride in 1,000 c.c. alcohol.

With 10 mm. absorption band appears from $^1/\lambda$ 3762 to 4125, and it persists until a thickness of 6 mm. is reached. With 4 mm. the absorption band disappears, and with 2 mm. the continuous spectrum is obtained.

Dipyridine.

158 gram in 1,000 c.c. alcohol.

With 5, 4, 3, and 2 mm. the spectrum is continuous to $^1/\lambda$ 3580. With 2 mm. there is a prolongation $^1/\lambda$ 3890. With 1 mm. an absorption band appears from $^1/\lambda$ 3890 to 4331.

·158 gram in 5,000 c.c. alcohol.

With 5 mm. there is an absorption band from $^1/\lambda$ 3890 to 4331. With 4 mm. the absorption band disappears and the spectrum extends to $^1/\lambda$ 4543.

Picoline.[1]

·094 gram in 20 c.c. alcohol.

With 5 and 4 mm. the spectrum is continuous to $^1/\lambda$ 3537, and with 3 and 2 mm. to $^1/\lambda$ 3556. With 1 mm. an absorption band appears from $^1/\lambda$ 3580 to 4331.

·094 gram in 100 c.c. alcohol.

With 5, 4, 3, 2, and 1 mm. the absorption band appears from $^1/\lambda$ 3580 to 4331. With 1 mm. the band is slightly narrower.

·094 gram in 500 c.c. alcohol.

With 5, 4, 3, and 2 mm. the absorption band appears from $^1/\lambda$ 3647 to 4331. With 1 mm. the absorption band has disappeared and the spectrum ends at $^1/\lambda$ 4560.

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[1] See also *Trans. Chem. Soc.* February 1882.

Quinoline.—Specimen I.[1]

(Prepared from Coal Tar.)

·129 gram in 20 c.c. alcohol.

With 5, 4, 3, 2, and 1 mm. the spectrum is continuous to $^1/\lambda$ 3080.

·129 gram in 100 c.c. alcohol.

With 5, 4, 3, 2, and 1 mm. the spectrum is continuous to $^1/\lambda$ 3151.

·129 gram in 500 c.c. alcohol.

With 5 mm. an absorption band (1) appears from $^1/\lambda$ 3151 to 3890. With 4 mm. the same band and two additional bands are seen, e.g. (2) from $^1/\lambda$ 3242 to 3297, and (3) from $^1/\lambda$ 3297 to 3537.

With 3 mm. the absorption band (3) has disappeared. With 3, 2, and 1 mm. we have the absorption bands (1) from $^1/\lambda$ 3187 to 3228, and (2) from $^1/\lambda$ 3242 to 3290.

·129 gram in 2500 c.c. alcohol.

With 5 mm. all the absorption bands had disappeared and the spectrum was continuous to $^1/\lambda$ 4248.

Quinoline Hydrochloride.—Specimen I.

·129 gram quinoline + HCl. in 20 c.c. alcohol. (HCl. was added until the solution gave an acid reaction.)

With 5, 4, 3, 2, and 1 mm. the spectrum was continuous to $^1/\lambda$ 2803. With 3, 2, and 1 mm. there was a feeble prolongation to $^1/\lambda$ 2887.

·129 gram + HCl. in 100 c.c. alcohol.

With 5 and 4 mm. the spectrum is continuous to $^1/\lambda$ 2887. With 3, 2, and 1 mm. an absorption band appears from $^1/\lambda$ 2941 to 3647.

·129 gram + HCl. in 500 c.c. alcohol.

With 5 mm. an absorption band appears from $^1/\lambda$ 3008 to 3647. This is persistent until a thickness of 2 mm. is reached, the band getting narrower as the thickness of the layer is reduced. With 1 mm. the band has disappeared and the spectrum is continued to $^1/\lambda$ 4130.

·129 gr. quinoline + HCl. in 2,500 c.c. alcohol.

With 5 mm. the spectrum is continuous to $^1/\lambda$ 4136. With 4, 3, 2, and 1 mm. a new absorption band appears from $^1/\lambda$ 4136 to 4547.

Quinoline.—Specimen II.

(Prepared synthetically by Skraup's reaction.)

·129 gram in 20 c.c. alcohol.

With 5, 4, 3, 2, and 1 mm. the spectrum is continuous to $^1/\lambda$ 3080.

·129 gram in 100 c.c. alcohol.

With 5, 4, 3, 2, and 1 mm. the spectrum is continuous to $^1/\lambda$ 3080.

·129 gram in 500 c.c. alcohol.

With 5 mm. an absorption band appears from $^1/\lambda$ 3151 to 3890. With 4 and 3 mm. this band is seen, but it gets narrower as the thickness of the layer of liquid is reduced. With 2 mm. the absorption band has disappeared and the spectrum extends to $^1/\lambda$ 4130.

Piperidine.

·085 gram in 20 c.c. alcohol.

With 5 mm. the spectrum extends to $^1/\lambda$ 3970, and with 1 mm. to $^1/\lambda$ 4130.

No absorption bands.

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[1] See also *Trans. Chem. Soc.* February 1882.

Tetrahydroquinoline.

·133 gram in 20 c.c. alcohol.

With 5, 4, 3, 2, and 1 mm. the spectrum is continuous to $^1/\lambda$ 3008·5.

·133 gram in 100 c.c. alcohol.

With 5 and 4 mm. the spectrum was continuous to $^1/\lambda$ 3073. With 3, 2, and 1 mm. an absorption band appeared from $^1/\lambda$ 3151 to 3647, which got narrower as the thickness of the layer of liquid was reduced.

·133 gram in 500 c.c. alcohol.

With 5 mm. the absorption band had disappeared and the spectrum was continuous to $^1/\lambda$ 3647. With 4, 3, and 2 mm. an absorption band appeared from $^1/\lambda$ 3701 to 4331, which got narrower as the thickness of the layer of liquid was reduced.

With 1 mm. the absorption band had disappeared and the spectrum extended to $^1/\lambda$ 4566, but was *somewhat* weak towards the violet end.

Tetrahydroquinoline Hydrochloride.

·1695 gram in 20 c.c. alcohol.

With 10, 9, 8, and 7 mm. the spectrum is continuous to $^1/\lambda$ 3008 With 6, 5, 4, 3, and 2 mm. an absorption band appears from $^1/\lambda$ 3080 to 3574, which gets narrower as the thickness of the layer of liquid is reduced. With 1 mm. this absorption band has disappeared, but another appears from $^1/\lambda$ 3647 to 4331.

·1695 gram in 100 c.c. alcohol.

With 5, 4, 3, 2, and 1 mm. an absorption band appears from $^1/\lambda$ 3647 to 4331.

·1695 gram in 500 c.c. alcohol.

With 5 and 4 mm. an absorption band appears from $^1/\lambda$ 3647 to 4331. With 3 mm. the absorption band has disappeared, and the spectrum extends to $^1/\lambda$ 4426·7.

Ortho-toluidine Hydrochloride.

·107 gram dissolved in 20 c.c. of alcoholic solution of HCl.

With 5 and 4 mm. the spectrum was continuous to $^1/\lambda$ 3647. With 3 and 2 mm. an absorption band appears from $^1/\lambda$ 3701 to 4426·7. With 1 mm. the absorption band disappears, and the spectrum is continuous to $^1/\lambda$ 4547·5.

Para-toluidine.

·107 gram in 20 c.c. alcohol.

With 5, 4, 3, 2 and 1 mm. the spectrum is continuous to $^1/\lambda$ 3080.

·107 gram in 100 c.c. alcohol.

With 5, 4, 3 and 2 mm. an absorption band appears from $^1/\lambda$ 3151 to 3701, which gets narrower as the thickness of the layer of liquid is reduced. With 1 mm. the absorption band disappears, and the spectrum is continuous to $^1/\lambda$ 3890.

·107 gram in 500 c.c. alcohol.

With 5, 4, and 3 mm. the spectrum is continuous to $^1/\lambda$ 3930. With 2 and 1 mm. an absorption band appears from $^1/\lambda$ 3890 to 4426. It is slightly narrower with the 1 mm. layer.

·107 gram in 2,500 c.c. alcohol.

With 5 mm. an absorption band appears from $^1/\lambda$ 4033 to 4331.

With 4 mm. the absorption band has disappeared, and the spectrum extends to $^1/\lambda$ 4660.

Para-toluidine Hydrochloride.

·1435 gram salt in 40 c.c. alcohol.

With 10, 8 and 6 mm. an absorption band appears from $^1/\lambda$ 3647 to 4253. With 4 mm. the absorption band has disappeared, and the spectrum extends to $^1/\lambda$ 4474·2.

Let us deal now with organic colouring matters, a class of substances which have naturally been more generally studied, but by observations made over a restricted range of spectrum lying between λ 7500 and λ 4000.

'*Ueber Absorption des Lichts durch Gemische von farbigen Flüssigkeiten.*'

By F. E. MELDE.[1]

Melde chiefly addressed himself to the following inquiries :—

Do the absorption bands which a coloured substance exhibits remain if the liquid be mixed with one or more other coloured solutions, without any chemical interaction taking place ? Is it possible for the change of temperature in a liquid which exhibits selective absorption to cause a shifting of the absorption bands ? His results showed that there was an alteration which was believed to be of a physical character. H. Burger[2] was strengthened in the belief that the changes observed by Melde were not merely physical, but partly chemical, taking into account the work of Magnus and H. W. Vogel.[3]

The subject was investigated very carefully by J. Landauer,[4] chiefly as a contribution towards a settlement of the question whether every chemical compound had its own absorption spectrum.[5] He undertook the spectral analytical examination of saffranin and its salts, since it has the very peculiar property of changing colour on the addition of concentrated acids in varying proportions to the red solution.[6] It became evident that each of the colours had its own spectrum. The green solutions extinguished the violet, the blue, and the red ; the blue-green behaved in similar manner until there was a portion of the red rays remaining which were not absorbed ; the blue solution took away merely the yellow rays, and the more the colour was changed to violet and red by addition of water, the more the spectrum went over to the green part. Drawings of the spectra of thick and thin layers of liquid show the movement of the absorption band from the red and yellow towards the green and blue, while a second absorption band about F and G moves into the more refrangible region, and goes, no doubt, into the ultra-violet. The change is caused by the formation of different hydrates in solution, which are capable of being carried possibly as far as complete dehydration. The addition of water of course reverses the change.

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[1] *Pogg. Ann.* vol. cxxiv. p. 91, and vol. cxxvi. p. 264.

[2] 'Spectroscopische Untersuchungen über die Constitution von Lösungen,' *Ber.* vol. ii. pp. 1876–78, 1878.

[3] *Praktische Spectralanalyse irdischer Stoffe*, pp. 123 and 212.

[4] 'Zur Kenntniss der Absorptionsspectra,' *Ber.* vol. ii. p. 1772.

[5] Moser, *Pogg. Ann.* vol. clx. p. 177, and *Ber.* vol. xi. p. 1416.

[6] Hofmann and Geyger, *Ber.* vol. v. p. 531.

Similar colour effects are produced by evaporating the solution of these salts, particularly of the sulphate. There are three hydrates formed, and eventually two hydrates and an anhydrous salt.

Ueber die Wandlung der Spectren verschiedener Farbstoffe.[1] *By* HERMANN W. VOGEL.

It is a known fact that absorption spectra of one and the same substance dissolved in different liquids do not always show the absorption bands in the same position. According to Kundt's law the broadening or shifting of the bands towards the red occurs owing to the greater dispersion or refraction equivalent of the solvent liquid, and this law holds good in very many cases. But there are cases where, on a change in the liquid solvent, there is no shifting towards the red, but on the contrary, towards the violet. In other instances even where the solvent liquid has no chemical action upon the dissolved substance, the whole character of the spectrum changes. A case in point is purpurin, which shows two beautiful absorption bands on F, the *b* group, and E, when dissolved in alcohol, but these bands are not seen in an aqueous solution. Naphthalene red shows very different absorption spectra according as it is dissolved in alcohol, in water, in resin, or is solid, or used to colour paper. The curves representing the absorption in the several cases are different. Coloured gelatine behaves in a similar manner to the solid substance.

Ueber die Verschiedenheit der Absorptionsspectra eines und desselben Stoffes.[2] *By* HERMANN W. VOGEL.

He refers to the researches on uranium salts made by Morton and Carrington Bolton, and gives the spectra of a number of inorganic coloured substances.

Ueber die Verschiedenheit der Absorptionsspectra eines und desselben Stoffes.[3] *By* HERMANN W. VOGEL.

The substances examined were corallin and fuchsin in alcohol, water, and in the solid state, and the absorption bands were found to be the same in the solution, and but slightly shifted towards the less refrangible end according to Kundt's law. Curves are shown in the original paper. The solid substances showed somewhat different bands from the solutions, not so strong in the case of fuchsin, and lying nearer the green. He examined also indigo vapour in thick and thin layers, in the solid state, and in solution. He compared the spectrum with that of anilin-blue in water and alcohol, cyanine, and methyl-violet both solid and dissolved in alcohol.

He dissolved purpurin in carbon disulphide, but could not see he bands described by Stokes.[4]

The following conclusions were drawn from Vogel's work :

1. There is a remarkable difference between the spectra of a single substance in the solid, in the liquid or dissolved, and in the gaseous

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[1] *Ber.* vol. ii. p. 622, 1878.

[2] *Ber.* vol. ii, p. 913, 1878.

[3] *Ber.* vol. ii. p. 1363, 'Absorptionsspectra organischer Körper,' 1878.

[4] *J. Chem. Soc.* vol. xii. p. 21.

state. Characteristic absorption bands which appear in one state of aggregation, either do not appear at all in another, or the bands are markedly altered in position, in intensity, or in appearance. The same absorption spectrum is shown by chlorophyll and by copper sulphate in the solid as well as in the dissolved state.

2. The spectra which one and the same substance yields in different solvents are indistinguishable in many cases, in other instances they are distinguished by the width of their bands, in others by a total difference in their characters, so that the spectra in no way correspond.

3. The rule given by Kundt that the absorption bands are shifted farther towards the red the stronger the dispersion of the liquid which is used as a solvent, is not satisfied in many cases. Sometimes the bands are shifted towards the blue, *e.g.*, uranium nitrate in water and alcohol and blue cobalt chloride in water and alcohol. Sometimes there is a strong alteration in the sense of Kundt's rule, and in other cases in the same region of rays the alteration is but trifling. Many absorption bands show in different media of solution the same or very nearly the same position, while at the same time others are shifted.

4. The position of absorption bands in the spectra of solid and dissolved substances can only in exceptional cases be of value as characteristic of the particular substance. Substances which are totally different exhibit bands in (almost) exactly the same positions. Very analogous substances exhibit in like proportions striking differences in the position of their bands.[1]

5. The law for absorption spectra, every substance has its own spectrum,[2] is only admissible in a very restricted sense.

The great number of polychroic substances show different colours and different spectra in the solid state, and it is a question which of these is to be regarded in the case of any one substance as its own special spectrum.

Zur Kenntniss der Alizarin-Farbstoffe und grünen Anilinfarben.[3]

By HERMANN W. VOGEL.

The spectra of these substances are described, and the changes caused by different reagents acting upon them, which give rise to different spectra.

Relation between the Composition of Organic Compounds and their Absorption Spectra.[4] *By* G. KRÜSS *and* S. ŒCONOMIDES.

It had been shown by Melde that the absorption spectrum of a mixed solution of two or more coloured substances is not the same as the spectrum of each taken in conjunction, but that displacements and concentrations of the absorption bands occur.[5] The changes being ascribed to chemical changes within the solutions, it became of interest to ascertain

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[1] Solid uranium salts, according to Morton and Carrington Bolton, *Chem. News*, vol. xxviii. p. 47.

[2] Moser, *Pogg. Ann.* vol. clx. p. 177.

[3] *Ber.* vol. ii. p. 1371, 1878.

[4] *Ber.* vol. xvi. pp. 2051–2056, 1883.

[5] *Ber.* vol. xv. pp. 1243–1249, 1882, 'Ueber die Constitution von Lösungen,' G. Krüss.

the nature of the chemical reactions involved. The replacements of hydrogen by alkyls, nitroxyl, and amidogen was the subject of investigation. The authors state that the subject had been partially investigated by Dunstan, Soret, and others, and appear to quote from the 'Pharm. Trans.' vol. xi. p. 54. In attributing work of the kind to Dunstan they were in error, and this misstatement has been repeated by other authors in different publications. Their experiments were made upon indigo and its derivatives, *m.* methyl-indigo, *m.* oxymethyl-indigo, ethyl-indigo, monobrom-indigo, dibrom-indigo, amido-indigo, and dibrom-amido-indigo, and show that the alkyl and oxyalkyl radicals shift the absorption bands towards the red, and that oxymethyl and ethyl exert a similar influence to methyl and ethyl, but are stronger in effect. An atom of bromine causes but little change, but the introduction of a second atom is equal in effect to a methyl group. It is stated that nitroxyl- and amido-groups have a reverse effect.

Note on the above-mentioned papers.—No accurate conclusions of a general character can be drawn from observations on a part of the spectrum such as was in this case made with a molecule of complex structure like indigo. It is necessary to take into account the effect on the ultra-violet, and undoubtedly there the effect of NO_2 is to shift the bands towards the red, and that of NH_2 is the same when the molecule into which these radicals enter is a simple one like benzene.

This is shown in the diagrams of Hartley and Huntington.[1] Compare benzene, aniline, with ortho- and para-nitraniline, phenol with ortho-nitrophenol and para-nitrophenol.[2]

Krüss and Œconomides examined (1883) solutions of indigo and its derivatives, with a view to decide whether the replacement of hydrogen by CH_3, C_2H_5, NH_2, NO_2, Br., &c., has a regular influence on the absorption spectrum of the compound. Derivatives of fluoresceïn and rosolic acid were examined by Krüss subsequently, with the result that the view previously put forward, namely, that the replacement of hydrogen in the benzene-ring or in the side chain by alkyl or oxyalkyl radicals and bromine, caused a shifting of the absorption bands towards the less refrangible end of the spectrum, whilst the introduction of an NH_2 or NO_2 has the opposite effect. The shifting of the bands increases in proportion to the number of substituted hydrogen atoms, when the same elements or radicals are analogously introduced.

In the case of alkyl radicals this also has been shown by Hartley and Huntington. Compare the plates of benzene, methyl-benzene, trimethyl-benzene, ethyl-benzene,[3] also pyridine and picoline (Hartley). It is particularly to be noted in the case of the general absorption and in the more pronounced intensity of the bands, which, however, do not, in the case of alkyl radicals, greatly alter throughout all dilutions in mere position.

Ueber innere Molekularbewegung.[4] *By* G. Krüss.

On the basis of the velocity of light, taken as 299,000 kilometres per second, Krüss calculated the oscillation frequencies in the principal absorp-

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[1] *Phil. Trans.* 1879.
[2] G. Krüss, *Ber.* vol. xviii. 1426–1433; *J. Chem. Soc. Abs.* p. 949, 1885.
[3] *Phil. Trans.* 1879.
[4] *Ber.* vol. xviii. pp. 2586-91, 1885.

tion bands of various dye-stuffs and colouring matters. He found the velocity greater the larger the number of hydrogen atoms in the molecule. His experiments do not appear to have been quantitative, as no proportions of a molecule of the substances taken are mentioned, nor are even the quantities of the substances or the thicknesses of the liquid recorded. The numbers recorded are given as the number of intra-molecular vibrations per billionths of a second.

	Solvent used	
	$CHCl_3$	H_2SO_4
Indigo	494·4	494·1
m. Methyl-indigo	482·5	—
m. Oxymethyl-indigo	459·4	—
Ethyl-indigo	458·2	—
Brom-indigo	493·2	—
Dibrom-indigo	479·9	—
Nitro-indigo	510·8	—
Amido-indigo	—	507·7
Dibrom-amido-indigo	—	511·0

A number of fluoresceïn derivatives were examined.

	Water	Alcohol
Fluoresceïn		612·2
Fluoresceïn potassium salt	605·3	621·9
Dibrom-fluoresceïn potassium	595·1	590·4 627·2
Tetrabrom-fluoresceïn	—	580·6 612·2
Tetrabrom-fluoresceïn potassium	579·6	569·4 608·5
Tetranitro-fluoresceïn	611·5	570·8
Tetranitro-fluoresceïn potassium	611·5	597·5
Dibromnitro-fluoresceïn	595·6	580 6 616·0
Dibromnitro-fluoresceïn potassium	595·6	583·6
Monomethyl-tetrabrom-fluoresceïn	—	579·6 612·2
Monomethyl-tetrabrom-fluoresceïn potassium	—	562·7 601·9
Monethyl-tetrabrom-fluoresceïn	—	578·7 611·5
Monethyl-tetrabrom-fluoresceïn potassium	—	557·3 598·0
Potassium rosolate	550·3	525·1
Potassium tetrabrom-rosolate	527·9	518·3

In the case of analogous replacements of the hydrogen atoms, the increase or decrease of molecular vibrations is proportional to the number of hydrogen atoms thus replaced. It seems that these results are in accord with some deductions from experimental results obtained by Rellstab, 'Inaugural Dissertation,' Bonn, 1868, on the transpirability of homologous compounds.

G. Krüss returns to this subject and gives an account of his experiments in the 'Zeitschrift für physikalische Chemie,' vol. ii. pp. 312–337,

1888. He was apparently quite unaware that the method of calculating the molecular vibrations of a substance had, seven years previously, been described in the 'Journal of the Chemical Society,' for 1881, and calculated for benzene, naphthalene, and anthracene, in a manner identical with that which he communicates. This is rendered evident from his article on absorption spectra in Graham-Otto's 'Ausführliches Lehrbuch der Chemie,' erster Band, pp. 683–694, edited by Dr. H. Landolt in 1898. There is an obituary notice of the author by Dr. Hugo Krüss, stating that this contribution was completed in 1889.

NECESSITY FOR EXAMINING THE ULTRA-VIOLET AND COLOURED SPECTRA TOGETHER.

There is some amount of uncertainty about conclusions drawn from observations made on only a part of the spectrum which may be illustrated by a glance at the diagram in Hartley and Huntington's paper, plate 22, which is described as that of ortho-nitrophenol, but is in reality the para-compound, and that of plate 23, erroneously termed para-nitrophenol, but is in reality the ortho-derivative (by accident the plates were transposed). In both instances there are two absorption bands, one in the visible region or blue, in No. 23, and a second in the ultra-violet. Any reaction which will reduce the velocity of the vibrations of the compound will shift both bands towards the less refrangible rays. The first band may thus be moved into the infra-red region, and the second into the visible part of the spectra, say the violet. By observations on the coloured rays only, it will be made to appear as if the first band had been moved towards the ultra-violet instead of in the opposite direction.

Another example—an actual case—is afforded by iodine green, methyl violet and rosaniline hydrochloride, when compared with triphenyl methane. The powerful absorption band of the hydrocarbon is carried down into the yellow and green by the influence on the molecule of the NH_2 groups and the chlorine; the red rays are transmitted, and a portion of the violet. In the case of methyl violet, the absorption band is carried down to a point near C, and it extends to G; a portion therefore of the red is transmitted, and part of the violet. With iodine green the absorption band in the less refrangible region extends into the extreme limit of visibility in the red, and there is absorption from between A and B $^1/\lambda$ 1800, until near F $^1/\lambda$ 2000 a band of transmitted rays extends from $^1/\lambda$ 2000 to 2200, or between F and G. There is then absorption in the violet from $^1/\lambda$ 2200 to 2800 in the ultra-violet, and beyond that again there is complete absorption from $^1/\lambda$ 2900 to 4000.

If the visible rays only are observed, and that at one thickness and one strength of solution, it might very easily appear that the combined effect of NH_2, the CH_3 group, and the I is to cause the band to be shifted from the yellow into the violet. Plate I. 'Chem. Soc. Trans. 1887, will serve to explain this. It will be well at this juncture to refer to the paper more fully.

Zur Kenntniss der Absorptionsspectra.
Das Chrysoïdin und verwandte Azofarbstoffe.[1]

J. Landauer made an examination of the absorption spectra of azo dyes. He showed that there was a marked change in the absorption

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[1] *Ber.* vol. xiv. p. 391, 1881.

bands when methyl is substituted for the amido group in such substances as chrysöidine.

Græbe[1] examined azo-colouring matters dissolved in sulphuric acid. By addition of carbon the bands shifted towards the red, OH and NH_2 cause the same displacement. The position of the substitution seems to have a regular influence on the position of the bands, and the extent of the shifting is about 20 micro-millimetres nearer to the red with α compounds of the naphthalene molecule than with the β derivatives. The sulphonic acid group, it is stated, produces a displacement in the opposite direction, which in amount approximates to 40 micro-millimetres.

Liebermann[2] examined the spectra of alkyl derivatives of oxyanthraquinones dissolved in cold strong sulphuric acid. The wave-lengths of bands measured are as follows :—

—	I	II	III
	λ	λ	λ
Alizarin	605	493	—
Alizarin ethyl ester	598	487	—
Anthraflavic acid	495	463	—
Dimethyl ester	501	473	437 very feeble
Diethyl ester	504	477	439 ,,
Quinizarin	551	509	483 feeble
Ethyl ester	564	520	484 ,,
Diethyl ester	577	535	494 ,,
Iso-anthraflavic acid	—	540	494 not sharp
Diethyl ester	—	505	492 not sharp
Flavo-purpurin	533	495	—
Diethyl ester	542	501	—
Anthragallol	525	492	—
Ethyl ester	—	515	Not sharp
Diethyl ester	—	515	Not sharp
Rufigallic acid	576	532	—
Triethyl ester	579	545	—

In this particular series again the alkyl radicals cause a shifting of the absorption bands towards the red. The extent of the shifting appears to be different in the different bands, and differs in the various substances.

Girard and Pabst[3] carefully examined the absorption spectra of diazo colours such as Biebrich scarlet, congo red, ponceau, and chrysoïdine, and illustrated their paper by drawings. The conclusions drawn from their observations were that homologous compounds, or compounds which are closely related in constitution, give similar absorption spectra. 1885.

In 1887 H. W. Vogel[4] also examined the same class of colouring matters, and drew the following conclusions :

(1) The substitution of methyl for hydrogen in diazobenzene shifts the position of the absorption bands towards the red end of the spectrum. The increase of wave-lengths is 10 millionths of a millimetre where the substitution takes place in the ortho- position, and 14 millionths of a millimetre in the case of the para- positions.

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[1] *Ber.* vol. xxvi. p. 130, R, 1893; and *Zeitschrift für physikalische Chemie*, vol. x. p. 673.

[2] *Ber.* vol. xxi. p. 2527, 1887.

[3] *Comptes Rendus*, vol. ci. pp. 157–160.

[4] *Sitzungsberichte d. preuss. Akad. d. Wiss. zu Berlin*, vol. xxxiv. pp. 715–718.

(2) The substitution of β-naphthol disulphonic acid S, or β-naphthol disulphonic acid R for β-naphthol sulphonic acid B, causes a shifting of the bands, which in the case of β-naphthol sulphonic acid S amounts to from 4 to 5 millionths of a millimetre.

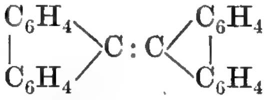
(3) In the substitution of methyl the space between the two bands becomes clearer, and the bands become more equal in intensity and width.

The substitution of β-naphthol sulphonic acid S or β-naphthol disulphonic acid R, in the place of the acid B, acts in a similar manner on the character of the bands. The solutions were made both with alcohol and with strong sulphuric acid.

OBSERVATIONS ON THE ORIGIN OF COLOUR AND ON FLUORESCENCE.[1]

Anthracene is shown to possess a very definite absorption band in the violet, and it is therefore a truly coloured substance. Its colour is the aggregate effect on the retina of those rays which are the complement in white light of the violet rays absorbed. The complementary colour to the violet can be seen only by transmission. Hence the colour which is due to fluorescence must be excluded from access to the eye, and also all reflected light. It is therefore necessary to look directly through thin layers of the substance, or to view it by transmitted light when the substance is fused. When examined in this manner, anthracene is seen even in very thin layers to have a greenish yellow colour. This colour belongs to only the very purest specimens.

Nietzki has stated that all hydrocarbons are colourless,[2] but this is not strictly the case. Anthracene is not the only hydrocarbon which possesses colour visible to the human eye. De la Harpe and Van Dorp[3] obtained a red hydrocarbon, $C_{26}H_{16}$, by passing fluorene over heated lead oxide. Mantz[4] established its molecular weight by Raoult's method, and assigned it the structural formula



C. Græbe's investigation[5] shows that the colour truly belongs to the substance, and that it becomes brighter in colour the more highly it is purified. He attributes the colour to the grouping $>C:C<$, as both the dibromide and the hydrocarbon $C_{26}H_{18}$ are colourless.

It may be remarked that the carbon grouping $>C:C<$ cannot alone be the cause of the colour, for if the carbons are united to H atoms or to alkyl radicals it may be safely predicted that no colour would result. It is this nucleus united to four benzene rings, each pair of which are themselves united, and so forming molecules with a great compactness of structure, which is the cause of the colour. Benzene is a substance with *invisible colour*, that is to say it exerts a powerful selective absorption in the invisible region, and by any series of chemical reactions which serve to retard the rate of vibration of the molecule, or of any group of ben-

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[1] *Trans. Chem. Soc.* 1893, p. 243, Hartley.

[2] Page 2 of the English edition of his work.

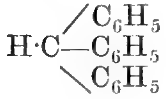
[3] *Ber.* vol. viii. p. 1048.

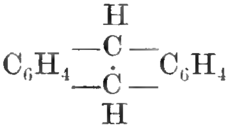
[4] *Inaugural Dissertation*, Geneva, 1892.

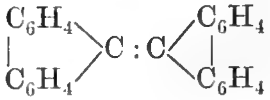
[5] *Ber.* vol. xxv. pp. 3146–49.

zenes united in one molecule, will cause the invisible colours of the ultra-violet region to become visible.

Triphenylmethane absorbs all the ultra-violet rays down to H, anthracene all the ultra-violet as well as a band of violet rays; the former is therefore all but a substance with visible colour, the latter is undoubtedly a coloured substance. But bi-diphenylene-ethylene is strongly coloured, and the nature of its colour is such as to show that it absorbs the violet, blue, and green rays. These hydrocarbons constitute an interesting illustration of the passage from a substance which just falls short of being coloured to one which is but faintly, and to a third which is strongly coloured.







Researches on the Relation between the Molecular Structure of Carbon Compounds and their Absorption Spectra. Part VIII. A Study of Coloured Substances and Dyes. (HARTLEY.)[1]

According to Dr. Otto Witt[2] the tinctorial character is conditional upon the simultaneous presence of a colour-producing group (chromogen) and a salt-forming group (chromophore) in the molecule. This investigation includes a study of the hydrocarbons in their relation to the more complex colouring compounds derived therefrom, considered in the light of Witt's views.

A perfectly colourless substance transmits all luminous and invisible vibrations without impairing their intensity; a coloured substance absorbs rays at either end of the spectrum, even beyond the limits of visibility, or say from λ 7800 to λ 2000, or it selects rays from the middle of the spectrum. Every fluorescent substance is therefore in a certain sense coloured, because it absorbs certain rays whether in the visible or ultra-violet region. Benzene, benzenoid hydrocarbons, phenols, &c., which exhibit selective absorption, are also coloured, although the eye, owing to absorption of the ultra-violet rays by the aqueous humour,[3] has a range of vision limited by the red and violet ends of the spectrum, and therefore cannot appreciate this variety of colour. Bands of selective absorption, it has been shown, are to be attributed to the effect of vibrations taking place within the molecules of a substance upon the rays which enter the substance, and are dependent upon the rate of vibration of the molecules themselves. To convert a carbon compound, therefore, such as benzene—which, owing to its powerful absorption in the ultra-violet, may be said to have *invisible colour*—into a compound with *visible colour*, it is only necessary to slacken its rate of vibration so that the molecule will absorb rays with oscillation frequencies occurring within the limits of visibility. Or, to put it in another way, the absorption band in the ultra-violet is transferred to rays of lower refrangibility. A chromogen is an invisibly coloured substance; a chromophore is an atom, or group of atoms, capable of reducing the rate

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[1] *Trans. Chem. Soc.* vol. li. 1887, p. 153.

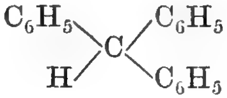
[2] *Ber.* vol. ix. p. 522.

[3] J. L. Soret, *Comptes Rendus,* vol. xcvii. p. 572.

of vibration of the molecules, with the result that it absorbs rays which are within the limits of visibility of the human eye. Instances of chromophores are afforded by oxygen and nitrogen, as in hydroxyl and nitroxyl. Or more rarely in the case of oxygen, when united to carbon, as in uric acid. Two benzene molecules doubly linked by two nitrogen atoms —N=N—as in azo-benzene, have their mode of vibration so modified that a colour as low down in the scale as the yellow rays is the result. These nitrogens are chromophores. Again, when two atoms of hydrogen in benzene are replaced by two atoms of oxygen as in quinone, a golden colour results. In this case the oxygen atoms are chromophores. The chromophoric properties of oxygen atoms when united in a certain manner to carbon, and especially to benzene nuclei, are strikingly illustrated by such bodies as resorcin-phthaleïn, &c.

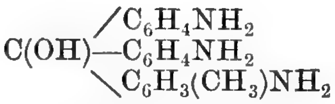
When methyl is substituted for hydrogen in benzene, three of the absorption bands are merged in one, and the oscillation frequencies of the rays absorbed are reduced, or in other words the general absorption is increased. The OH, NH_2, and NO_2 radicals invariably act in this manner whether absorption bands are shifted or not.

Triphenylmethane,



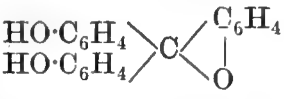
The absorption curve of this substance has the same *general character* as that of benzene, with the following modifications. There is one broad absorption band with just an indication of a second one being merged in this. The amplitude of the vibrations, as shown by the intensity of the absorption bands, is very largely increased, and the rate of vibration of the absorbed rays is very greatly reduced. A milligram molecule of benzene, for instance, begins to transmit rays with oscillation frequencies 3760 and 4330, while $\frac{1}{125}$th of a milligram molecule transmits all rays as far as 4650. With triphenylmethane a milligram molecule transmits nothing beyond H or oscillation frequency 2510; $\frac{1}{2125}$th of a molecule transmits rays as far as 4600.

Rosaniline base,



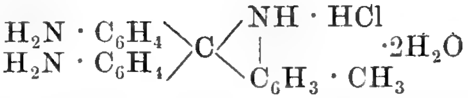
Here, the introduction of the methyl and amide groups to form rosaniline causes the molecule to absorb all rays beyond C or $1/\lambda$ 1250; $\frac{1}{100}$th causes an absorption near D $1/\lambda$ 1670, extending to near H $1/\lambda$ 2450, while $\frac{1}{125}$th of a molecule transmits all rays to $1/\lambda$ 4600.

Aurin,



The introduction of the hydroxyls causes greater absorption than the introduction of the amide groups. $\frac{1}{325}$th of a molecule absorbs everything beyond C $1/\lambda$ 1520; while $\frac{1}{585}$th absorbs as far as D $1/\lambda$ 1670. $\frac{1}{600}$th absorbs from $1/\lambda$ 1780 to between Q and R or $1/\lambda$ 3100; and $\frac{1}{1250}$th practically transmits the whole spectrum.

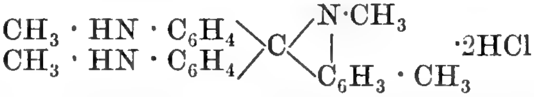
Rosaniline hydrochloride,



$$\begin{array}{l}H_2N\cdot C_6H_4\\ H_2N\cdot C_6H_4\end{array}\!\!>C<\!\!\begin{array}{l}NH\cdot HCl\\ \,|\\ C_6H_3\cdot CH_3\end{array}\cdot 2H_2O$$

In this substance the absorption is greater than in rosaniline, all rays beyond C and between B and C ($^1/\lambda$ 1500) are absorbed. $\frac{1}{3025}$th of a milligram molecule absorbs all rays beyond $^1/\lambda$ 1600 between B and C. $\frac{1}{3050}$th absorbs all from $^1/\lambda$ 1600 to near H or $^1/\lambda$ 2500; while $\frac{1}{3125}$th transmits all rays to $^1/\lambda$ 4600.

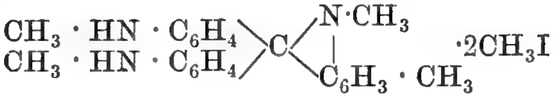
Trimethylrosaniline hydrochloride (Methyl Violet).



$$\begin{array}{l}CH_3\cdot HN\cdot C_6H_4\\ CH_3\cdot HN\cdot C_6H_4\end{array}\!\!>C<\!\!\begin{array}{l}N\cdot CH_3\\ \,|\\ C_6H_3\cdot CH_3\end{array}\cdot 2HCl$$

The introduction of the methyl groups increases the opacity of the liquid; it begins to transmit red rays with little more than $\frac{1}{2500}$th of a milligram molecule; with $\frac{1}{3000}$th it transmits from $^1/\lambda$ 1500 near C to $^1/\lambda$ 2500 near H, and absorbs all beyond. With $\frac{1}{3050}$th of a molecule it transmits rays between G and H, while $\frac{1}{3125}$th transmits all to $^1/\lambda$ 4400.

Trimethyl-rosaniline di-methyl-di-iodide (Iodine Green),



$$\begin{array}{l}CH_3\cdot HN\cdot C_6H_4\\ CH_3\cdot HN\cdot C_6H_4\end{array}\!\!>C<\!\!\begin{array}{l}N\cdot CH_3\\ \,|\\ C_6H_3\cdot CH_3\end{array}\cdot 2CH_3I$$

The addition of two methyl iodides to the molecule of trimethylrosaniline causes complete absorption of rays as far down as $^1/\lambda$ 1350. $\frac{1}{2950}$th of a molecule transmits rays between $^1/\lambda$ 1350 and 1390; the absorption then continues to F ($^1/\lambda$ 2050). Rays are transmitted from $^1/\lambda$ 2050 to $^1/\lambda$ 2200; absorption occurs again to near N ($^1/\lambda$ 2780) and transmission to near O ($^1/\lambda$ 2890). With $\frac{1}{3125}$th of a molecule all rays are transmitted to $^1/\lambda$ 4600.

On carefully comparing the curves of the rosaniline series of dyes with triphenyl-methane and benzene, it is seen that they are modifications of the benzene curve. All these curves are drawn to scale. The closeness of relationship of the triphenyl-methane curve to the dyes is much greater than that of the benzene curve, and the curves of the three dyes are modified in such a manner that they follow each other closely. The modification is such that the molecules of greatest mass transmit the least light, and the light is composed of rays vibrating with least rapidity, thus indicating, in the case of the dyes, a greater amplitude and less rapidity of vibration than that of the molecule of triphenyl-methane, while the difference in this respect between this substance and benzene is extraordinary.

Azobenzene, $C_6H_5\cdot N:N\cdot C_6H_5$.

$\frac{1}{5}$th of a milligram molecule of azobenzene transmits the visible rays as far as a point lying between C and D, or $^1/\lambda$ 1625; $\frac{1}{525}$th of a molecule transmits to between E and F, or $^1/\lambda$ 1970; $\frac{1}{575}$th of a molecule transmits to between E and F, or $^1/\lambda$ 2020; then occurs an absorption as far as M, or $^1/\lambda$ 2690. $\frac{1}{610}$th of a molecule transmits to just beyond F, or $^1/\lambda$ 2090; then occurs an absorption to between G and H, or $^1/\lambda$ 2470.

Rays are then transmitted to near N, or $^1/\lambda$ 2780, after which there is but little absorption with $\frac{1}{620}$th of a molecule, and that lies at about $^1/\lambda$ 3900.

Chrysoïdine hydrochloride, $C_6H_5 \cdot N : N \cdot C_6H_3(NH_2)_2$, 2HCl.

Comparing chrysoïdine with azobenzene the rate of the vibrations is much reduced, and their amplitude is increased. There is, with $\frac{1}{610}$th of a molecule, complete absorption beyond $^1/\lambda$ 1800 ; what appears below this point is an absorption band, apparently the principal band of azobenzene modified by being extended from $^1/\lambda$ 1800 to $^1/\lambda$ 2890, or near O, but with $\frac{1}{625}$th of a molecule all absorption practically ceases.

The absorption of the following azobenzene and azonaphthalene derivatives has also been examined :—

Bismarck Brown,

$$NH_2 \cdot C_6H_4 \cdot N : N \cdot C_6H_3(NH_2)_2.$$

Tropæolin O.,

$$NaSO_3 \cdot C_6H_4 \cdot N : N \cdot C_6H_3(OH)_2.$$

Helianthin,

$$HSO_3 \cdot C_6H_4 \cdot N : N \cdot C_6H_4 \cdot N(CH_3)_2.$$

Benzene-azo-β-naphtholdisulphonic acid,

$$C_6H_5 \cdot N : N \cdot C_{10}H_4(HSO_3)_2 \cdot OH_\beta.$$

Sulpho-xylene-azo-β-naphtholdisulphonic acid,

$$HSO_3 \cdot C_8H_8 \cdot N : N \cdot C_{10}H_4(HSO_3)_2 \cdot OH_\beta.$$

Cumene-azo-β-naphtholdisulphonic acid,

$$C_9H_{11} \cdot N : N \cdot C_{10}H_4(HSO_3)_2 \cdot OH_\beta.$$

Phenyl-azo-phenyl-β-naphtholsulphonic acid (Croceine Scarlet),

$$C_6H_5 \cdot N : N \cdot C_6H_4 \cdot N : N \cdot C_{10}H_5(HSO_3) \cdot OH_\beta.$$

Biebrich Scarlet,

$$NaSO_3 \cdot C_6H_4 \cdot N : N \cdot C_6H_4(NaSO_3) \cdot N : N \cdot C_{10}H_6 \cdot OH_\beta.$$

In these substances the amplitude of the vibrations is virtually the same as in chrysoïdine, and the character of their curves is similar, though no two are alike. These substances are very varied as regards the hydrocarbon radicals from which they are derived. It follows, therefore, that the nitrogen is largely concerned in the development of the colours, and that the hydrocarbon radicals are of comparatively small importance so long as they are benzenoid in character.

Sodium α-naphthol-azophenylsulphonate,

$$OH_\alpha \cdot C_{10}H_6 \cdot N : N \cdot C_6H_4 \cdot SO_3Na.$$

(Tropæolin 000 No. 1).

Sodium β-naphthol-azo-phenylsulphonate,

$$OH_\beta \cdot C_{10}H_6 \cdot N : N \cdot C_6H_4 \cdot SO_3Na.$$

(Tropæolin 000 No. 2).

Although these two bodies are isomeric, and only differ in that the first contains α, the second β naphthol, they differ considerably in their absorptive power. The first transmits all rays through $\frac{1}{125}$th of a molecule, while No. 2 absorbs all beyond $^1/\lambda$ 1780, when only $\frac{1}{600}$th of a molecule is present.

α-*Naphthol-azonaphthylsulphonic Acid* (Acid Brown),

$$OH_\alpha \cdot C_{10}H_6 \cdot N_\alpha : N_\alpha \cdot C_{10}H_6 \cdot HSO_{\alpha 3}.$$

β-*Naphthol-azonaphthylsulphonic Acid* (Fast Red),

$$OH_\beta \cdot C_{10}H_6 \cdot N_\alpha : N_\alpha \cdot C_{10}H_6 \cdot HSO_{\alpha 3}.$$

Although these two bodies only differ slightly in constitution, in fact, merely as regards the position of the OH group, their absorption curves differ widely.

Murexide.—Uric acid, which is closely related to murexide, exhibits an extraordinary absorption band when an aqueous solution of the acid is examined in layers 15 millimetres in thickness. Since the substance requires 15,000 parts of water for its solution, this is some indication of the extraordinary absorptive power of uric acid and of the effect of the linking of several carbon and nitrogen atoms, and the combination of oxygen atoms with carbon. Urea is extraordinarily diactinic.

The curves of the rosaniline series of dyes are modifications of the benzene curve, standing, however, in a closer relationship to the curve of triphenylmethane than to that of benzene itself. The curves are modified in such a manner that the molecules of greatest mass transmit least light, and the light is composed of rays vibrating with least rapidity, thus indicating greater amplitude and less rapidity of vibration of the molecule. The curves of the azo-colours are likewise modifications of the azobenzene curves.

A general conclusion drawn from this work is that *when absorption takes place in the visible region the ultra-violet rays are also absorbed.* It appears, therefore, hopeless to expect a strongly coloured organic substance to transmit the ultra-violet rays.

Beziehungen zwischen Zusammensetzung und Absorptionsspectrum organischer Verbindungen.

Althausse[1] and G. Krüss communicated a paper in which they observed that, first, an increase in the percentage of carbon causes the absorption bands to pass towards the less refrangible portion of the spectrum; secondly, the wave-lengths of bands of absorption are the same in different thionine salts, whether the solution contains hydrochloride, hydriodide, or other salts of this base; thirdly, the addition of hydrogen causes the bands to pass towards the blue; fourthly, if a substance is examined spectroscopically in a solution suitable to commercial requirements, the colour of an unknown derivative of the compound in question may be foretold from its spectrum with tolerable accuracy.

THE ABSORPTION SPECTRA OF ISOMERS OF THE AROMATIC SERIES.

In the examination of aromatic derivatives (Hartley and Huntington) and of some of the homologues of benzene (Hartley), three isomeric nitranilines were examined and three xylenes; the spectra of the latter

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[1] *Ber.* vol. xxii. p. 2065, 1889.

have already been described. The striking examples of isomerism remarked in the tropæolines, with corresponding differences in the curves of their molecular vibrations, suggested a systematic examination of some of the simpler isomeric derivatives of benzene as being an interesting subject for investigation.

Researches on the Relation between the Molecular Structure of Carbon Compounds and their Absorption Spectra. Part IX. (HARTLEY).[1]

On Isomeric Cresols, Dihydroxybenzenes and Hydroxybenzoic Acids.

The results of the examination of the absorption spectra of (i.) ortho-, meta- and para-cresol; (ii.) hydroquinone (quinol), pyrocatechol, and resorcinol; (iii.) salicylic acid, metahydroxybenzoic acid, and parahydroxybenzoic acid, are given.

The oscillation frequencies of the most extreme rays transmitted by a milligram-molecule of the four classes of isomeric substances, are the following:—

Xylenes		Cresols		Dihydroxybenzenes		Hydroxybenzoic Acids	
Ortho .	. 3611	Meta .	. 3433	Meta .	. 3466	Para .	. 3359
Meta .	. 3580	Ortho .	. 3413	Ortho .	. 3399	Meta .	. 3080
Para .	. 3537	Para .	. 3359	Para .	. 3151	Ortho .	. 2986

It is seen, therefore, that in the case of the xylenes, cresols, and dihydroxybenzenes, the 1 : 4 derivatives exercise the greatest absorption. It is also to be noted that the cresols and dihydroxybenzenes follow the same order of transparency, while in the case of the hydroxybenzoic acids this order is reversed, and in the case of the xylenes it is different from that of any of the other three series.

On the assumption that the absorption of rays manifested by any three isomerides is a measure of its rate of vibration, and consequently of the dissipation of energy resulting in the formation of the molecule, the following classification may be deduced:—

Dissipation of Energy during Formation.

	Least		Greatest
Xylenes	Para	Meta	Ortho
Cresols	Para	Ortho	Meta
Dihydroxybenzenes	Para	Ortho	Meta
Hydroxybenzoic Acids	Ortho	Meta	Para

It is worthy of note that v. Rechenberg,[2] from the heat of combustion of the three hydroxybenzoic acids, places them in the same order as that given above.

Description of the Spectra of the substances examined.

Ortho-cresol, $C_6H_4(CH_3)\cdot OH$. 1 : 2.

·108 gram in 20 c.c. alcohol.

With 5, 4, 3, 2 and 1 mm. an absorption band appears from $^1/\lambda$ 3413 to 4125, which gets narrower as the thickness of the layer of liquid is reduced.

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[1] *Trans. Chem. Soc.* vol. liii. p. 641, 1888.

[2] *J. pr. Chem.* vol. xxii. pp. 1–45.

·108 gram in 100 c.c. alcohol.

With 5, 4, 3, 2 and 1 mm. an absorption band appears from $^1/\lambda$ 3493 to 4016, which gets narrower as the thickness of the layer of liquid is reduced, and in the case of 1 mm. is somewhat indistinct.

Meta-cresol, $C_6H_4(CH_3) \cdot OH$. 1 : 3.

·108 gram in 20 c.c. alcohol.

With 5, 4, 3, 2 and 1 mm. an absorption band appears from $^1/\lambda$ 3433 to 4125.

·108 gram in 100 c.c. alcohol.

With 5, 4, 3 and 2 mm. an absorption band appears from $^1/\lambda$ 3493 to 3890, which gets narrower as the thickness of the layer of liquid is reduced. With 1 mm. the absorption band has disappeared, and the spectrum extends $^1/\lambda$ 4331.

Para-cresol, $C_6H_4(CH)_3 \cdot OH$. 1 : 4.

·108 gram dissolved in 20 c.c. alcohol.

With 5, 4, 3, 2 and 1 mm. an absorption band appears from $^1/\lambda$ 3359 to 4125, which gets narrower as the thickness of the layer of liquid is diminished.

·108 gram in 100 cc. alcohol.

With 5, 4, 3 and 2 mm. an absorption band appears from $^1/\lambda$ 3392 to 3890. With 1 mm. the absorption band has disappeared, and the spectrum extends to $^1/\lambda$ 4253.

Pyrocatechol, $C_6H_4(OH)_2$. 1 : 2.

·110 gram in 20 c.c. water.

With 5, 4 and 3 mm. the spectrum is continuous to $^1/\lambda$ 3399. With 2 mm. an absorption band appears from $^1/\lambda$ 3439 to 4125. The same band appears with 1 mm., but is somewhat narrower.

·110 gram in 100 c.c. water.

With 5, 4, 3, 2 and 1 mm. an absorption band appears from $^1/\lambda$ 3460 to 4016, which gets narrower as the thickness of the layer of liquid is reduced.

·110 gram in 500 c.c. water.

With 5 mm. an absorption band appears from $^1/\lambda$ 3531 to 3768. With 4 mm. the absorption band has disappeared, and the spectrum extends to $^1/\lambda$ 4374.

Resorcinol, $C_6H_4(OH)_2$. 1 : 3.

·110 gram in 20 c.c. water.

With 5 and 4 mm. the spectrum is continuous to $^1/\lambda$ 3466. With 3, 2, and 1 mm. an absorption band appears from $^1/\lambda$ 3487 to 4125, which gets narrower as the thickness of the layer of liquid is reduced.

·110 gram in 100 c.c. water.

With 5, 4, 3, 2 and 1 mm. an absorption band appears from $^1/\lambda$ 3507 to 4016, which gets narrower as the thickness of the layer of liquid is reduced.

·110 gram in 500 c.c. water.

With 5 mm. an absorption band appears from $^1/\lambda$ 3647 to 3768. With 4 mm. the absorption band has disappeared, and the spectrum is continuous to $^1/\lambda$ 4374.

Hydroquinone, $C_6H_4(OH)_2$. 1 : 4.

·110 gram in 20 c.c. alcohol.

With 5 mm. the spectrum is continuous to $^1/\lambda$ 3151. With 4, 3, 2, and 1 mm. an absorption band appears from $^1/\lambda$ 3151 to 3890.

·110 gram in 100 c.c. alcohol.

With 5, 4, 3, 2, and 1 mm. an absorption band appears from $^1/\lambda$ 3187 to 3832, which gets narrower as the thickness of the layer of liquid is diminished.

·110 gram in 500 c.c. alcohol.

With 5, 4, 3, and 2 mm. an absorption band appears from $^1/\lambda$ 3297 to 3531, which gets narrower as the thickness of the layer of liquid is reduced. With 1 mm. the absorption band disappears, and the spectrum extends to $^1/\lambda$ 4660.

Salicylic Acid, $C_6H_4(OH)COOH$. 1 : 2.
(From Oil of Wintergreen.)

·138 gram in 20 c.c. alcohol.

With 5, 4, and 3 mm. the spectrum extends to $^1/\lambda$ 2986. With 2 and 1 mm. an absorption band appears from $^1/\lambda$ 3008·5 to 3826.

·138 gram in 100 c.c. alcohol.

With 5, 4, 3, 2, and 1 mm. an absorption band appears from $^1/\lambda$ 3008·5 to 3757, which gets narrower as the thickness of the layer of liquid is reduced.

·138 gram in 500 c.c. alcohol.

With 5 mm. the absorption band appears from $^1/\lambda$ 3080 to 3525, and with 4 mm. from $^1/\lambda$ 3151 to 3494. With 3 mm. the absorption band has disappeared, and the spectrum extends to $^1/\lambda$ 4033. With 1 mm. an absorption band appears from $^1/\lambda$ 4130 to 4326.

·138 gram in 2,500 c.c. alcohol.

With 5 and 4 mm. an absorption band appears from $^1/\lambda$ 4130 to 4326. With 3 mm. the absorption band has disappeared, and the spectrum extends to $^1/\lambda$ 4550.

Metahydroxybenzoic Acid, $C_6H_4(OH)COOH$. 1 : 3.

·138 gram dissolved in 20 c.c. alcohol.

With 5, 4, 3, and 2 mm. the spectrum extends to $^1/\lambda$ 3080. With 1 mm. an absorption band appears for $^1/\lambda$ 3080 to 3826.

·138 gram in 100 c.c. alcohol.

With 5, 4, 3, 2, and 1 mm. an absorption band appears from $^1/\lambda$ 3080 to 3826, which gets narrower as the thickness of the layer of liquid is reduced.

·138 gram in 500 c.c. alcohol.

With 5, 4, and 3 mm. an absorption band appears from $^1/\lambda$ 3187 to 3568, which gets narrower as the thickness of the layer of liquid is reduced.

With 2 mm. the absorption band has disappeared, and the spectrum extends to $^1/\lambda$ 4028. With 1 mm. an absorption band appears from $^1/\lambda$ 4055 to 4311.

·138 gram in 2,500 c.c. alcohol.

With 5, 4, 3, and 2 mm. an absorption band appears from $^1/\lambda$ 4055 to 4311. With 1 mm. the absorption band disappears, and the spectrum extends to $^1/\lambda$ 4658.

Parahydroxybenzoic Acid, $C_6H_4(OH).COOH$. 1: 4.

·138 gram in 20 c.c. alcohol.

With 5 mm. the spectrum extends to $^1/\lambda$ 3359, and gradually extends to $1/\lambda$ 3480 as the thickness of the layer of liquid is reduced to 1 mm.

·138 gram in 100 c.c. alcohol.

With 5, 4, 3, and 2 mm. the spectrum extends to $^1/\lambda$ 3480 (λ 2875). With 1 mm. an absorption band appears from $^1/\lambda$ 3525 to 4415.

·138 gram in 500 c.c. alcohol.

With 5, 4, 3, 2, and 1 mm. an absorption band appears from $^1/\lambda$ 3525 to 4415, which gradually gets narrower as the thickness of the layer of liquid is reduced.

·138 gram in 2,500 c.c. alcohol.

With 5, 4, 3, and 2 mm. an absorption band appears from $^1/\lambda$ 3641 to 4297, which gets narrower as the thickness of the layer of liquid is reduced. With 1 mm. the absorption band has disappeared, and the spectrum extends to $^1/\lambda$ 4658.

TAUTOMERISM.

A Study of the Absorption Spectra of Isatin, Carbostyril, and their Alkyl Derivatives in relation to Tautomerism. (HARTLEY *and* DOBBIE.)[1]

The examination of absorption spectra has recently been successfully applied to the study of the relationship between compounds commonly described as *tautomeric* and *desmotropic*. In those cases, for example, in which a substance and two related isomeric alkyl compounds having respectively the lactam and the lactim constitution are known, it is uncertain whether the supposed parent substance has a constitution similar to that of either of the derivatives. Thus there are two methyl derivatives of isatin, the constitution of each of which has been satisfactorily determined from its chemical reactions, but there is no unquestionable evidence which proves that the constitution of isatin itself is similar to that of either of the derivatives.

It is known that the substitution of a methyl or ethyl group for an atom of hydrogen, without other alteration in the structure of the substance, merely increases the general absorption very slightly for each CH_2 added to the molecule,[2] that is, it slightly shortens the transmitted spectrum, but makes practically no difference in the character of the absorption ; for instance, it scarcely increases its intensity, nor does it convert a general absorption into one that is selective, or *vice versâ*.

The curves of molecular absorption of such substances afford the desired information concerning the relationship of their constitution to that of their respective derivatives.

The spectra of carbostyril and methylpseudocarbostyril both show an absorption band in the same position, and the spectra of the two substances are in other respects almost identical, the only difference being that the general absorption is slightly increased in the case of methyl- and ethylpseudocarbostyril, which is the effect usually produced when

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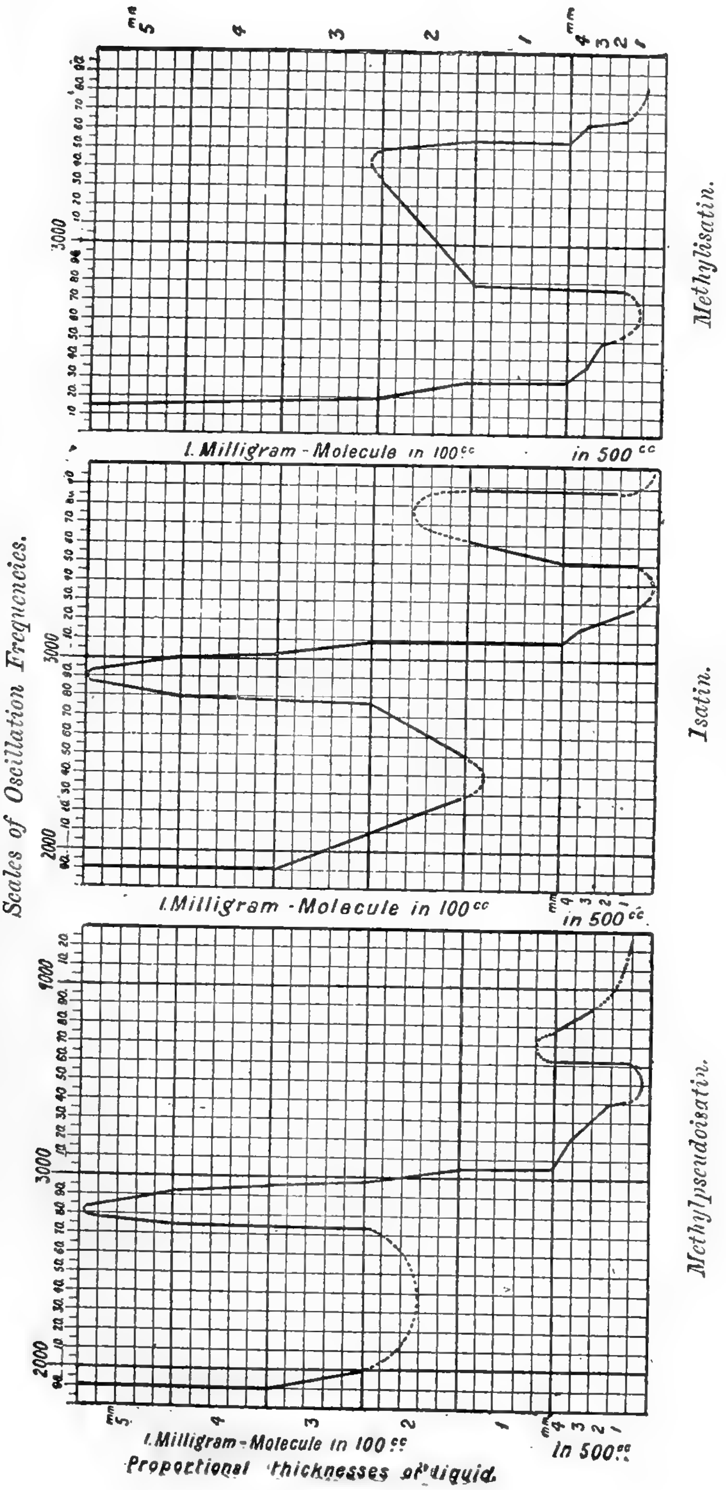
[1] *Trans. Chem. Soc.* 1899, p. 640.

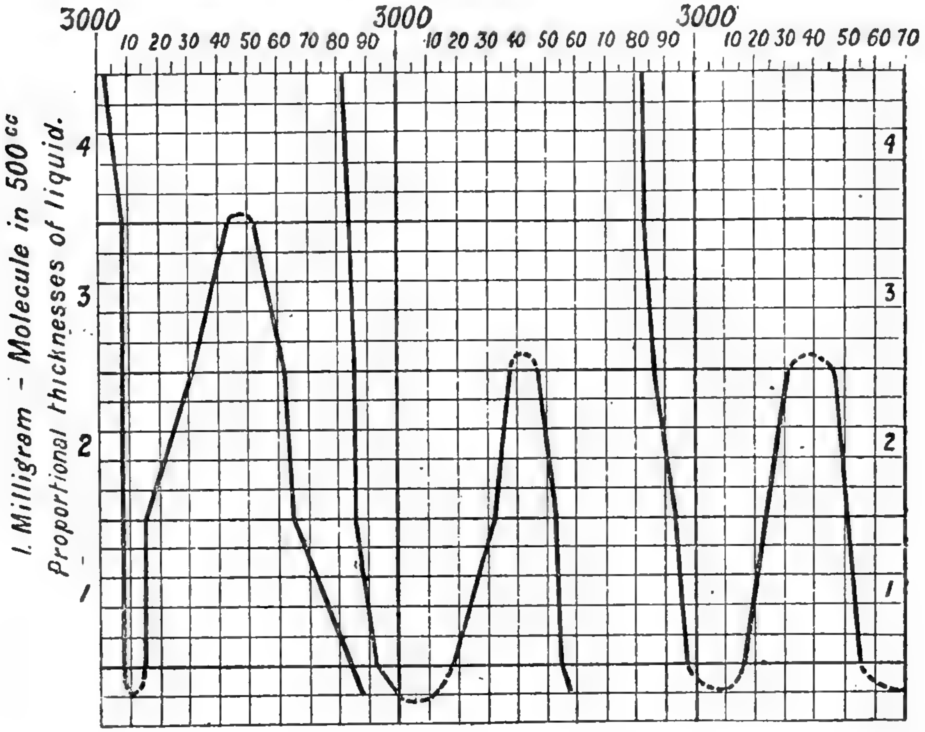
[2] *Phil. Trans.* vol. clxx. pt. 1, p. 257, 1879



Curves of Molecular Vibrations.

alkyl radicals are substituted for hydrogen. The spectra of methylcarbostyril differ in a marked manner from those of carbostyril and methylpseudocarbostyril ; the absorption band occupies a different position, is less persistent and less intense than the corresponding band of the latter, and the amount of the general absorption is less. Isatin and its derivatives show similar relations. In the spectra of isatin there are two absorption bands. The spectra of methylpseudoisatin closely resemble those of isatin, likewise exhibiting two absorption bands and about the same extent of general absorption. In methylisatin there is only one strong absorption band.

Scales of Oscillation Frequencies.



Methylcarbostyril. *Carbostyril.* *Methylpseudocarbostyril.*

Curves of Molecular Vibrations.

The very close resemblance between the curves of molecular absorption of carbostyril and methyl- and ethylpseudocarbostyril, and between those of isatin and methylpseudoisatin, point to identity of constitution, and, inasmuch as the chemical behaviour of methylpseudocarbostyril and methylpseudoisatin show that these compounds are lactams, the lactam constitution must also be assigned to carbostyril and isatin. This conclusion agrees with that arrived at by Goldschmidt and Meissler,[1] who employed a purely chemical method in their investigations, and also with the more recent results of Knorr.[2]

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[1] *Ber.*, 1890, vol. xxiii. p. 253.

[2] *Annalen*, 1896, vol. ccxciii. p. 81.

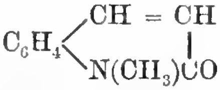
General Description of Spectra of Carbostyril, $C_9H\text{-}NO$.

Complete absorption of all rays beyond $^1/\lambda$ 2700 until we arrive at a dilution of 1 milligram-molecule of the substance in 500 c.c. of liquid with 5 mm. of thickness, when the rays extend to 2770.

At 3 mm. thickness an absorption band becomes visible, which extends to 1 milligram-molecule in 2500 c.c., and 1 mm. thickness of liquid.

At 2 milligram thickness at 1 in 500 c.c. it lies between $^1/\lambda$ 2900 and 3300, the rays are transmitted then to $^1/\lambda$ 3500, after which there is total absorption. The transmission of the continuous spectrum extends to $^1/\lambda$ 4000 beyond the absorption band, which has almost disappeared at 1 milligram-molecule in 2500 c.c. at 2 mm. thickness.

Methylpseudocarbostyril,



$$C_6H_4\Big\langle\begin{matrix}CH = CH \\ \qquad | \\ N(CH_3)CO\end{matrix}$$

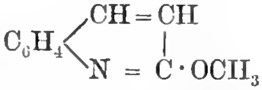
Total absorption of all rays beyond $^1/\lambda$ 2680 in from 25 mm. to 15 mm. of liquid, and beyond $^1/\lambda$ 2780 down to 1 mm. thickness 1 milligram-molecule in 100 c.c.

Complete absorption to $^1/\lambda$ 2850 by 3 mm. of solution containing 1 milligram-molecule in 500 c.c. absorption band from $^1/\lambda$ 2850 to 3370. Very feeble transmission of rays from 3370 to 3500.

This absorption band is distinctly seen down to 2 mm. of liquid or 1 milligram-molecule in 2500 ; the continuous rays then extend to about 4050.

It will thus be seen that this spectrum curve very closely resembles that of carbostyril, the general absorption being slightly increased, which is what is usual when methyl takes the place of hydrogen or CH_2 is added to the molecule.

Methylcarbostyril,



$$C_6H_4\Big\langle\begin{matrix}CH = CH \\ \qquad | \\ N = C\cdot OCH_3\end{matrix}$$

Complete transmission of all rays to $^1/\lambda$ 3000, with 1 milligram-molecule in 500 c.c. and 5 mm. of liquid. Rays beyond are all absorbed.

At 3 mm. the rays extend to $^1/\lambda$ 3050, and are then completely absorbed to about 3350, and are transmitted to 3500 ; in other words there is an absorption band between 3050 and 3350 ; rays beyond it are transmitted to $^1/\lambda$ 3500.

This band is very feeble at 5 mm., but is just visible down to a thickness of 4 mm. of liquid, containing 1 milligram-molecule in 2,500 c.c. The rays showing absorption lie between $^1/\lambda$ 3000 and 3050. Beyond that they are transmitted imperfectly to about 3800.

The chief differences between this spectrum and that of the pseudo compound are the greater length of spectrum transmitted, the different position of the absorption band, and its less persistent character.

General Description of the Spectrum of Isatin, $C_8H_5NO_2$.

Total absorption of all rays as far as $^1/\lambda$ 2780 by 10 mm. thickness of a solution of 1 milligram-molecule in 100 c.c.

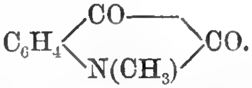
Total absorption of all rays by 5 mm. of 1 milligram-molecule in 100 c.c. as far as $^1/\lambda$ 2780, very feeble transmission to 3000. The same a little stronger by 4 mm.

Total absorption beyond 1 milligram-molecule in 100 c.c., 3 mm. thick, transmits rays very feebly from $^1/\lambda$ 2000 to 2170, an absorption band occurs as far as 2780, the rays are transmitted from $^1/\lambda$ 2780 to 3070. Total absorption beyond.

The absorption band continues until 4 mm. of 1 milligram-molecule in 560 c.c., though much enfeebled. Beyond 3170 there is total absorption to about $^1/\lambda$ 3630, with, as it were, another absorption band. It continues to 2 mm. of milligram-molecule in 500 c.c. between 3200 and 3630, after which there is total absorption beyond $^1/\lambda$ 3870. There is a very strong absorption beyond 3900.

Isatin crystals are deep red, like fused potassium dichromate.

Methylpseudoisatin,



$C_6H_4\left\langle\begin{matrix}CO\text{——}\\N(CH_3)\end{matrix}\right\rangle CO.$

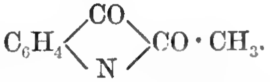
There is complete absorption of all rays by 10 mm. of 1 milligram-molecule in 100 c.c. By 5 mm. the strong rays between $^1/\lambda$ 2740 and 2900 are transmitted, all rays beyond are totally absorbed. There is a strengthening of the transmitted rays by thicknesses of 4 mm. and 3 mm. between $^1/\lambda$ 2740 and 2970. Total absorption beyond.

At 2 mm. and 1 mm. the absorption of rays less refrangible than $^1/\lambda$ 2740 is much diminished, that is to say, the absorption band hereabouts is weakened.

By thicknesses of 5, 4, 3 mm. of 1 milligram-molecule in 500 c.c. there is nothing transmitted beyond $^1/\lambda$ 3030, except the very strong line at 3600. There is very strong absorption beyond this line until we get to 4 mm. of 1 milligram-molecule in 2,500 c.c., when the rays between $^1/\lambda$ 3600 and 3840 are feebly transmitted, and there is only a very feeble transmission of strong rays beyond lying between $^1/\lambda$ 4250 and 4400, and so gradually the absorption diminishes.

Methylpseudoisatin has a colour more resembling cinnabar than potassium dichromate.

Methylisatin,



$C_6H_4\left\langle\begin{matrix}CO\\N\end{matrix}\right\rangle CO\cdot CH_3.$

With 1 milligram-molecule in 100 c.c. there is a total absorption of rays down to a thickness of 10 mm.

At 5 mm. there is a very feeble transmission of rays between $^1/\lambda$ 2000 and 2170.

At 3 mm. it is evident that a very strong absorption band lies between 2180 and about 3350, when rays are very feebly transmitted, all beyond 3470 being totally absorbed.

This absorption band gradually diminishes in intensity, but more rapidly on the part of the rays of shorter wave-length than is the case with those lying between $^1/\lambda$ 2270 and 2870. For instance, 2 mm. of liquid containing 1 milligram-molecule in 500 c.c., absorbs the rays between $^1/\lambda$ 2600 and 2770. Total absorption is seen beyond 3600.

Methylisatin is orange red, like powdered potassium dichromate.

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, Professor A. SMITHELLS, *and* Professor S. P. THOMPSON.

THE progress in the teaching of science in elementary schools which was noted in the last report of your Committee has been more than maintained in so far as the number of scholars receiving instruction is concerned. The following table, made up from the return issued by the Education Department, gives the figures for the scientific class subjects, and for English by way of comparison. It will be remembered that for the eight years preceding the Code of 1890, English was obligatory as a class subject if any such subject was taken in the school. The placing it merely on a level with the other subjects had the effect of reducing the number of departments in which English was taken from 20,304 in 1889–90 to 19,825 in 1890–91, while in the same years the number of departments taking Elementary Science rose from the almost nominal figure of 32 to 173. The table shows the progress from that time onwards. It will be observed that there is an extraordinary increase in Object Lessons, which it was pointed out last year would be the case owing to the giving of Object Lessons in the three lower standards being made obligatory after September 1, 1896. The full effect of this change has hardly yet appeared. The return for 1897–98 should show a figure almost equal to the total number of departments. This ascendency of Object Lessons is fully capable of explaining the decrease in Elementary Science, and does not necessarily involve any lessening of the child's knowledge of Nature. It is rather a question of nomenclature than anything else, in some schools the object lessons course in the lower standards being still registered under the name of Elementary Science.

Class Subjects—Departments	1891–92	1892–93	1893–94	1894–95	1895–96	1896–97	1897–98
English . . .	18,175	17,394	17,032	16,280	15,327	14,286	13,456
Geography . . .	13,485	14,256	15,250	15,702	16,171	16,646	17,049
Elementary Science .	788	1,073	1,215	1,712	2,237	2,617	2,143
Object Lessons . .	—	—	—	—	1,079	8,321	21,882

The number of departments in 'schools for older scholars' for the year 1897–98 was 23,043, all but two of which took one or more class subjects. But History was taken in 5,780 departments, and needlework (as a class subject for girls) in 7,252 departments, and sundry minor subjects in 972, making, with the other four subjects of the table, a total of 68,534. This shows an average of very nearly three class subjects to each department, but it must be borne in mind that the same subject is not always taken in all the standards, in which case three or more class subjects will appear in the return for a single department.

It has been previously remarked that 'the increased teaching of scientific specific subjects in the higher standards is the natural consequence of the greater attention paid to natural science in the lower part of the schools.' The following table shows that such is the actual result:—

Specific Subjects.—Children	1891–92	1892–93	1893–94	1894–95	1895–96	1896–97	1897–98
Algebra . .	28,542	31,487	33,612	38,237	41,846	47,225	53,081
Euclid . .	927	1,279	1,399	1,468	1,584	2,059	2,471
Mensuration .	2,802	3,762	4,018	5,614	6,859	8,619	10,828
Mechanics . .	18.000	20,023	21.532	23,806	24,956	26,110	27,009
Animal Physiology	13,622	14,060	15,271	17,003	18,284	19,989	22,877
Botany . .	1,845	1,968	2,052	2,483	2,996	3,377	4,031
Principles of Agriculture	1,085	909	1,231	1,196	1,059	825	870
Chemistry . .	1,935	2,387	3,043	3,850	4,822	5,545	6,978
Sound, Light, and Heat	1,163	1,168	1,175	914	937	1,040	1,155
Magnetism and Electricity	2,338	2,181	3,040	3,198	3,168	3,431	3,905
Domestic Economy	26,447	29,210	32,922	36,239	39,794	45,869	51,259
Total .	98,706	108,434	119,295	134,008	146,305	164,089	184,464

It may be noted that every one of these specific subjects shows an actual increase; and the totals indicate an increase of more than 20,000, a larger rise than has been recorded in any previous year.

In last year's report the number of scholars in Standards V., VI., and VII. was estimated at 615,000. The Government returns, in the form in which they are now presented, enable your Committee to make a much more precise estimate; and it now appears that the number of scholars, including the Ex-VII., must have been about 650,000. This figure would give 25·3 per cent. as the proportion examined in these specific subjects as compared with the number of children qualified to take them, and the table below has been altered accordingly. The mean number of such scholars for the year 1897–98 is 693,242, which will give 26·6 per cent. as the proportion of actual to possible students; 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, and shows that the great depression which characterised several years has been succeeded by a gradual and steady rise:—

1882–83 . .	29·0 per cent.	1890–91 . .	20·2 per cent.
1883–84 . .	26·0 „	1891–92 . .	19·7 „
1884–85 . .	22·6 „	1892–93 . .	20·2 „
1885–86 . .	19·9 „	1893–94 . .	20·9 „
1886–87 . .	18·1 „	1894–95 . .	22·7 „
1887–88 . .	16·9 „	1895–96 . .	24·2 „
1888–89 . .	17·0 „	1896–97 . .	25·3 „
1889–90 . .	18·4 „	1897–98 . .	26·6 „

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, 1899. They also illustrate the great advance that has been made in the teaching of Elementary Science, including Object Lessons, as a class subject.

Class subjects—Departments	1890-1	1891-2	1892-3	1893-4	1894-5	1895-6	1896-7	1897-8	1898-9
Elementary Science . .	11	113	156	183	208	246	364	322	310
Object Lessons . .	—	—	—	—	—	—	—	442	657

The work under the Evening Continuation Schools Code continues to progress, as will be seen by the following table, which gives the number of scholars taking scientific subjects in the year 1897–98 compared with those for the previous year.

Science Subjects	Number of Scholars	
	1896–97	1897–98
Euclid	1,036	1,525
Algebra	7,467	9,996
Mensuration	27,388	29,966
Elementary Physiography	3,712	4,807
Elementary Physics and Chemistry	3,135	2,902
Domestic Science	—	117
Science of Common Things	10,910	13,874
Chemistry	5,658	6,590
Mechanics	1,365	1,129
Sound, Light, and Heat	726	813
Magnetism and Electricity	3,834	3,967
Human Physiology	5,865	6,237
Hygiene	3,179	4,062
Botany	692	763
Agriculture	2,355	2,300
Horticulture	1,001	1,354
Navigation	68	37
Ambulance	9,086	13,030
Domestic Economy	19,565	23,271
Totals . . .	107,042	126,740

The differences represent a total increase of 19,698, which is equivalent to 18·4 per cent. The only actual decreases are in Elementary Physics and Chemistry, Mechanics, Agriculture, and Navigation. It may be remarked that it is rather the practical than the theoretical subjects which are receiving less attention. The Mathematical subjects are still advancing rapidly, and so are Elementary Physiography and the Science of Common Things. The cognate subjects of Hygiene and Ambulance are evidently rising in popular favour. The same may be said of Horticulture. It would be interesting to know the relative proportions of young men and young women in these latter classes, but the Government returns do not supply this information. The only one of these subjects reserved exclusively for women is Domestic Economy. Domestic Science, as distinguished from the preceding, has only recently been formulated, and the first-fruits are only beginning to make their appearance in the column for the latter year. Unlike the day school work, which is largely governed by the requirements of the Education

Department, and the preferences of managers and teachers, the Evening Continuation classes are to a great extent regulated by the public local demand, which rather seems to be for a continuation of the studies which have been begun in the Elementary Schools than for those practical subjects which are specially provided for by the Technical Instruction Act.

The London School Board have just passed a series of resolutions on the subject of the teaching of science in their schools, and amongst others that 'Experimental Science instruction was desirable for girls as well as for boys:'—that 'scholars of about Standard IV. should have an opportunity of doing some practical work themselves, such as linear (or other) measurement:'—and that 'where some definite science is taught in the upper part of the school, the teaching of Experimental Science in the lower part of the school should lead up to it.' The extension of the teaching of Science in the Board Schools has necessitated the Science demonstrators giving more and more attention to the preparing of the ordinary teachers for giving practical instruction in Science in their classes. These teachers have usually obtained certificates for one or more sciences under the Science and Art Department, but that does not necessarily qualify for the practical teaching of science according to modern views. Hence the need of the preparation above referred to. It would seem desirable that only those teachers who have some interest in, or aptness for, experimental work should be selected for this kind of training, and after having become thus qualified, they should be assigned, as far as possible, to this particular work. To carry this out more thoroughly the Board have decided 'that Experimental Science classes for teachers be started under the Board in the autumn,' and 'that there be courses of Pedagogical Lectures to secure the practical teaching of Elementary Science, confined to teachers who have reached a certain standard of scientific knowledge of the subject on which the lectures are given.'

It is to be hoped that under the newly constituted Education Department far more attention will be given than heretofore to improving the conditions under which science is taught in schools. Especially is it important that attention should be paid to the practical training of pupil teachers in the elements of scientific method. The time given to such work is altogether inadequate at present. But in some ways too much is often attempted, and from this point of view your Committee think it desirable to recall attention to the recommendations in the last paragraph of their Report for 1897, as up to the present time no action has been taken by the Education Department.

Isomeric Naphthalene Derivatives.—Report of the Committee, consisting of Professor W. A. TILDEN (*Chairman*) *and* Dr. H. E. ARMSTRONG (*Secretary*).

THE experiments on the etherification of betanaphthol and its derivatives, referred to in the previous report, have been continued by Mr. Davis, the formation of methylic and propylic ethers having also been investigated.

Methylic, ethylic, and propylic alcohols have an almost identical effect.

The results are of interest in comparison with those obtained by V. Meyer and others in the case of carboxylic acids. Meyer, it is well known, has shown that a single group, in a position contiguous to the acid radicle, has little influence on the limit of etherification, and only affects the rate of change: but this is not true of betanaphthol, as 1 chlorobetanaphthol yields only about 10 per cent. of ether, although betanaphthol gives over 90 per cent. and nitronaphthol cannot be etherified.

The effect is, in a measure, the reciprocal of that referred to in Sections 10 and 13 of a 'Synopsis for a Discussion on Laws of Substitution, especially in Benzenoid Compounds,' printed later in this volume. The first act in the formation of an ether is probably the association of the group which becomes etherified with the etherifying agent; but the attractive power of the phenolic oxygen is much affected by changes in the radicle with which it is associated, and consequently both the rate and limit of etherification are modified by every change in the hydrocarbon radicle. Probably the carbonyl oxygen in acids plays a part similar to that here pictured as played by the hydroxylic oxygen in naphthol.

But it is not improbable that the nucleus also plays a part in etherification, especially as betanaphthol—in which the nucleus is obviously less saturated than is the nucleus in phenol—yields so much larger a proportion of ether than does phenol. Under the most favourable conditions phenol affords at best about 25 per cent. of ether when digested with alcohol and sulphuric acid.

The Action of Light upon Dyed Colours.—Report of the 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 (1898–9) the work of this Committee has been continued, and a large number of wool and silk patterns, dyed with various natural and artificial *violet* and *grey* 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 Edward 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 pattern, 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 removed, 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 March 12, 1898, certain sets being subsequently removed on the following dates: April 20, May 28, June 27, October 22, 1898; April 25, 1899. 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 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. March 12 to April 20, 1898.

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 1898–9, 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' (3rd edit. 1897).

VIOLET COLOURING MATTERS.

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' (March 12 to April 20, 1898) 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 XV.		
Acid Colours.	1.	Red Violet 4RS. Sodium salt of dimethyl-rosaniline-trisulphonic acid. S. and J. 313.
,,	2.	Red Violet 5RS. Sodium salt of ethyl-rosaniline-trisulphonic acid. S. and J. 311.
,,	19.	Acid Violet 4BN. Sodium salt of benzyl-penta-methyl-triamido-triphenyl-carbinol-sulphonic acid. S. and J. 312.
,,	23.	Acid Violet 6B. Acid sodium salt of tetraethyl-dibenzyl-p-rosaniline-disulphonic acid. S. and J. 317.
,,	24.	Alkali Violet. Sodium salt of tetraethyl-monomethyl-phenyl-p-rosaniline-monosulphonic acid. S. and J. 318.
,,	27.	Acid Violet 12B. Constitution not published.
,,	30.	Acid Violet 3B. Constitution not published.
,,	31.	Alkali Violet CA. Sodium salt of benzylated methyl-ethyl-p-rosaniline-mono-sulphonic acid.
,,	33.	Acid Violet 2B. Constitution not published.
,,	35.	Alkali Violet R. Constitution not published.
Basic Colours.	5.	Hofmann's Violet. Monoethyl-rosaniline hydrochloride. S. and J. 302.
,,	10.	Regina Violet. Diphenyl-rosaniline hydrochloride. S. and J. 294.
,,	11.	Regina Purple. Monophenyl-rosaniline-acetate. S. and J. 307.
,,	12.	Ethyl Violet. Hexaethyl-p-rosaniline hydrochloride. S. and J. 305.
,,	15.	Methyl Violet 6BO. Pentamethyl-benzyl-p-rosaniline hydrochloride. S. and J. 306.
,,	16.	Crystal Violet. Hexamethyl-p-rosaniline hydrochloride. S. and J. 304.
,,	17.	Violet 3B. Constitution not published.
	18.	Methyl Violet B extra. Pentamethyl-p-rosaniline hydrochloride S. and J. 303.

Safranine Colours.

Basic Colours.	3.	Giroflée. Dimethyl-xylyl-safranine chloride. S. and J. 464.
,,	7.	Rubramine. S. and J. 500.

Basic Colours. 8. Methylene Violet 2RA. Dimethyl-safranine chloride. S. and J. 462.
" 9. Rosolane. Phenyl-tolu-safranine chloride. S. and J. 467.
" 20. Fast Neutral Violet B. ms-Ethyl-dimethyl-ethyl-safranine chloride. S. and J. 460.

Eurhodine Colours.

Basic Colours. 24. Neutral Violet extra. as-Dimethyl-diamido-phenazine hydrochloride. S. and J. 448.

Oxazine Colours.

Basic Colours. 21. Cresyl Fast Violet 2B. Constitution not published.
" 2. Rhoduline Violet. Constitution not published.

CLASS II. FUGITIVE COLOURS. (WOOL.)

The colours of this class show very marked fading at the end of the second 'fading period' (April 20 to May 28, 1898), and after a year's exposure they have entirely faded, or only a tint remains.

Triphenylmethane Colours.

Wool Book XV.
Acid Colours. 20. Acid Violet 6B. Sodium salt of dimethyl-dibenzyl-diethyl-triamido-triphenyl-carbinol-disulphonic acid. S. and J. 316.
" 21. Acid Violet 7B. Sodium salt of diethyl-dimethyl-diphenyl-triamido-triphenyl-carbinol-disulphonic acid.
" 22. Acid Violet 5B. Constitution not published.
" 25. Acid Violet 8B extra. Constitution not published.
" 26. Acid Violet 6BN. Sodium salt of tetramethyl-p-tolyl-triamido-ethoxy-triphenyl-carbinol sulphonic acid. S. and J. 319.
" 28. Fast Acid Violet 10B. S. and J. 314.
" 32. Acid Violet 2B extra. Constitution not published.
" 37. Acid Violet 4BG extra. Constitution not published.
" 40. Guinea Violet 4B. Constitution not published.
" 42. Acid Violet 5BF. Constitution not published.
Wool Book XVI.
Mordant Colours. 9. Chrome Violet (Cr). Ammonium salt of aurine-tricarboxylic acid.

Azo Colours.

Wool Book XV.
Direct Cotton Colours. 1. Congo Violet. From benzidine, and β-naphthol-sulphonic acid B. S. and J. 186.
" 2. Heliotrope B. From dianisidine, and ethyl-β-naphthylamine-sulphonic acid F. S. and J. 232.
" 3. Heliotrope 2B. From benzidine, β-naphthol-sulphonic acid B, and α-naphthol-disulphonic acid Sch. S. and J. 185.
" 4. Benzo Violet R. Constitution not published.
" 5. Azo Corinth. From tolidine, amido-phenol-sulphonic acid, resorcinol, and naphthionic acid. S. and J. 271.
" 6. Congo Corinth G. From benzidine, naphthionic acid, and α-naphthol-sulphonic acid NW. S. and J. 183.
" 7. Hessian Violet. From diamido-stilbene-disulphonic acid, α-naphthylamine, and β-naphthol. S. and J. 249.
" 8. Oxamine Violet. From benzidine, and β-amido-α-naphthol-β-sulphonic acid. S. and J. 188.
" 10. Congo Corinth B. From tolidine, naphthionic acid, and α-naphthol-sulphonic acid NW. S. and J. 214.
" 11. Azo Violet. From dianisidine, naphthionic acid, and α-naphthol-sulphonic acid NW. S. and J. 233.
" 12. Azo Mauve. From tolidine, amido-naphthol-disulphonic acid, and α-naphthylamine. S. and J. 212.

Natural Colouring Matters.

Wool Book XVI.
Mordant Colours. 1. Sapanwood (Cr). Wood of Cæsalpinia sapan.
" 2. Peachwood (Cr). Wood of Cæsalpinia echinata.
" 3. Logwood (Sn). Wood of Hæmatoxylon campechianum

CLASS III. MODERATELY FAST COLOURS. (WOOL.)

The colours of this class show distinct fading at the end of the second period (April 20 to May 28, 1898), which becomes more pronounced at the end of the third period (May 28 to June 27, 1898). A pale tint remains at the end of the fourth period (June 27 to October 22, 1898), and at the end of a year's exposure the colour has entirely faded, or, at most, mere traces of colour remain.

Azo Colours.

Wool Book XV.
Acid Colours. 7. Azo Acid Violet 4R. Constitution not published.
" 8. Azo Acid Violet R extra. Constitution not published.
" 10. Azo Acid Violet B extra. Constitution not published.
" 15. Fast Violet (blue shade). From *p*-toluidine-sulphonic acid, α-naphthylamine, and β-naphthol-sulphonic acid S. S. and J. 151.
" 16. Fast Violet (red shade). From sulphanilic acid, α-naphthylamine, and β-naphthol-sulphonic acid S. S. and J. 148.
" 43. Victoria Violet 4BS. Sodium salt of *p*-amido-aniline-azo-1·8-dioxy-naphthalene-3·6 disulphonic acid. S. and J. 38.
" 44. Victoria Violet 5B. Constitution not published.

Safranine Colours.

Basic Colours. 23. Paraphenylene Violet. S. and J. 473.

Induline Colours.

Acid Colours. 14. Naphthyl Violet. Constitution not published.

Oxazine Colours.

Acid Colours. 45. Gallanilic Violet. Sodium bisulphite compound of gallocyanine-anhydride-anilide.

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.

Pyronine Colours.

Wool Book XV.
Acid Colours. Violamine G. Sodium salt of dimesidyl-*m*-amido-phenolphthaleïn-sulphonic acid. S. and J. 350.
" Acid Violet 4R. Constitution not published.
" Violamine R. Sodium salt of diortho-tolyl-*m*-amido-phenolphthaleïn-sulphonic acid. S. and J. 349.
" Violamine B. Sodium salt of diphenyl-*m*-amido-phenolphthaleïn-sulphonic acid. S. & J. 348.
Mordant Colours. Galleïn W (Al) (Sn) (Cu). Oxidation product of pyrogallol-phthaleïn. S. and J. 366.

Azo Colours.

Direct Cotton Colours. 9. Diamine Violet N. From benzidine, and β-amido-naphthol-γ-sulphonic acid. S. and J. 180.
Mordant Colours. 3. Chrome Prune (Cr). Constitution not published.

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.

Oxyketone Colours.

Wool Book XVI.
Mordant Colours. Alizarin Cyanine G (Al) (Sn). Constitution not published.
„ Alizarin Cyanine GR (Al) (Sn). Constitution not published.
„ Alizarin Cyanine R (Al). Pentaoxy-anthraquinone. S. and J. 406.
„ Alizarin Cyanine 2R (Al) (Sn) (Cu). Constitution not published.
„ Alizarin Claret R (Cr). Constitution not published.

Oxazine Colours.

Mordant Colours. Gallocyanine DH (Cu). Dimethyl-phenyl-ammonium-dioxy-phenoxazine-carboxylic acid. S. and J. 418.

Azo Colours.

Mordant Colours. Chrome Bordeaux 6B (Cr). Constitution not published.

GREY COLOURING MATTERS.

Class II. Fugitive Colours. (Wool.)

Safranine Colours.

Wool Book XVII.
Basic Colours. 1. Methylene Grey P. Constitution not published.
„ 3. Methylene Grey (green shade). Constitution not published.

Class III. Moderately Fast Colours. (Wool.)

Safranine Colours.

Basic Colours. 7. Methylene Grey O. Constitution not published.
„ 9. New Methylene Grey G. Constitution not published.

Induline Colours.

Acid Colours. 1. Aniline Grey B. Constitution not published.
„ 3. Aniline Grey R. Constitution not published.
„ 4. New Grey P. Constitution not published.
Basic Colours. 2. New Fast Grey. Constitution not published.
Direct Cotton Colours. { 8. Direct Grey I. Constitution not published.
9. Direct Grey R. Constitution not published.

Oxazine Colours.

Basic Colours. 5. Fast Grey R. Constitution not published.
„ 8. Fast Grey B. Constitution not published.
„ 10. Metamine Grey M. Constitution not published.

Azo Colours.

Direct Cotton Colours. 1. Neutral Grey G. Constitution not published.
2. Benzo Grey S extra. Constitution not published.
„ 5. Zambési Grey B. Constitution not published.

Class IV. Fast Colours. (Wool.)

Safranine Colours.

Basic Colours. 4. New Methylene Grey B. Constitution not published.

Induline Colours.

Wool Book XVII.
Direct Cotton 12. Direct Grey 4B. Constitution not published.
Colours.

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 colours was for the most part the same as on wool, the differences observed being too unimportant to warrant a special classification for silk.

Concluding Observations.

These experiments on the Action of Light on Dyed Colours have been continuously in progress from 1892 to 1899, during which period over 10,600 dyed patterns have been exposed to light, representing about 900 colouring matters, including nearly all those at present in use.

The following tables give a *résumé* of the relative fastness to light of all the colours examined, arranged in order of shade and according to their chemical constitution.

Red Colours.

	Very fugitive	Fugitive	Moderately fast	Fast	Very fast
Azo colours	6	47	60	35	3
Triphenylmethane colours	—	7	—	—	—
Pyronine colours	19	5	—	1	—
Acridine colours	—	1	—	—	—
Oxyketone colours	—	—	2	1	11
Safranine colours	5	1	—	—	—
Induline colours	2	—	2	1	—
Natural colours	3	11	2	2	10
Total	35	72	66	40	24

Orange and Yellow Colours.

	Very fugitive	Fugitive	Moderately fast	Fast	Very fast
Nitro colours	5	—	—	1	—
Hydrazone colours	—	—	—	2	—
Azoxy colours	—	—	—	3	10
Azo colours	10	18	31	19	18
Triphenylmethane colours	1	—	1	—	—
Pyronine colours	1	—	—	—	—
Acridine colours	4	—	—	—	—
Oxyketone colours	—	—	—	2	13
Thiobenzenyl colours	3	—	—	—	—
Quinolin colours	1	1	—	—	—
Natural colours	8	16	3	2	11
Total	33	35	35	29	52

Green Colours.

	Very fugitive	Fugitive	Moderately fast	Fast	Very fast
Azo colours	—	1	2	2	—
Triphenylmethane colours	5	13	3	—	—
Pyronine colours	—	—	—	—	1
Quinoneoxime colours	—	—	—	—	6
Oxyketone colours	—	—	—	—	1
Safranine colours	—	1	—	—	—
Natural colours	1	—	—	—	—
Total	6	15	5	2	8

Blue Colours.

	Very fugitive	Fugitive	Moderately fast	Fast	Very fast
Azo colours	4	28	15	1	—
Triphenylmethane colours	5	4	13	2	—
Oxyketone colours	—	—	—	—	8
Oxazime colours	6	5	2	1	1
Thiazime colours	5	1	—	—	2
Safranine colours	1	4	—	—	—
Induline colours	—	—	12	1	—
Prussian blue	—	—	—	—	1
Natural colours	—	3	1	—	1
Total	21	45	43	5	13

Violet Colours.

	Very fugitive	Fugitive	Moderately fast	Fast	Very fast
Azo colours	—	11	7	2	1
Triphenylmethane colours	18	12	—	—	—
Pyronine colours	—	—	—	5	—
Oxyketone colours	—	—	—	—	9
Oxazime colours	2	—	1	—	1
Safranine colours	6	—	1	—	—
Induline colours	—	—	1	—	—
Natural colours	—	3	—	—	—
Total	26	26	10	7	11

Brown Colours.

	Very fugitive	Fugitive	Moderately fast	Fast	Very fast
Azoxy colours	1	—	3	—	—
Azo colours	9	46	15	2	—
Oxyketone colours	—	—	—	—	10
Chromogen	—	—	—	—	1
Natural colours	—	6	8	1	20
Total	10	52	26	3	31

Black and Grey Colours.

	Very fugitive	Fugitive	Moderately fast	Fast	Very fast
Azo colours	3	20	36	4	—
Oxyketone colours	—	—	—	4	1
Oxazime colours	—	1	3	—	—
Safranine colours	—	2	2	1	—
Induline colours	—	—	6	1	—
Natural colours	—	1	3	—	—
Total	3	24	50	10	1

GENERAL TABLE.

(Including all the colours in the above tables.)

	Very fugitive	Fugitive	Moderately fast	Fast	Very fast
Nitro colours	5	—	—	1	—
Hydrazone colours	—	—	—	2	—
Azoxy colours	1	—	3	3	10
Azo colours	32	171	166	65	22
Triphenylmethane colours	29	36	17	6	—
Pyronine colours	20	5	—	—	1
Acridine colours	4	1	—	—	—
Quinoneoxime colours	—	—	—	7	6
Oxyketone colours	—	—	2	1	53
Oxazime colours	8	6	6	—	2
Thiazime colours	5	1	—	1	2
Safranine colours	12	8	3	3	—
Induline colours	2	—	24	—	—
Thiobenzenyl colours	3	—	—	—	—
Quinolin colours	1	1	—	—	—
Chromogen	—	—	—	—	1
Prussian blue	—	—	—	—	1
Natural colours	3	40	17	5	42
Total	134	269	96	96	140

The above tables show clearly that, although the coal-tar dyestuffs include a very large number which yield fugitive colours, there are also many which yield fast colours. It is seen that both these classes are also represented among the natural or vegetable dyestuffs, and the prevalent idea that the latter are fast while the former are fugitive is merely a popular error. This opinion has, however, been so long fixed in the popular mind that it is to be hoped the conclusive proof of its fallacy afforded by these experiments will cause it to be finally abandoned. These tables, indeed, show that coal-tar furnishes the dyer with a larger number of colours fast to light than are derived from any other source.

The work of the Committee being now limited to the examination of dyes on the cotton fibre, as well as new colouring matters introduced each year, the Secretary will continue the investigation without requiring any grant in aid, and a reappointment of the Committee is not necessary.

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. F. A. BATHER, Mr. G. C. CRICK, Mr. A. H. FOORD, Mr. H. FOX, Dr. WHEELTON HIND, Dr. G. J. HINDE, Professor P. F. KENDALL, Mr. J. W. KIRKBY, Mr. R. KIDSTON, Mr. G. W. LAMPLUGH, Professor G. A. LEBOUR, Mr. G. H. MORTON, *the late* Professor H. A. NICHOLSON, Mr. B. N. PEACH, Mr. A. STRAHAN, *and* Dr. H. WOODWARD. (*Drawn up by the Secretary.*)

THE Committee report that the work during the past twelve months has been proceeding on the same lines as before. The reports from the specialists to whom the Eccup collection has been referred are not yet complete. Reports on special districts have been received from Dr. Wheelton Hind and Mr. G. H. Morton; the latter hopes to report more fully later on. These reports are appended. The recent evidence obtained does not seem to afford any assistance in the selection of zone fossils capable of being used outside the special districts to which they were first found applicable. Thus, *Chonetes papillionacea*, a species characteristic of the Lower Scar Limestone of Westmoreland and Yorkshire, has recently been reported by Dr. Hind from the Upper part of the Carboniferous Limestone of the Congleton district in Cheshire; while Mr. Morton finds that several common species, previously considered to be characteristic of the upper and middle subdivisions of the Carboniferous Limestone in the west of the country, occur in Anglesey and along the Menai Strait in the lower division.

Owing to constant absence from England, Mr. Garwood has with regret been obliged to resign the office of Secretary to the Committee. The Committee are, however, glad to state that Dr. Wheelton Hind has undertaken to transact the business of the Committee in future, if they are re-appointed.

The Committee have been unable to carry out any further exploration during the year, and have therefore not drawn any of the money granted by the Association at the last meeting.

APPENDIX.

I. *Report on Carboniferous Rocks and Fossils; South Pennine District.*
By Dr. WHEELTON HIND.

I prefer to subdivide the Carboniferous rocks, as they occur in S.W. Yorkshire, Lancashire, Cheshire, Derbyshire, and Staffordshire, into two groups only—Upper and Lower.

UPPER . .	Coal measures. Millstone grit. Shales.
LOWER . .	Limestones, massive.

THE COAL MEASURES.—With regard to the sequence of coal measures in the various districts, I would refer to my schemes with the horizons at which the molluscs occur, printed in Part II. of my monograph on the British *Carbonicola, Anthracomya* and *Naiadites.*

The species of the genus *Anthracomya* seem to me particularly useful in each coalfield as denoting zones which I have more particularly worked out in the North Staffordshire coalfield, the upper coal measures consisting of red measures with sandstones, ironstones, a few corals and spirorbis limestones. The latter are, however, found almost to the base of the North Staffordshire coalfield. The typical shell of the lower part of this series is *Anthracomya Phillipsii,* which passes down to the Knowles Ironstone, below which it is not found. In the North Staffordshire and Manchester coalfields, a small shell, *Anthracomya calcifera* (Hind), appears to denote a zone some 300 yards above the zone of *A. Phillipsii.* In the North Staffordshire coalfield this zone occurs just below the Penkhull sandstone, hitherto mapped as Permian by the Geological Survey.

Anthracomya minima is typical of the Knowles Ironstone.

Anthracomya Adamsii and *A. pulcra,* confined to the Burnwood or Little Mine Ironstone.

Carbonicola turgida, typical of a bed a few yards above the moss coal.

Carbonicola nucularis, C. cuneiformis, Anthracomya Williamsoni, A. subcentralis, only found in roof of Hardmine coal.

Carbonicola similis is found only about the horizon of the Cockshead coal.

The genus *Naiadites* comes in with the Knowles seam, and is found at several horizons below this to the base of the Coal Measures.

The gannister series appears to be absent in North Staffordshire, unless it is represented by thin beds with *Aviculopecten papyraceus* about the Stinking Coal, Cheadle and Froghall, and over the lower coals of Wetley Moor.

The Hutton cannel seam of Wigan is characterised by a bivalve like a Schizodus (the Tellinomya of H. Bolton), probably unfilled casts of *Carbonicola turgida,* and the Arley mine by *Carbonicola robusta.*

The Millstone Grit series appears destitute of molluscan remains, the beds thin out to the south-west, only two remaining along the west flank of the Pottery coalfield.

Four important marine bands occur in the North Staffordshire coalfield, one high up over the Bay mine, with

Aviculopecten, sp.
Nucula, sp.
Discina, sp.
Lingula, sp.
Macrocheilus
Nautilus
Productus
Spirifer

Another over the Gin mine—

Orthoceras, sp.
Discites, sp.
Goniatites, sp.
Euomphalus
Pleurotomaria, sp.
Loxonema, sp.
Bellerophon, sp.
Macrocheilus, sp.
Spirifer
Productus semireticulatus
Chonetes Laguessiana
Nucula gibbosa
„ *undulata* (?)
Schizodus, sp.
Solenomya primæva

One over the Moss coal, with *Lingula mytiloides*.

One over the four-foot Wetley Moor coal with *Lingula mytiloides* and compressed goniatites.

Below the Millstone Grits occurs a series of shales with gannister-like sandstones said to be 3,000 feet thick, an estimate which I consider much too large, for the beds are much rolled, and form a series of anti- and synclinals from east to west, and wherever there appears to be a direct sequence from limestone to the grits there is never room for more than about 1,000 feet of Measures. Below this gritty bed are a series of shales with bullions and thin earthy limestones.

These beds are characterised by a curious fauna which seems to have lived on till the Lower Coal Measures of Lancashire were laid down. The fauna comprises several forms of goniatites.

Glyphioceras Phillipsii, *G. micronotum*, *G. vesica*, *G. implicatum*, *G. platylobum*, *G. stenolobum*, *G. nitidum*, *G. reticulatum*, *G. Davisi*, *G. diadema*, *Dimorphoceras Gilbertsoni*, *D. discrepans*, *Gastriosceras carbonarium*, *G. Listeri*, *Nautilus*, *Orthoceras*, *Nuculana stilla*, *Schizodus antiquus*, *Posidoniella lævis*, *P. Kirkmani*, *P. varians*, *Aviculopecten papyraceus*. Gastropoda of several genera also occur.

Messrs. Barnes and Holroyd, who have for some years watched the tunnel driven by the London and North-Western Railway under Pule Hill, Marsden, have made a fine collection from the bullions contained in the shales. These are evidently on the same horizon as the shales of High Greenwood, Cumsworthdean, near Todmorden, from which localities long lists are given in Davis and Lees's 'West Yorkshire.' I have detected the same bullions with fossils near Dane Bridge, Cheshire, and the Coombes Leek, Staffordshire, and am of opinion that this bed occurs not far below the Shale or Pendle Grit; and I believe it to be the representative of the Pendle Limestone as found on Pendle Hill.

At Congleton Edge, Cheshire, which is nearly 1,000 feet high, there is a complete sequence from the first bed of millstone grit to the limestone massif. This range of the escarpment of this hill is formed by millstone grit; two beds, the first and third, with a few feet of intervening shale occur. Some 200 yards below this is a quarry, at the base of which are beds of hard, gannister-like quartzose sandstone with plant remains, which may be the representative of the shale grit. These are succeeded with laminated black shale crammed with compressed goniatites, *Posidoniella lævis* and *P. Kirkmani*. Above these are 10 to 20 feet of grey marl with layers of calcareous bullions, in which the following fauna occurs:—

Ceratiocaris Oretonensis
Dythiocaris testudineus
Orthoceras, sp.
Glyphioceras diadema
,, sp.
Nautilus, sp.
Terebratula hastata
Spirifer glaber
,, *bisulcatus*
Athyris planosulcata
,, *ambigua*
Orthis resupinata
,, *Michelini*
Streptorhynchus crenistria
Productus semireticulatus

Discina nitida
Lingula scotica
,, *mytiloides*
Pecten, sp. 2
Myalina peralata
Posidoniella semisulcata
Modiola transversa
Protoschizodus orbicularis
Parallelodon obtusus
,, sp.
Nucula gibbosa
,, *æqualis*
Ctenodonta sinuosa
Edmondia sulcata
Mytilimorpha rhombea

Productus longispinus
„ *Cora*
„ *scabriculus*
Chonetes Laguessiana
Sanguinolites, sp.
Bellerophon Hiulcus
„ *Urei*
Euomphalus, sp.
Pleurotomaria monilifera
Macrocheilus, sp.

The fauna found in the excavations for a reservoir at Eccup, near Leeds, contains numerous species identical with those found at Congleton Edge.

Messrs. Barnes and Holroyd drew my attention this year to a bed of grit on the east flank of Pule Hill, Marsden, filled with fossils—chiefly casts. The number of specimens is large but the variety small, and including :—

Goniatites, sp.
Pleurotomaria, sp.
Bellerophon, sp.
Lingula, sp.
Sedgwickia attenuata
Schizodus antiquus
Myalina Verneuillii.
„ *Flemingi.*

Nowhere in the district do limestones of any thickness occur between the limestone 'massif' below and the base of the Millstone Grit which corresponds to the Yoredale series ; and I consider that there are no grounds for assuming that the beds of shale and sandstone which occur in this position in the South Pennine area are in any way the equivalents of the Yoredale series of Wensleydale.

The Mountain Limestone.—Since Messrs. Barnes and Holroyd drew my attention to the occurrence at Castleton of beds of rolled shells, and limestone pebbles with occasional quartz pebbles, which occupy the highest portions of the 'massif' of Mountain Limestone, and which they interpret as contemporaneous limestone beach, I, with Mr. A. Howe, have traced this bed over North Staffordshire, Cheshire, and Derbyshire, wherever the upper beds are exposed. It seems to have been laid down as a shore which retreated from north to south, before the shales were laid down upon it. Various shells occur in this beach. *Chonetes papilionacea*, and *Producti*, *Strophomena analoga*, trilobites and many teeth of *Psammodus*, *Psephodus*, and other fish remains, which are very similar to those of the main limestone Leyburn. Below this bed come highly fossiliferous beds of corals, molluscs, with others of encrinital origin. Below still come a series of limestones with narrow bands of chert and beds of encrinites, and finally hard, thick-bedded limestones with sparse fossils.

All the celebrated fossiliferous localities of Derbyshire and Staffordshire occur at the top of the limestone massif, where all the species occur together in the same bed. Most of the fossils are semi-rolled, and very few lamellibranchs have both valves in contact, and I doubt if they are in the place where the animals died. Elsewhere in the series fossil mollusca are rare.

I am unable to find any fossils distinctive of zones in the limestone of this area, with perhaps one exception, and that local. *Productus humerosus* characterises the Cauldon Low beds, but is not found elsewhere. These beds I consider to come near the top of the massive beds of limestone.

It is the intention of Mr. Howe and myself to publish a paper of details on the occurrence of the conglomerate beds and the carboniferous sequence in this area in the near future, for which we are now gathering statistics.

Note on Nucula gibbosa.—This shell comes in the Calciferous Sandstone beds of Fife, and ranges through the Carboniferous Limestone Series of Scotland. Occurs in abundance in the Redesdale ironstone ; is not met with, *pace* the compilers of lists, in the Carboniferous Limestone, but occurs in the shales below the Millstone Grits, and in the true Coal Measures of North Staffordshire.

Note on Lowick Fossils.—Mr. John Dunn, of Redesdale, has collected a very large percentage of the species listed for Lowick in a bed of limestone at the Combs, Redesdale, which is the four-laws limestone, from its relation to the four-laws coal.

II. *Report on Carboniferous Rocks and Fossils ; North Wales District.*

Mr. G. H. Morton reports that he has in preparation a list of the fossils found in the carboniferous limestone of North Wales. It contains the result of collections made in four separate areas, viz.—Llangollen, Flintshire, the Vale of Clwyd, and Anglesey. The list shows the range of the species in the subdivisions of the formation in each of the four areas, not merely by an asterisk, but by letters indicating the relative frequency and rarity of the species.

The list has been completed, with the exception of the part relating to Anglesey, but another year will be necessary to finish that area. Collecting in Anglesey and along the Menai Strait has already shown that several common species, previously considered to be characteristic of the Upper and Middle subdivisions of the carboniferous limestone occur there in the lower subdivision. It appears that the occurrence of species in definite horizons depends more on the lithological character of the strata than on the horizon at which they occur.

As the collecting in Anglesey will be finished early next year, it is obviously desirable to postpone the presentation of the list until it can be given in its final form.

III. *Report on Carboniferous Rocks and Fossils ; Isle of Man District.*

Mr. Lamplugh writes concerning the Isle of Man :—‘ In the preparation of the Survey memoir of that area, several collections of Manx carboniferous fossils have been examined by the Palæontologists of the Geological Survey, and a substantial list of fossils has been compiled, which it is hoped may be of service in correlating the carboniferous rocks of the island with those of the mainland. As a result of this work it is found that there are well-marked variations in the fauna of different parts of the limestone, as the Rev. J. G. Cumming pointed out fifty years ago, but the zonal value of these variations is somewhat doubtful, as the changes seem to indicate differences in the physical condition of sedimentation, rather than the dying out of species, and the evolution of others. The collections examined were the labelled portion of the Cumming collection of King William’s College, Castletown, Miss Briley’s collection, Mr. R. Law’s collection, Dr. Hind’s collection, and the collections of the Woodwardian Museum and of the Geological Survey.’

The Committee hope to make use of these lists, and to refer to them more fully in a future report.

Irish Elk Remains.—Report of the Committee, consisting of Professor W. BOYD DAWKINS (*Chairman*), His Honour DEEMSTER GILL, Rev. Canon SAVAGE, Mr. G. W. LAMPLUGH, *and* Mr. P. M. C. KERMODE (*Secretary*), *appointed to examine the Conditions under which Remains of the Irish Elk are found in the Isle of Man.*

As soon as possible after our reappointment last September we commenced excavating at the Loughanruy in Ballaugh, where, as stated in our first Report (1897), the Edinburgh specimen was found in 1819.

We reached the undisturbed white marl at a depth of 9 feet, and penetrated through it at 18 feet, uncovering an area of about 12 yards by 2, in a line parallel with and about 6 feet north of the boundary hedge where the original example had been discovered. Unfortunately the weather broke, and though we had shored up our trench with timber the water burst through and prevented further work.

Samples were forwarded to Mr. James Bennie, who again kindly assisted the Committee by preparing the material.

Mr. Clement Reid examined and reported on the remains thus obtained. The plants, as he points out, include singularly few species, and there is no trace of dry soil species among them. In the silt, the large number of leaves all belonging to a single species of willow suggests that we are dealing with a poverty-stricken flora, such as might occupy the island soon after the ice had passed away, and before there had been time for many plants to be introduced.

The question whether the megaceros marl may not show a milder climate than the succeeding deposit must still remain an open one. All the plants in the marl have an exceedingly wide range, both northern and southern, and there is nothing in any way characteristic except the fragments belonging to *Lepidurus* (*apus*) *glacialis.* Mr. Reid, however, fairly points out that this is only a single specimen, and, the species being abundant in the overlying bed with Arctic Willows, it would not be safe to found much on it—a light thing of this sort might so easily fall in and be taken out with the lower bed.

The species found were :—

Silt (*Bed C of our first Report*).

Lepidurus glacialis (abundant).
Ranunculus aquatilis.
Salix herbacea (abundant).
Carex.

Marl (*F of first Report*).

Lepidurus glacialis (one fragment).
Ranunculus aquatilis.
,, flammula.
,, repens.
Littorella lacustris.
Empetrum nigrum.
Potamogeton natans.
,, ? sp.
Carex.

No trees are found in either deposit, and this circumstance, perhaps, shows that a mild climate did not exist during the deposition of the marl.

Photographs of Geological Interest in the United Kingdom.—Tenth Report of the Committee, consisting of Professor JAMES GEIKIE (*Chairman*), Professor T. G. BONNEY, Dr. TEMPEST ANDERSON, Mr. J. E. BEDFORD, Mr. H. COATES, Mr. C. V. CROOK, Mr. E. J. GARWOOD, Mr. J. G. GOODCHILD, Mr. WILLIAM GRAY, Mr. ROBERT KIDSTON, Mr. A. S. REID, Mr. J. J. H. TEALL, Mr. R. H. TIDDEMAN, Mr. H. B. WOODWARD, Mr. F. WOOLNOUGH, *and* Professor W. W. WATTS (*Secretary*). (*Drawn up by the Secretary.*)

THE Committee have the honour to report that during the year 324 new photographs have been received, bringing the total number in the collection to 2,325. The average yearly income during the decade has thus been 233.

In addition to this 61 prints and 6 slides have been given to the duplicate collection, making a total of 391 photographs received during the year. About forty are already in hand for next year.

Thirteen old prints have also been renewed by the kindness of Mr. Gray, Mr. Eaton, Mr. Stelfox and Mr. Welch.

The usual scheme showing the geographical distribution of photographs is appended. The following counties are now represented for the first time :—Bedford, Buckingham, Hereford, Berwick, Linlithgow, Kerry, and Tipperary. The following counties are more richly represented than hitherto :—Devon, Northumberland, Stafford, Suffolk, Warwick, Radnor, Fife, Inverness, and Mayo.

Several of the donations are of exceptional interest. Mr. A. S. Reid has carried out a photographic survey of the Island of Eigg, and has already presented to the collection 27 enlarged photographs, to illustrate the Scuir of Eigg and its remarkable history as told by Sir Archibald Geikie. The set includes photographs of the pitchstone of the Scuir, the river gravel underneath it, and many other phenomena of volcanic and tectonic interest in the island. He has also given a set of prints which will be circulated with the duplicate collection as a model of a local survey.

Another connected series illustrating the physical history of the Yorkshire rivers is communicated by Mr. Godfrey Bingley, who took the photographs at the suggestion of Mr. Kendall. The series is not yet finished, but it is already a most useful and instructive one, and bids fair to become very valuable as a record of ancient physical changes, while it admirably illustrates the value of photographic records for this purpose. Besides this set Mr. Bingley has contributed other photographs from Yorkshire and Lancashire, and Mr. Cuttriss gives further examples of his photographs of caves.

To Mr. A. K. Coomara Swamy the Committee are indebted for a large series of prints taken mainly during excursions made by the Geologists' Association into Scotland, Devon, Dorset, Kent, Gloucestershire, and elsewhere ; volcanic phenomena, unconformities, denudation, weathering, contortion, and the position of important rock zones, are all illustrated by this series. Mr. H. C. McNeill also gives other photographs taken on excursions of the Geologists' Association and described in the Proceedings of that body.

—	Previous collection	New additions (1899)	Total	Duplicates			
				Previous collection	Additions (1899)		Total
					Prints	Slides	
ENGLAND—							
Bedfordshire .	—	3	3	—	—	—	—
Buckinghamshire . .	—	4	4	—	1	—	1
Cornwall .	37	1	38	3	—	—	3
Devonshire .	95	27	122	8	—	—	8
Dorset . .	52	7	59	6	—	—	6
Durham . .	23	4	27	1	—	—	1
Gloucestershire . .	12	3	15	1	—	—	1
Herefordshire .	—	1	1	—	—	—	—
Hertfordshire .	7	3	10	—	—	—	—
Kent . .	60	7	67	13	—	—	13
Lancashire .	49	3	52	10	—	—	10
Leicestershire .	91	2	93	20	—	—	20
Northumberland . .	27	14	41	—	—	—	—
Shropshire .	28	1	29	8	—	—	8
Staffordshire .	34	9	43	6	2	2	10
Suffolk . .	4	6	10	—	—	—	—
Surrey . .	21	3	24	3	—	—	3
Sussex . .	8	1	9	—	—	—	—
Warwickshire .	18	21	39	1	1	1	3
Worcestershire	5	5	10	1	—	—	1
Yorkshire .	363	50	413	60	—	—	60
Others . .	245	—	245	39	—	—	39
Total . .	1179	175	1354	180	4	3	187
WALES—							
Denbighshire .	13	2	15	5	—	—	5
Radnorshire .	1	19	20	—	—	—	—
Others . .	109	—	109	38	—	—	38
Total . .	123	21	144	43	—	—	43
CHANNEL ISLANDS . .	14	1	15	—	—	—	—
ISLE OF MAN .	52	—	52	4	—	—	4
SCOTLAND—							
Banff . .	4	—	4	—	1	—	1
Berwickshire .	—	4	4	—	—	1	1
Edinburgh .	40	7	47	10	—	—	10
Fifeshire . .	14	10	24	7	—	—	7
Inverness-shire	38	27	65	1	27	—	28
Lanarkshire .	5	2	7	5	—	—	5
Linlithgowshire . .	—	2	2	—	—	—	—
Perthshire .	19	1	20	3	—	—	3
Stirlingshire .	13	2	15	2	—	—	2
Others . .	83	—	83	20	—	—	20
Total . .	216	55	271	48	28	1	77

—	Previous collection	New additions (1899)	Total	Duplicates			
				Previous collection	Additions (1899)		Total
					Prints	Slides	
IRELAND—							
Antrim . .	165	17	182	26	3	—	29
Cork . .	1	1	2	—	—	—	—
Donegal . .	35	4	39	2	—	—	2
Down . .	55	14	69	15	1	—	16
Dublin . .	21	6	27	3	—	—	3
Galway . .	24	4	28	3	—	—	3
Kerry . .	—	10	10	—	—	—	—
Londonderry .	19	3	22	1	—	—	1
Mayo . .	6	8	14	1	—	—	1
Tipperary .	—	1	1	—	—	—	—
Others . .	18	—	18	1	—	—	1
Total . .	344	68	412	52	4	—	56
ROCK STRUCTURES . .	73	4	77	28	3	—	31
ENGLAND .	1179	175	1354	180	4	3	187
WALES . .	123	21	144	43	—	—	43
CHANNEL ISLANDS .	14	1	15	—	—	—	—
ISLE OF MAN .	52	—	52	4	—	—	4
SCOTLAND .	216	55	271	48	28	1	77
IRELAND . .	344	68	412	52	4	—	56
ROCK STRUCTURES . .	73	4	77	28	3	—	31
FOREIGN . .	—	—	—	3	22	2	27
Total . .	2001	324	2325	358	61	6	425

Mr. Welch contributes, through the Belfast Naturalists' Field Club, 43 platinotypes taken with his usual skill in Ireland. Glaciated surfaces and transported blocks, the Silurian district of Mayo and Galway, the volcanic district of the North-east of Ireland, and various tectonic phenomena are illustrated by the photographs. One set illustrates a new industry in the country, the excavation of the diatomaceous clay of the river Bann for use as 'Kieselguhr.' Mr. Phillips also sends through the same Club a set of Irish photographs.

The Midland district is beginning to be better represented in the collection, chiefly owing to contributions by Mr. W. Jerome Harrison, Professor Allen, Mr. Evers Swindell, Mr. Watson, and students of Mason University College. Thus the Nuneaton Cambrian and Precambrian Rocks show a very considerable series, while the Abberley Hills, the Permian, Trias, and Lias of the district, the volcanic rocks of the South Staffordshire Coalfield, the boulders and superficial deposits, are all being illustrated.

Mr. Garrett, of the Durham College of Science, gives photographs taken under the direction of Professor Lebour along the Northumberland and Durham Coast and elsewhere, illustrating chiefly the Carboniferous and Permian Rocks, and including the remarkable structures found in the latter.

The representatives of the late W. Topley have presented 19 photographs taken on the rivers Elan and Claerwen on the site of the new Birmingham waterworks. A most useful account of the geological features of these photographs has been communicated by Mr. H. Lapworth, the chief authority on the geology of the district.

Mr. J. A. Cunningham has illustrated photographically the contorted Carboniferous Limestones of the Loughshinny district, near Dublin, some of which have been rendered classic by the Memoirs of the Geological Survey of Ireland.

Amongst other sets the following should be especially mentioned :—The Ingleton district by Mr. F. N. Eaton, the Devonshire coast by Miss Partridge, the Purbeck, Portland, and Lower Greensand Strata in Buckinghamshire by Mr. Pledge, and a series of dykes in Down by Miss Andrews.

To the donors and others above mentioned and to the following, the Committee are much indebted :—Miss Silverston, Mr. R. McF. Mure, Mr. J. H. Baldock, Mr. A. Watkins and Mr. H. Cecil Moore, Mr. E. J. Garwood, Mr. K. F. Bishop, Mr. W. G. Orme, Mr. W. Wickham King, Mr. W. Gray, Mr. Stelfox, and Mr. G. Nichols.

There is still much room for work in the Pennine Chain, especially its western side, the Weald, the Cotswolds and Edge Hills, North and South Wales, the Yorkshire Moors and Wolds, the Malverns, the Oxford and Cambridge districts, Cornwall, the Southern Uplands and the Highlands of Scotland, and in central and southern Ireland.

Notices of the work of the Committee have appeared in many periodicals and journals, and an article was published in 'Science Work' illustrated by a beautiful reproduction of one of Mr. Reid's photographs of the Scuir of Eigg.

The photographs received during the year have been mounted and will be exhibited at Dover, after which they will be bound up and deposited with the rest of the collection at 28 Jermyn Street, where they may always be referred to on application to the Librarian. The collection is arranged geographically in twenty-seven albums under the heads of counties, and their natural topographical divisions. A catalogue arranged under counties is kept in the Library for reference, and the card catalogue is maintained up to date as new photographs are received.

The numbers of six old lost photographs, which it has not been possible to recover, have been finally cancelled and some of this year's prints and one renewal have been inserted in their place ; such numbers are those on List I., between 2 and 302, and a separate list (II.) of the cancelled photographs is given.

Certain corrections in former lists have been kindly made by Mr. Welch, to whom the thanks of the Committee are due. These are placed in List III., in which are also placed 13 photographs renewed by Mr. Gray, Mr. Eaton, Mr. Welch, and Mr. Stelfox.

Many geologists, British and foreign, have expressed a desire to possess examples of geological photographs which they have seen in the collection. The Committee are willing to undertake the publication of a small experimental series if a guarantee fund can be formed as a safeguard against loss.

The publication would take the form of the issue of about twenty photographs in platinotype or carbon, or high-class process reproductions, accompanied by descriptive letterpress. If the subscribers preferred, lantern slides might be issued instead of prints or in addition to them.

The *duplicate collection* has been sent, entire or in part, to the following local societies:—The Manchester Geological Society; the Hertfordshire Natural History Society; The Essex Field Club; the Scientific Society of the Birmingham and Midland Institute; the Vesey Club, Sutton Coldfield; the Croydon Microscopical Society; and the South-Eastern Union of Natural History Societies.

The additions to this collection during the year are given in List IV. 61 prints and 6 slides have been received, and the whole collection now numbers 324 prints and 101 slides. A list of donors to this collection is appended to List IV., and to each of them the Committee express their thanks.

It has been found desirable to admit to this collection photographs illustrative of such geological phenomena as do not occur in England, or are more typically represented abroad. Thus Mr. Coomara Swamy has contributed a set of photographs of volcanic phenomena from the Auvergne and the Eifel; Professor Hutton one of earth-pyramids in New Zealand; while the collection already contained photographs of earth-pyramids from Botzen, and one of the false bedding in the face of the Sphinx.

Applications by local societies for the loan of this collection should be made to the Secretary. Either prints or slides, or both, can be lent, with a descriptive account of the slides. The carriage, and the making good of any damage to slides or prints, are borne by the borrowing society.

TENTH LIST OF GEOLOGICAL PHOTOGRAPHS

(TO JULY 30, 1899).

NOTE.—This list contains the geological photographs which have been received by the Secretary 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 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 *do not assume the copyright of any photographs* included in this list. Inquiries respecting photographs, and applications for permission to reproduce them, should be addressed to the photographers direct.

The very best photographs lose half their utility, and all their value as documentary evidence, unless accurately described; and the Secretary would be grateful if, whenever possible, such explanatory details as can be given were written on the forms supplied for the purpose, and *not on the back of the photograph or elsewhere.* Much labour and error of transcription would thereby be saved. A local number by which the print can be recognised should be written on the back of the photograph and on the top right-hand corner of the form.

Copies of photographs should be sent *unmounted* to W. W. Watts, Mason University College, Birmingham, and forms may be obtained from him.

The size of photographs is indicated as follows :—

L = Lantern size.	1/1 = Whole plate.
1/4 = Quarter-plate.	10/8 = 10 inches by 8.
1/2 = Half-plate.	12/10 = 12 inches by 10, &c.

E signifies Enlargements.

* indicates that photographs and slides may be purchased from the donors, or the address given with the series.

LIST I.

ACCESSIONS IN 1898-1899.

ENGLAND.

BEDFORD.—*Photographed by* H. C. McNEILL, 29 *North Villas, Camden Square, N.W.* 1/2.

Regd. No.		
2267	(1) Heath House, Shenley Hill, Leighton.	Lower Greensand Carstone.
2268	(2) Stone Lane Hill Heath .	„ „ White sand.
2269	(3) „ .	„ „ „

BUCKINGHAM.—*Photographed by* J. H. PLEDGE, 115 *Richmond Road, N.E.* 1/2.

2305	(1) Pit, between Towersey and Kingsey.	Beds of Purbeck facies, overlying Portland 'Creamy Limestone.' 1898.
2306	(3) Near King's Cross, Haddenham.	Probable Middle Purbeck, Lower Purbeck, and Portland Beds. 1898.
2307	(10) 'Bugle Pit,' Stone, near Hartwell.	Purbeck and Portland Beds. 1898.
2308	(6) Sandpit by Windmill, Stone.	False-bedded 'Lower Greensand.' 1898.

CORNWALL.—*Photographed by* J. H. BALDOCK, *Overdale, St. Leonard's Road, Croydon.* 1/2.

2120	( ) Kynance Cove	Stack of Serpentine. 1898.

DEVONSHIRE.—*Photographed by* A. K. COOMARA SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

2052	( ) Coddon Hill, Barnstaple .	Culm-measures and Radiolarian Chert. 1898.
2053	( ) Saunton	Raised Beach. 1898.
2054	( ) „	Sand dunes. 1898.
2055	( ) Baggy Point	'Ripple-marked' Surface. 1898.
2056	( ) „	Denudation, joints, and bedding in Devonian Rocks. 1898.
2057	( ) Shaldon, Teignmouth . .	Permian conglomerate. 1898.
2058	( ) Bindon, W. of Lyme Regis .	Landslip cliff. 1898.

Photographed by Miss E. M. PARTRIDGE, 75 *High Street, Barnstaple.* 1/4.

2177	(11) Saunton	Raised Beach on Pilton Beds. 1898.
2178	(10) „	„ „ „ „
2179	(8) Valley of Rocks, Lynton .	Joints and weathering in Lynton Beds. 1898.
2180	(9) „ .	„ „

Regd. No.		
2239	(7) Saunton	Current-bedding in Raised Beach. 1898.
2270	(12) Budleigh Salterton Cliffs .	Honeycomb weathering in Triassic Sandstone. 1899.
2271	(13) West of Combe Martin .	Folded Ilfracombe Beds. 1899.
2272	(14) Under Lantern Hill, Ilfracombe	Cleavage and Bedding in Ilfracombe Slates. 1899.
2273	(15) Under the Ilfracombe Hotel, Ilfracombe.	Cleavage crossing Folded rocks. 1899.

Photographed by W. W. Watts, *Mason University College, Birmingham.* 1/4.

2	(W 90) Hope's Nose, near Torquay.	Contorted and Cleaved Slates and Grits (Devonian). 1899.
14	(W 92) Hope's Nose, near Torquay.	Contorted Grits pinched into lenticles. 1899.
2148	(W 93) Hope's Nose, nr. Torquay.	Raised Beach on Devonian Rocks. 1899.
2149	(W 94) ,, ,, ,,	Raised Beach with boulders at base. 1899.
2150	(W 95) ,, ,, ,,	,, ,, ,, ,,
2151	(W 97) ,, ,, ,,	,, ,, ,, ,,
2152	(W 96) ,, ,, ,,	Raised Beach showing detail of contact with Devonian Rocks. 1899.
218	(W 80) R. Dart above Dartmouth.	A drowned river valley. 1899.
301	(W 81) R. Dart above Dartmouth.	,, ,, ,, ,,
302	(W 82) R. Dart above Dartmouth.	,, ,, ,, ,,
2332	(W 83) Tributary of R. Dart near Dartmouth.	,, ,, ,, ,,

Dorset.—*Photographed by* A. K. Coomara Swamy, *Walden, Worplesdon, Guildford.* 1/4.

2059	( ) Blashenwell . . .	Miniature Caves in Tufa. 1898.
2060	( ) Maiden Castle, Dorchester.	Lynchets or Cultivation-terraces. 1898.
2061	( ) Linton Hill, Abbotsbury .	Corallian Rocks. 1898.
2062	( ) Eype, west of Bridport Harbour.	Fault; Bathonian against Middle Lias. 1898.
2063	( ) Burton Bradstock Cliff .	Bridport Sands. 1898.
2064	( ) ,, ,, ,,	Bridport Sands and Inferior Oolite Limestone. 1898.
2065	( ) Thorncombe Beacon . .	Junction of Upper and Middle Lias. 1898.

Durham.—*Photographed by* F. C. Garrett, *Durham College of Science, Newcastle-on-Tyne.* 1/4.

2167	(9) Frenchman's Bay . .	Apparent Unconformity in Magnesian Limestone. 1897.
2168	(10) Marsden Bay . . .	Top of 'Breccia Gash.' 1897.
2169	(11) ,, ,, ...	'Breccia Gash.' 1897.
2170	(12) North of Whitburn . .	'Cannon-ball Limestone.' 1897.

Gloucester.—*Photographed by* A. K. Coomara Swamy, *Walden, Worplesdon, Guildford.* 1/4.

2066	( ) View from Frocester Hill .	Cotteswold Escarpment. 1898.
2067	( ) Minchinhampton . .	Great Oolite. 1898.
2068	( ) Huntley	West of boundary fault; overfolded (?) May Hill grits. 1898.

HEREFORD.—*Photographed by* A. WATKINS, *Hampton Park, Hereford. Through* H. CECIL MOORE. 1/2.

Regd. No.			
2127	( )	West end of Dog Hill Tunnel, Ledbury.	Passage Beds between Old Red Sandstone and Silurian Rocks. 1884.

HERTFORDSHIRE.—*Photographed by* A. K. COOMARA SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

2069	( )	Hatfield Hyde, Hatfield .	Boulder-clay with layer of sand. 1898.
2070	( )	,, ,, .	Great Chalky Boulder-clay. 1898.
2071	( )	Brickfield near Ayot Station.	Pipe in Chalk letting down Woolwich and Reading Beds. 1898.

KENT.—*Photographed by* A. K. COOMARA SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

2072	( )	East of East End Lane, North Sheppey.	Bagshot Beds and London Clay. 1898.
2073	( )	Near Warden Point, Sheppey.	London Clay; Valley with slipped Septaria.
2074	( )	Road to High Rocks, Tunbridge Wells.	Weathering of Tunbridge Wells Sandstone. 1898.
2075	( )	Road to High Rocks, Tunbridge Wells.	Weathering of Tunbridge Wells Sandstone. 1898.
2076	( )	High Rocks, Tunbridge Wells.	Weathering and Jointing of Tunbridge Wells Sandstone. 1898.
2077	( )	High Rocks, Tunbridge Wells.	Weathering and Jointing of Tunbridge Wells Sandstone. 1898.
2078	( )	High Rocks, Tunbridge Wells.	Weathering and Jointing of Tunbridge Wells Sandstone. 1898.

LANCASHIRE.—*Photographed by* S. W. CUTTRISS, 6 *Fieldhead Terrace, Camp Road, Leeds.* L.

2176	( )	Ease Gill	Dry Waterfall in Carboniferous Limestone. 1898.

Photographed by GODFREY BINGLEY, *Thorniehurst, Headingley, Leeds.* 1/2.

2194	(4779)	Clough Foot, Dulesgate, near Todmorden.	Coal-seam in Rough Rock. 1899.
2195	(4780)	Clough Foot, Dulesgate, near Todmorden.	,, ,, ,, ,,

LEICESTER.—*Photographed by* W. T. TUCKER, *Loughborough.* 1/2.

2284	( )	East of Mount Sorrel .	Furrowing and smoothing of Granite. 1897.
2285	( )	,, ,, .	,, ,, ,, ,,

NORTHUMBERLAND.—*Photographed by* E. J. GARWOOD, *Dryden Chambers, Oxford Street, W.C.* 1/1

2153	( )	Half a mile north of Warkworth.	Boulder-clays on Coal Measures.

Photographed by F. C. GARRETT, *Durham College of Science, Newcastle-on-Tyne.* 1/4.

2154	(1)	Old Fourstones Quarries .	Fold in Great Limestone. 1897.
2155	(2)	,, ,, .	,, ,, ,,

Regd. No.			
2156	(3)	Prudhamstone Quarry	Coals, shales, &c., in Prudhamstone Sandstone. 1897.
2157	(4)	,, ,,	Coals, shales, &c., in Prudhamstone Sandstone. 1897.
2158	(5)	Fourstones Quarry	Great Limestone. 1897.
2159	(6)	S.E. of Crag Point, Hartley.	Fault in Coal Measures. 1896.
2160	(7)	,, ,, ,,	,, ,, ,, ,,
2161	(8)	Charlie's Garden, Seaton Delaval.	Faults in Coal Measures. 1896.
2162	(13)	Whitley	Local Unconformity in Coal Measures. 1897.
2163	(14)	,,	,, ,, ,, ,, ,,
2164	(15)	Whitley Coast	Irregular Bedding and Patches of Coal in Coal Measure Sandstone. 1896.
2165	(16)	,, ,,	Irregular Bedding and Patches of Coal in Coal Measure Sandstone. 1896.
2166	(17)	,, ,,	Irregular Bedding and Patches of Coal in Coal Measure Sandstone. 1896.

SHROPSHIRE.—*Photographed by* H. EVERS-SWINDELL, *Red Hill, Stourbridge. Through* W. WICKHAM KING. 1/2.

2235	( )	Gatacre Hall Farm, near Enville.	Permian Breccia sandstone. 1897.

STAFFORDSHIRE.—*Photographed by* DR. F. J. ALLEN, *Mason University College, Birmingham.* 1/2.

2188	( )	Near Church, Kinver	Base of Bunter Pebble-beds. 1898.
2189	( )	Compton, near Enville	Jointing in Permian Calcareous Conglomerate. 1898.
2190	( )	,, ,,	Jointing in Permian Calcareous Conglomerate. 1898.

Photographed by W. JEROME HARRISON, *Claremont Road, Handsworth, Birmingham.* 1/2.

2275	( )	California, near Harborne.	Bunter Sandstone.
2276	( )	Codsall, near Wolverhampton.	Lower Keuper Sandstone.
2277	( )	Hailstone Quarry, Rowley Regis.	Dolerite (Rowley Rag).
2278	( )	Bushbury, near Wolverhampton.	Striated Boulder of Criffel Granite.
2279	( )	Wolverhampton Park	Boulder of Criffel Granite.
2280	( )	West of Wolverhampton	Boulder of Criffel Granite.

SUFFOLK.—*Photographed by* A. K. COOMARA SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

2080	( )	Near Martello Tower, Aldeburgh.	Damage due to storm. 1898.
2081	( )	S. of Aldeburgh	,, ,, ,, ,,
2082	( )	Hall's Brickyard, Aldeburgh	Chillesford Clay and (Mid-glacial) Sands. 1898.
2083	( )	Dunwich Cliff	Norwich Crag. 1898.
2084	( )	Westleton	Westleton Beds. 1898.
2085	( )	,,	,, ,, ,,

SURREY.—*Photographed by* A. K. COOMARA SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

2086	( )	New Railway, Burgh Heath, near Epsom.	Drift and Thanet Sand 'piped' into Chalk. 1898.
2087	( )	,, ,, ,,	Patch of Eocene Sand in Drift. 1898.
2088	( )	Tuesley, near Godalming	'Pebble-beds' of Lower Greensand. 1898.

SUSSEX.—*Photographed by* A. K. COOMARA SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

Regd. No.			
2079	( )	Boar's Head, Eridge . .	Weathering of Wealden Sandstone. 1898.

WARWICKSHIRE.—*Photographed by* A. K. COOMARA SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

2089	( )	Newbold Cement Works, Rugby.	Anticline in Lower Lias. 1898.

Photographed by T. BLUNDELL, *Icknield Street Board School, Birmingham, and contributed by* W. JEROME HARRISON.

2125	( )	Stockton	Lower Lias Limestone and Shale; site of Ichthyosaurus. 1898.
2283	( )	"	Boulder of Mount Sorrel Granite.

Photographed by C. J. WATSON, *Acock's Green, Birmingham.* 1/2.

2126	( )	Stockton	Ichthyosaurus found in Lower Lias. 1898.

Photographed by W. JEROME HARRISON, *Claremont Road, Handsworth, Birmingham.* 1/2.

2128	( )	Abel's Quarry, Hartshill .	Junction of Cambrian and Precambrian Rocks. 1899.
2129	( )	Caldecote Windmill Quarry, Nuneaton.	Cambrian Quartzite, middle division. 1899.
2130	( )	" " "	" " " "
2131	( )	Anchor Quarry, Hartshill .	Cambrian Quartzite, lowest division. 1899.
2132	( )	" " "	" " " "
2133	( )	Chapel End, Nuneaton .	Carboniferous Basement, Unconformable on Cambrian shales. 1899.
2134	( )	" "	" " "
2137	( )	" "	" " "
2135	( )	" "	Contorted Cambrian shales. 1899.
2136	( )	" "	" " " "
2138	( )	Stockingford Brickworks .	Carboniferous Clays and Sandstones 1899.
2139	( )	" "	" " "
2281	( )	Nuneaton	Faults in Keuper Marls.
2282	( )	Cannon Hill Park, Birmingham.	Boulder of Arenig Felstone.

Photographed by W. G. ORME, *Mason University College, Birmingham.* 1/2.

2192	( )	Chapel End, Nuneaton .	Carboniferous conglomerate resting unconformably on Cambrian shales. 1899.
2193	( )	" "	" " "

Photographed by K. F. BISHOP, 18 *New Street, West Bromwich.* 1/4.

2191	( )	Harbury Brickworks . .	Lower Lias showing bedding. 1898.

WORCESTERSHIRE.—*Photographed by* A. K. COOMARA SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

2090	( )	Walsgrove Quarry, Abberley	Inversion of Ludlow Rock. 1898.

Photographed by DR. F. J. ALLEN, *Mason University College, Birmingham.* 1/2.

2187	( )	Abberley Hill . . .	Permian Breccia. 1898.

Photographed by H. Evers-Swindell, *Red Hill, Stourbridge, through* W. Wickham King. 1/2.

Regd. No.			
2236	( )	Shut Mill, Clent Hills .	Permian Breccia. 1898.
2237	( )	Adam's Hill, Clent . .	,, ,, 1891.
2238	( )	Abberley Hill . . .	Trappoid Breccia of Permian or Triassic Age. 1892.

Yorkshire.—*Photographed by* F. N. Eaton, *Higher Lane, Aintree, Liverpool.* 1/4.

2140	( )	Pecca Falls, R. Greta, Ingleton.	Cut through vertical, ancient rock.
2141	( )	R. Doe, Ingleton . . .	Gorge in ancient rocks.
2142	( )	Yew Tree Gorge, R. Doe, Ingleton.	Overhanging gorge in ancient rocks.
2143	( )	R. Doe, Ingleton . . .	Gorge in ancient rocks.
2144	( )	Near the Strid, R. Wharfe .	Jointing in Carboniferous rocks.
2145	( )	,, ,, ,,	,, ,, ,,

Photographed by S. W. Cuttriss, 6 *Fieldhead Terrace, Camp Road, Leeds.* L.

2171	( )	Rowten Pot, Kingsdale .	Carboniferous Limestone; 365 feet deep. 1898.
2172	( )	Yordas Cave, Kingsdale .	Carboniferous Limestone; interior. 1898.
2173	( )	,, ,, ,,	,, ,, ,, ,,
2174	( )	Bull Pot, ,,	Exterior; 220 feet deep. 1898.
2175	( )	Jingling Pot, ,,	,, 180 ,, ,,

Photographed by Godfrey Bingley, *Thorniehurst, Headingley, Leeds.* 1/2 *and* 1/4.

2196	(4771)	Near Summit, Todmorden	Third Grit, with slickensides. 1899.
2197	(4773)	Summit Brickworks, near Todmorden.	Glacial Drift. 1899.
2198	(4774)	Snoddle Hill, Blackstone Edge Summit, nr. Todmorden	Three Landslips in Millstone Grit. 1899.
2199	(4747)	Malham, near Tarn .	One source of R. Aire. 1899.
2200	(4753)	,, ,,	,, ,, ,,
2201	(4749)	Near Old Smelt Mill, Malham.	Sink of stream which rises on Kirkby Fell. 1899.
2202	(4741)	Malham	Spring, Aire Head. 1899.
2203	(4743)	,, ...	,, ,, ,,
2204	(4795)	Cawood, near Selby .	Confluence of R. Wharfe and R. Ouse. 1899.
2205	(4644)	Gannister Quarry, Meanwood, Leeds.	Root of Fossil Tree. 1898.
2206	(4638)	,, ,,	,, ,,
2207	(4693)	Spa Gill, Grantley Gates, near Ripon.	Intake of R. Skell Gorge. 1899.
2208	(4694)	Grantley Gates, near Ripon.	,, ,, ,,
2209	(4699)	River Skell, from Fountains Abbey.	,, ,, ,,
2210	(4700)	Mackershaw Bridge, Studley, near Ripon.	Gorge of R. Skell. 1899.
2211	(4701)	Near Mackershaw, Studley.	,, ,, above Mackershaw. 1899.
2212	(4713)	Mackershaw, Studley. 1/4.	Swallow-hole, R. Skell. 1899.
2213	(4703)	,, ,,	Intake of R. Skell Gorge, below Weir. 1899.
2214	(4707)	Clapthorne, near Ripon. 1/4.	Gravel-pit in supposed Moraine. 1899.

Regd. No.		
2215	(4718) Thieve's Gill, near Ripon.	Temporary Glacial valley of R. Ure. 1899.
2216	(4719) " "	" " " " "
2217	(4720) " "	" " " " "
2218	(4717) Near Lindrick Farm, near Ripon. 1/4.	Roman Ridge; steep eastern face of Moraine. 1899.
2219	(4705) Lindrick Farm, near Ripon.	Lateral escape of old valley of R. Ure through Roman Ridge. 1899.
2220	(4704) The Avenue, Studley, Ripon.	Exit of old gorge of R. Ure. 1899.
2221	(4714) Studley. 1/4 . .	Dry valley, Kendall's Walk. 1899.
2222	(4715) " "	" " "
2223	(4695) Aldfield Lane Ends, near Ripon.	Old river bed; intake of Kendall's Walk. 1899.
2224	(4740) Sun Wood, Low Grantley, near Ripon.	Abandoned channel of R. Laver. 1899.
2225	(4739) " "	" " " "
2226	(4734) Low Grantley, near Ripon	Entrance to abandoned channel of R. Laver. 1899.
2227	(4738) " "	Confluence of R. Laver and Holborn Beck. 1899.
2228	(4735) " "	" " "
2229	(4737) " "	Holborn Beck, cutting through coarse gravel of old Delta. 1899.
2230	(4733) Below Winksley Mill, near Ripon.	Gorge of R. Laver. 1899.
2231	(4729) Winksley, near Ripon .	" " "
2232	(4723) Cote Hill, Galphay, near Ripon.	Gravel-pit in supposed Moraine. 1899.
2233	(4722) Laverton, near Kirkby Malzeard, Ripon.	Valley of R. Laver above point of glacial diversion. 1899.
2234	(4721) Kirkby Malzeard, near Ripon.	Inner face of outermost Lateral Moraine of Uredale. 1899.

WALES.

DENBIGHSHIRE.—*Photographed by* F. N. EATON,* *Higher Lane, Aintree, Liverpool.* 1/4.

2146	( ) Llangollen . . .	General view of Dee Valley.
2147	( ) Dee Valley, Berwyn .	" " "

RADNOR.—*Photographed by* MR. HUDSON* (H), MR. J. OWEN,* Newtown (O), *and others. Contributed by the representatives of the late* W. TOPLEY, *and the geological features explained by* H. LAPWORTH. 1/1, &c.

2286	( ) Site of Dam, Caban Coch, Rhayader	Base of Upper Llandovery Beds and intermediate Shale Group.
2287	( ) " "	Lower and Upper Conglomerates, Shale Group, and Grits of Upper Llandovery.
2288	(20077 H) " "	Upper Llandovery Conglomerates and fault.
2289	(O) " " 1/2	From down stream.
2290	( ) Caban Coch, Rhayader .	Upper Llandovery Conglomerates and alluvial stretch above site of dam.
2291	( ) Elan Valley and R. Claerwen above Caban Coch, Rhayader.	Rivers in flood.
2292	(20078 H) Capel Nant Gwyllt, Rhayader. 1/2.	Upper Llandovery Conglomerate.
2293	(10860 H) Capel Nant Gwyllt, Rhayader, site of submerged dam (Careg ddu). 1/2.	Lower Llandovery rocks.

Regd. No.		
2294	(20092 H) Pont-yr-Elan, Rhayader. 1/2.	Scenery of plateau of Central Wales.
2295	(O) Pont Hyllfau (?), below Pen-y-Gareg Dam, R. Elan, Rhayader. 1/2.	Pot holes.
2296	(20087 H) Craig-yr-allt Goch, below Craig Goch Dam, Rhayader.	Tarannon Group?
2297	(20091 H) Site of Craig Goch Dam, R. Elan, Rhayader. 1/2.	Typical scenery of plateau of Mid-Wales.
2298	(20090 H) Site of Craig Goch Dam (?), R. Elan, Rhayader. 1/2.	
2299	( ) Above Craig Goch Dam, Aber Calletwr, R. Elan, Rhayader.	
2300	(20081 H) Site of Dam, Dol-y-Mynach, R. Claerwen, Rhayader.	Lower Llandovery Grits.
2301	(20082 H) Proposed site of Cil Oerwynt Dam, R. Claerwen, W. of Dol-y-mynach.	,, ,, ,,
2302	(H) Nant Gwynllyn, Rhayader. 1/2.	Tarannon Group.
2303	(H) ,, ,,	,, ,,
2304	(20089 H) Grisiau Fall, Rhayader. 1/2	

SCILLY ISLANDS.

Photographed by J. H. Baldock, *Overdale, St. Leonard's Road, Croydon.* 1/4.

2121	( ) St. Mary's . . .	Weathered block of Granite.

SCOTLAND.

Berwickshire.—*Photographed by* A. K. Coomara Swamy, *Walden, Worplesdon, Guildford.* 1/4.

2091	( ) Siccar Point . . .	Unconformable Junction of Upper Old Red Sandstone on Silurian rocks. 1898.
2092	( ) ,, ,, . . .	,, ,, ,, ,,
2093	( ) ,, ,, . . .	,, ,, ,, ,,
2094	( ) ,, ,, . . .	,, ,, ,, ,,

Edinburgh.—*Photographed by* A. K. Coomara Swamy, *Walden, Worplesdon, Guildford.* 1/4.

2095	( ) Queen's Drive, Arthur's Seat.	Columnar Basalt. 1898.
2096	( ) ,, ,,	Agglomerate. 1898.
2097	( ) ,, ,,	Jointed Agglomerate. 1898.
2098	( ) ,, ,,	Glaciated surface. 1898.
2099	( ) Carlton Hill . . .	Sandstone caught up in Basalt. 1898.
2100	( ) ,, ,,	,, ,, ,, ,,
2101	( ) S.E. of Forth Bridge .	'White Trap' in Carboniferous shales, 1898.

FIFESHIRE.—*Photographed by* A. K. COOMARA SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

Regd. No.			
2102	( )	Coalyard Hill, near St. Monans.	Agglomerate. 1898.
2103	( )	” ” ”	” ”
2104	( )	” ” ”	” ”
2105	( )	” ” ”	Dykes cutting Tuff. 1898.
2106	( )	Near Newark Castle, St. Monans.	Small Basalt Neck. 1898.
2107	( )	Elie	Raised Beaches. 1898.
2108	( )	One mile west of Burntisland.	Weathering of Picrite. 1898.
2109	( )	” ” ”	Brecciated beds beneath Picrite. 1898.
2110	( )	Dodhead Quarry, near Burntisland.	‘White Trap’ in Carboniferous shale. 1898.
2111	( )	Abden Shore, E. of Kinghorn.	Amygdaloidal Basalt in junction with Shales and Limestone. 1898.

INVERNESS-SHIRE.—*Photographed by* A. S. REID, *Trinity College, Glenalmond.* 12/10 *and* 7/5.

2240	(EG 79)	Scuir of Eigg . .	End-on view from East. 1898.
2241	(EG 44)	” ”	” ” ”
2242	(EG 80)	” ”	Showing flank of Old Valley. 1898.
2243	(EG 75)	” ”	Distant view showing Basalt terraces. 1898.
2244	(EG 78)	” ” side view of east end.	To show slope of Old Valley. 1898.
2245	(EG 82)	” ” from S.S.W.	Banding of Pitchstone. 1898.
2246	(EG 89)	” ” from South.	” ” ”
2247	(EG 47)	” ” on ridge	Pitchstone filling Tributary Valley. 1898.
2248	(EG 69)	Miller's Cottage, Kildonan, Eigg.	Distant view of Scuir. 1898.
2249	(EG 67)	On the ridge of the Scuir, Eigg.	Lake. 1898.
2250	(KD 39)	Scuir of Eigg. 7/5 .	Columnar Pitchstone. 1898.
2251	(EG 46)	” ”	River Conglomerate under Pitchstone. 1898.
2252	(EG 92)	” ”	” ” ”
2253	(EG 91)	” ”	” ” ”
2254	(EG 45)	Beneath the Scuir of Eigg.	Brecciated base of Pitchstone resting on river Conglomerate. 1898.
2255	(EG 81)	” ”	” ” ”
2256	(KD 28)	Near Galmisdale, Eigg. 7/5.	Wedge-shaped vein of Basalt. 1898.
2257	(KD 19)	Shore Cliff, Eigg. 7/5.	Two basic dykes. 1898.
2258	(EG 49)	Laig Bay, Eigg . .	The ‘Jurassic Oasis.’ 1898.
2259	(EG 60)	” ”	Basic sill in Jurassic rocks. 1898.
2260	(KD 6)	” ” 7/5 .	Weathered concretions in Jurassic Sandstone. 1898.
2261	(EG 64)	” ”	Natural arch in Jurassic Sandstone. 1898.
2262	(EG 63)	Dun Thalargain, Eigg .	Concretions in Jurassic Sandstone; Plateau Basalts. 1898.
2263	(EG 62)	Cliff, N. end of Eigg .	Jurassic Sandstone and concretions. 1898.
2264	(EG 68)	Isle of Rum from W. of Scuir of Eigg.	Pitchstone in foreground in Tributary Valley. 1898.
2265	(EG 90)	Isle of Rum, from N.W. of Scuir of Eigg.	Plutonic rock scenery. 1898.
2266	(KD 38)	” ” 7/5	” ” ”

LANARK.—*Photographed by* R. McF. MURE,* 35 *Underwood, Paisley.* 1/2.

Regd. No.			
2117	( )	Partick, near Glasgow .	Forest in Coal measures.
2118	( )	,, ,,	Fossil tree in Coal measures.

LINLITHGOW.—*Photographed by* A. K. COOMARA SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

2114	( )	Silvermine Quarry, N. of Bathgate.	'White Trap' dyke in Carboniferous Shales. 1898.
2115	( )	Near Standing Stones, N. of Bathgate.	Feature due to dyke. 1898.

PERTH.—*Photographed by* Miss M. SILVERSTON, 33 *Portland Road, Edgbaston.* 1/4.

2116	( )	Falls of Bracklinn, near Callander.	Old Red Sandstone Conglomerate, bedded and jointed. 1898.

STIRLING.—*Photographed by* A: K. COOMARA SWAMY, *Walden, Worplesdon, Guildford.* 1/4.

2112	( )	'Todholes,' Sauchiemuir	Hurlet Limestone. 1898.
2113	( )	Sauchiemuir . . .	Esker. 1898.

IRELAND.

ANTRIM.—*Photographed by* R. WELCH,* *Lonsdale Street, Belfast.* 1/1. *Contributed through the Belfast Naturalists' Field Club.*

2014	(5156)	Cushendall . . .	Triassic Conglomerate. 1898.
2015	(5160)	Loughaveema, Ballycastle	'Cañons' and 'Pot' in miniature. 1897.
2016	(5161)	,, ,,	'Pot' in Alluvium. 1897.
2017	(5162)	,, ,,	Suncracks in peaty Alluvium. 1897.
2018	(620)	Lough-na-Cranagh, Fair Head.	Situated on Dolerite. 1896.
2039	(797)	Cathedral Caves, Portrush	Indurated Chalk with rolled Flints on floor. 1885.
2040	(226)	The Wishing Arch, Portrush.	Chalk, capped by Plateau Basalt. 1890.
2041	(374)	Grand Causeway, looking to the cliffs.	Basalt peak with Columnar Basalt in foreground. 1886.
2042	(652)	Carrick-a-raide, island and bridge.	Volcanic Agglomerate. 1893.
2043	(5110)	Ballycastle . . .	The North Star Dyke, in Carboniferous Sandstone. 1895.
2044	(622)	Kenbane Head and Rathlin Island.	Headland of Chalk, penetrated by Basaltic dykes. 1896.
2045	(268)	Garron Point and Castle .	Slipped plateau of Basalt. 1890.
2319	(5158)	Carrig-usnagh, Ballycastle.	Honeycomb weathering of Carboniferous Sandstone on shore. 1898.
2320	(5156b)	Red Bay, Cushendall .	Current-bedding in Triassic Sands and fine Conglomerate. 1897
2321	(5202)	Grant's Mines, Toome .	Diatomaceous Clay of the R. Bann, excavated for 'Kieselguhr.' 1899.
2322	(5201)	,, ,,	Face of Diatomaceous Clay. 1899.
2323	(5203)	,, ,,	Diatomaceous Clay, excavated. 1899.

CORK.—*Photographed by* Miss M. SILVERSTON, 33 *Portland Road, Edgbaston.* 1/4.

2119	( )	Near Crosshaven, entrance to Cork Harbour.	Bedding and cleavage. 1898.

DONEGAL.—*Photographed by* R. WELCH,* *Lonsdale Street, Belfast. Contributed through the Belfast Naturalists' Field Club.* 1/1.

Regd. No.		
2046	(2217) Great Arch, Doaghbeg, Portsalon.	Marine denudation of Quartzite. 1893.
2047	(2211) 'Seven Arches,' Portsalon	Caves in bedded Quartzite. 1893.
2048	(2204) Portsalon . . .	Quartz-veins along joints of Quartzite. 1893.
2049	(1390) Bundoran Strand . .	Bedding in Carboniferous rocks. 1892.

DOWN.—*Photographed by* R. WELCH,* *Lonsdale Street, Belfast. Contributed through the Belfast Naturalists' Field Club.* 1/1.

2019	(5114) Ardglass . . .	Vertical Ordovician rocks.
2050	(13) Happy Valley, Mourne Mountains.	Granite Screes, encroached upon by bog. 1898.
2051	(5111) Ardglass . . .	Ordovician rocks on shore. 1894.
2317	(5181) Killard Point, Ardglass .	Weathering of indurated Sand and Gravel. 1899.
2318	(5182) Jackdaw Galleries, Killard Point.	„ „ „

Photographed by Miss M. K. ANDREWS, 12 *College Gardens, Belfast.* 1/4.

2309	(1) Two miles S. of Newcastle .	Large Felsite dyke, with inclusions of Ordovician rock. 1898.
2310	(2) „ „	„ „ „
2311	(3) „ „	Intermingling of Felsite and Ordovician rock. 1898.
2312	(4) „ „	Fragment of banded Ordovician rock, included in Felsite. 1898.
2313	(5) „ „	Central section of dyke. 1898.
2314	(6) Quarter mile S. of Green Harbour.	Dyke of altered Andesite traversing Ordovician rock; porphyritic labradorite. 1898.
2315	(7) „ „ „	„ „ „ 1898.
2316	(8) „ „ „	General view of dyke. 1898.

Photographed by J. ST. J. PHILLIPS, 61 *Royal Avenue, Belfast.* 1/4.

2324	(279) Bloody Bridge, Newcastle.	River cutting through fan-talus. 1898.

DUBLIN.—*Photographed by* J. A. CUNNINGHAM, 2 *Seaview Terrace, Donnybrook.* 1/2.

2181	(1) South of Loughshinny Village.	Overfolded Upper Carboniferous Limestone. 1899.
2182	(2) „ „ „	Fold in Upper Carboniferous Limestone. 1899.
2183	(3) „ „ „	„ „ „
2184	(4) South end of inlet at Loughshinny.	Bent anticlinal axis in Upper Carboniferous Limestone. 1899.
2185	(5) Greenhills, near Crumlin .	Gravel section in Esker. 1899.
2186	(6) „ „	Current-bedding in Esker Sands. 1899.

GALWAY.—*Photographed by* R. WELCH,* *Lonsdale Street, Belfast. Contributed through the Belfast Naturalists' Field Club.* 1/1.

2020	(2373) Killary Fiord . .	Silurian Rocks. 1897.
2021	(2376) Salruck, Little Killary .	„ „ „
2022	(5169B) Lough Muck . .	Glaciation. 1897.
2023	(5169) „	„ „

KERRY.—*Photographed by* R. WELCH,* *Lonsdale Street, Belfast. Contributed through the Belfast Naturalists' Field Club.* 1/1.

Regd. No.		
2024	(5186) Cloghvorragh . .	Erratic of Carboniferous Limestone, weighing 400 tons, resting on Old Red Sandstone. 1898.
2025	(5183) Sheen River, Kenmare .	Pot-hole, with contained boulders. 1898.
2026	(5188) Loo Bridge . . .	Ice-rounded bluff of Old Red Sandstone. 1898.
2027	(5187) Moll's Gap, Kenmare .	Ice-rounded rocks and Derrygarriff Mountain. 1898.
2028	(5184) Carrigacapeen or Mushroom Rock, Cleady, Kenmare	Erratic of Old Red Sandstone, weighing 30 tons, resting on Pillar of Carboniferous Limestone. 1898.
2029	(5185) ,, ,,	,, ,, ,,

Photographed by J. ST. J. PHILLIPS, 61 *Royal Avenue, Belfast.* 1/4.

2325	(276) Near Lake Barfinachy .	Perched Block of Old Red Sandstone. 1898.
2326	(278) Cloghvorragh, Knockeirka.	Large Erratic block of Carboniferous Limestone. 1898.
2327	(275) Moll's Gap, Derrygarriff Mountain.	Contorted Strata of large Overfold. 1898.
2328	(277) Near Morley Bridge .	Glaciated Rocks. 1898.

LONDONDERRY.—*Photographed by* J. ST. J. PHILLIPS, 61 *Royal Avenue, Belfast.* 1/2.

2329	(272) Foot of Benevenagh .	Landslip from Basalt Plateau. 1898.
2330	(273) Benevenagh . . .	,, ,, ,, ,,
2331	(274) Dog's Leap, River Roe .	Pot-holes in Schists. 1898.

MAYO.—*Photographed by* R. WELCH,* *Lonsdale Street, Belfast. Contributed through the Belfast Naturalists' Field Club.* 1/1.

2030	(2370) Killary Fiord and Devilsmother.	Fiord passing into Valley. 1897.
2031	(2367) Erriff Valley . . .	Steep-sided Valley at head of Fiord. 1897.
2032	(2382) Delphi	Valley and mountains. Silurian rocks. 1897.
2033	(2387) Mweelrea and Great Killary, from Dernasliggan.	Mouth of a Fiord. 1897.
2034	(2371) Head of Killary Fiord .	Head of a Fiord. 1897.
2035	(2369) Erriff Valley and Head of Killary Fiord.	Fiord passing into valley at its head. 1897.
2036	(2385 B) Ben Greggan, Delphi .	*Roche moutonnée.* 1898.
2037	(2385) Doolough and Ben Greggan, Delphi.	Peak and cirque in Silurian rocks. 1897.

TIPPERARY.—*Photographed by* R. WELCH,* *Lonsdale Street, Belfast. Contributed through the Belfast Naturalists' Field Club.* 1/1.

2038	(5190) Rock of Cashel . .	Anticline in Carboniferous strata. 1898.

ROCK-STRUCTURES, &c.

Photographed by A. S. REID, *Trinity College, Glenalmond.* 1/2.

2122	(EG 1) Top of Craiglea, Perth .	Glaciated Slate, surface of hill-top, 1,500–1,600 feet.
2123	(EG 2) Craiglea Quarry, Perth	False-bedding in Slate.
2124	(EG 17) Millhaugh, R. Almond, Perth.	Fragments of sedimentary rock included in acid rock.

Photographed by Miss E. M. Partridge, 75 *High Street, Barnstaple.* 1/4

Regd. No.		
2274	(16) Filleigh, near South Molton, Devon.	Nodular forms of Wavellite.

LIST II.

NUMBERS OF OLD PHOTOGRAPHS CANCELLED.

2	Cheshire, Storeton . . .	Footprint bed. Report 1890.
14	„ Thurstaston Hill . .	Bunter outlier. 1890.
218	Yorkshire, Burdale . . .	1890.
263	Antrim, N. Coast	Chalk cliffs. 1890.
301	Isle of Man, Spanish Head . .	Clay slates. 1891.
302	„ Douglas Head . .	Contorted Clay slates. 1891.

983*a*, 984*a*, 985*a*, 986*a*, see p. 19.

LIST III.

RENEWALS AND CORRECTIONS.

Photographs renewed by F. N. Eaton,* *Higher Lane, Aintree, Liverpool.* 1/4.

842	Thornton Force, Ingleton . .	Fall on the River Greta. 1894.
843	„ „ „ . .	„ „ „ „

A set of photographs taken and presented by J. Stelfox in 1890 having fallen into some confusion and loss, the lost prints have been renewed by R. Welch through the Belfast Naturalists' Field Club. Mr. Welch has also been so good as to revise the original descriptions of some of the older photographs, and his revisions are printed below. The prints which have been renewed are marked thus† :—

Report	Regd. No.		
1890	245 246	Fair Head, from the sea .	Columnar Basalt.
	†254	(R. W. 657) Portbraddan, Whitepark Bay.	Denudation of Chalk at east end of great fault which drops down the Causeway area.
	255	(J. S. 612) Kenbane Head.	Headland of Chalk.
	256	Cathedral Cave, Portrush.	Cave in Chalk.
	260	(J. S. 27) Ballintoy . .	Marine denudation.
	†261	(R. W. 648) Elephant Rock, Ballintoy . . .	Denudation of intrusive sheet of Columnar Basalt.
	†262	Near Ballintoy . . .	Arch of denudation in Chalk.
1892	654	Dunree Head, Lough Swilly	
	657	Island of Muck . . .	Marine denudation.
	658	Slope of Slieve Bearnagh, Mourne Mountains.	Granite boulders.
	659	Spellack Cliff, Slieve Meel More.	
	660	North summit of Slieve Bearnagh, Mourne Mountains.	Effects of wind erosion.
1894	877	Pass of Salruck, Little Killery River, Connemara.	Erosion of river valley.
	961	Port Leaca. . . .	Marine erosion.
	963	Glenariff	Large 'Pot-hole.'
	969–971	Whitewell . . .	Basalt on eroded surface of Chalk.
	976	Moylena	Current-bedding in Drift Sands
	1009–1011	Neills Hill. . .	Current-bedded Drift Sand.

Renewed by W. Gray, *Glenburn Park, Belfast.* 1/2.

Regd. No.		
264	Larne	The 'Larne Gravels.' Raised Beach with worked flints.
265	(32) Larne	" " "
266	(33) Fair Head	Transported block of Trap.
267	(34) Strangford Lough, Down .	" "
270	(37) The Madman's Window, Glenarm.	Natural Arch in Chalk.
271	(38) Ballywillin	Curved columns of Basalt.
272	(39) Derriaghey	Outcrop of New Red Sandstone.
273	(40) Cushendun	Cave in Old Red Sandstone Conglomerate.

The following alterations in numbers of photographs reported in 1894 have been made in consequence of duplication.

Down.—*Photographed by* W. Gray, *Glenburn Park, Belfast. E.*

263	Cloughmore	Block of Newry Granite (formerly 983*a*).
268	The Butterlump, Strangford Lough.	Basalt Erratic on New Red Sandstone (formerly 984*a*)
269	Ballyquintin Point . . .	Vertical Silurian Rocks (formerly 986*a*).
274	On the shore near Bloody Bridge	Silurian rocks (formerly 985*a*).

LIST IV.

THE DUPLICATE (LOAN) COLLECTION.

The numbers placed after the description of the photograph refer to the list of names and addresses given at the end. The first refers to the photographer, who is also the donor in most cases. When he is not, the donor is indicated by a second number.

Full localities and descriptions are given in present and previous lists under the numbers.

This collection is arranged geologically, and from time to time the less perfect and less typical photographs will be removed and better ones substituted as they are given. Those laid aside can always be seen, sent, or returned by request.

* indicates that prints and slides may be bought from the photographer. P. indicates prints. S. indicates slides.

Rock-Structures.

Bedding.

Regd. No.		
2191	Bedding in Lower Lias . .	Harbury Brick-pit, Warwick. 40 P. S.
2123	False-bedding in Slate . .	Craiglea Quarry, Perth. 15 P.

Evidences of Earth-movement.

Folding and Faulting.

F. 17	Contorted Strata . .	Axenstrasse, Lake of Lucerne, Switzerland. 40 P.
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Example of a Photographic Survey.

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2254 **2255**	Brecciated base of Pitchstone which rests on River Gravel.	Scuir of Eigg, Inverness-shire. 15 P.
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2258 **2259** **2260**	Jurassic Sandstones with Basic Sill and weathered concretions.	Laig Bay, Eigg, Inverness-shire. 15 P.
2261 **2262** **2263**	Natural Arch and concretions in Jurassic Sandstones.	Laig Bay, Eigg. 15 P. Dun Thalargain, Eigg. 15 P. N. end of Eigg. 15 P.
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Names and Addresses of Photographers and Donors.

15. A. S. Reid, Trinity College, Glenalmond, Perth, N.B.
40. A. K. Coomara Swamy, Walden, Worplesdon, Guildford.
53. H Larkin, Canterbury College, New Zealand.
54. Professor Hutton, Canterbury College, New Zealand.
55. K. F. Bishop, 18 New Street, West Bromwich.
56. W. Gray, Glenburn Park, Belfast.
57. J. H. Pledge, 115 Richmond Road, London, N.E.

Erratic Blocks of the British Isles.—Report of the Committee, consisting of Professor E. HULL (*Chairman*), Mr. P. F. KENDALL (*Secretary*), 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. F. M. BURTON, Mr. J. LOMAS, Mr. A. R. DWERRYHOUSE, Mr. J. W. STATHER, *and* Mr. W. T. TUCKER, *appointed to investigate the Erratic Blocks of the British Isles, and to take measures for their preservation.* (*Drawn up by the Secretary.*)

THE attention of the Committee has been concentrated mainly upon the erratics of Yorkshire, and they have again to acknowledge the great services rendered by the Yorkshire Boulder Committee, and the subsidiary organisation working on the eastern side of the county under the auspices of the Hull Geological Society.

Of the value of their work it would be difficult to speak too highly, especially when it is borne in mind that it is not a new-born zeal which animates the workers, but that year by year they have devoted themselves to the task, and now enter upon the second decade.

The most noteworthy new facts relate to the dispersal of erratics of Scandinavian origin, which have now been traced over a much wider area and to much greater altitudes than previously; moreover, the distribution of type sets of rocks from the east coast of Norway amongst the active workers has given them a firmer basis upon which to work, and several of the rocks have now been recognised in the drift of Yorkshire.

The new records of Scandinavian rocks enlarge our knowledge of their dispersal in two important particulars: their horizontal range has been much extended, and they have been traced to altitudes far exceeding that previously ascribed to them. The discovery of Norwegian rocks to the westward of the Chalk Wolds announced in the report presented last year has been supplemented by two new records at Brantingham Thorp and Elloughton respectively.

The well-known Rhomb-porphyry has been found by Mr. J. W. Stather at Speeton at an altitude of 400 feet above Ordnance Datum, by Messrs. Kendall and Muff at altitudes exceeding 600 feet at several points on the northern slopes of the Cleveland Hills, but the greatest height to which this rock has been traced in Britain is indicated by Mr. Stather's discovery of a specimen embedded in Boulder-clay at 810 feet Ordnance Datum on West Rigg in the Lockwood Hills.

Some interesting facts have been brought to light on the Cleveland Hills, where Messrs. Kendall and Muff have found that at high altitudes there is a significant absence of the rocks which belong to the Teesdale dispersion, such as Shap granite, Brockram, and Whin sill, while all Carboniferous rocks are exceedingly rare; while, on the other hand, Magnesian Limestone of a type which appears to be restricted to the coast of Durham is very abundant in association with a profusion of porphyrites from the Cheviots, and occasional flints, Scandinavian rocks and shell fragments.

An important aid to the elucidation of the origin of the erratics of the east coast of England is given by Mr. Jesson, of the Danish Geological Survey, who states that the pink flints of the English Drift are not known in Denmark.

CHESHIRE.

Reported by Mr. W. A. DOWNHAM, *F.G.S.*

Disley, at High Lane end of railway cutting—

Eskdale granite.

Reported by the Yorkshire Boulder Committee. By the Boulder Committee of the Hull Geological Society, July 26, 1899.
By Mr. W. H. CROFTS.

Brantingham Thorp—

Rhomb-porphyry, 3 inches by 2 inches by 2 inches. West of the village, in the sand-hill field.

By Mr. F. F. WALTON, *F.G.S.*

Coney Garth, near Brandsburton—

Rhomb-porphyry, 6 inches in diameter.

Brigham Hill, near North Frodingham—

Rhomb-porphyry.

By Mr. THOS. SHEPPARD.

Yedmandale, near West Ayton—

Rhomb-porphyry.

By Mr. J. W. STATHER, *F.G.S.*

Ayton, East—

Garnetiferous schist.

Bainton on the Wolds—

Basalt, granite, grit, brockram. From the Boulder-clay in the railway cutting east of the station.

Brandsburton—

Rhomb-porphyry. Two pebbles 3 inches and 4 inches in diameter. From the Barf Hill Quarry.

Cayton Bay—

Shap granite, 2½ feet, by 2½ feet, by 2 feet. On the shore, under Red Cliff, 300 or 400 yards north of the fault.

Elloughton, Brough—

Augite-syenite (Laurvikite), 12 inches, by 15 inches, by 18 inches. From the Mill Hill gravel quarry, 100 feet above O.D.

Filey—

Elæolite syenite. Two pebbles, 3 inches to 4 inches in diameter. From the Boulder-clay on the Carr Naze.

A mass of Upper Lias shale, 60 feet long by 30 feet broad, containing many fossils, including *Ammonites communis*, *Leda ovum*, *Belemnites*, sp.

&c., embedded in the Boulder-clay beach, south of the town. This boulder is situated 120 feet from the present cliff, about half a mile south of the Mile Haven ravine (Primrose Valley).

Rhomb-porphyry. Two specimens. From the brickfield on the Scarborough road, 1 mile north.

Flambro—

Rhomb-porphyry, 3 inches in diameter. Brickfield west of village.

Garton on the Wolds—

Rhomb-porphyry. Two pebbles, each about 3 inches in diameter. From the Craike Hill quarry.

Gristhorp—

Rhomb-porphyry. Granite from Angermanland. Collected on the beach.

Rudstone—

Rhomb-porphyry, 3 inches in diameter. Found, along with numerous other boulders of the usual Holderness type, in small quarry opened in the Gypsey gravels, 1½ miles north of the village, on the road to North Burton.

Seamer—

Basaltic rock, 3 feet, by 2 feet, by 2 feet, 200 feet above O.D. Seamer Moor Lane, immediately north of Way-dale Lane end.

Speeton—

Rhomb-porphyry; Silurian (?) fossiliferous rock (?), 400 feet above O.D. From the moraine on which Speeton Mill stands.

Thornwick Bay, Flambro.

Augite-syenite (Laurvikite), 4 inches, by 3 inches, by 3 inches.

Note.—Following a suggestion in the Holderness memoir, we have become accustomed to regard Denmark as the source of the pink flints, common in the Boulder-clays of Holderness. This proves to be erroneous. Mr. A. Jesson, of the Danish Geological Survey, recently informed the Secretary (Mr. Stather) that pink flints do not occur in either the Cretaceous rocks or the Drifts of Denmark, and are quite unknown there.

Reported by Messrs. P. F. KENDALL *and* H. B. MUFF.

Goathland, near Scarr Wood.—480 O. D.—

In red Boulder-clay: mica-schist, gneiss, Cleveland dyke, Chalk-flint, Triassic sandstone, Jurassic sandstone, Cheviot porphyrite, and Sparagmite (?) sandstone.

Goathland, 200 *yards east of the church.*—520 O. D.—

In Boulder-clay: porphyrite, flint.

Moss Dyke, Goathland.—O.D.—

Cheviot-porphyrite, felsite, basalt, Sparagmite (?) sandstone.

Randay Rigg, Goathland.—595 O. D.—

1 Cleveland dyke.

Quarry above middle of Lealholm.—625 O. D.—

Flint, porphyrite, andesite, granite, greenish grit (? Sparagmite), quartzite, oolite with Nerinæa, basalt.

Quarry at corner of road Lealholm to Stonegate.—625 O. D.—

Carboniferous chert, Magnesian limestone, Millstone Grit, quartz-porphyry (? Elfdalen).

Stonegate, old railway cutting near bridge.—560 O. D.—

Sparagmite (?) sandstone, porphyrite, basalt, granite, quartz-porphyry, andesite, andesitic ash and breccia, Carboniferous chert (two specimens), Carboniferous limestone (one specimen), Millstone Grit (4 specimens), Carboniferous basement conglomerate, of Roman Fell type (one specimen), flint, jasper, Poikilitic sandstone, Old Red Sandstone (?), gneiss, hornblende-schist (two specimens), quartzite with pebbles of mica-schist, vein quartz. The matrix consisted largely of fragments of Upper Lias shale.

Another cutting near Wood Hill House contained a similar assemblage of stones, but Magnesian limestone, with botryoidal structure, was very abundant, and a specimen of Middle Lias, with *Pecten equivalvis*, was found.

Commondale, near Skelderskew Farmhouse.—560 O. D.—

Porphyrite, grey grit (? Sparagmite), hornblende-schist, Shap granite.

Iburndale, 250 *yards north of Throstle Nest.*—80 O. D.—

Shap granite.

Iburndale, path above New May Beck.—675 O.D.—

Granite, porphyrite.

West Rigg, near Lockwood Reservoir.—810 O. D.—

In Boulder-clay: Flint, porphyrite, grit (? Sparagmite), quartzite, basalt, coarse felspathic grit, andesite, Carboniferous chert, schist, granite, 1 Rhomb-porphyry found by Mr. J. W. Stather *in situ* in the Boulder-clay.

Danby, at junction of Ewe Crag Beck and Black Beck.—625 O. D.—

Porphyrite, granite, Rhomb-porphyry.

Peak Station.—650 O. D. In gravel—

Gneiss, porphyrite, granite, basalt, ophitic dolerite, flint (some black), Magnesian limestone (resembling that near Sunderland), vein-quartz, quartzite, sandstone (? Sparagmite), blue-green felspathic grit, Triassic sandstone, Millstone Grit (two specimens), quartz-porphyry (? Elfdalen), jasper, hornblende-schist, andesite. No Carboniferous limestone or Lias observed.

Peak, on Moor near Green Dike.—825 O. D.—

Quartz-porphyry, porphyrite, granite, basalt, flint.

Danby, near Doubting Castle.—725 O. D.

Porphyrite, granite, flint, basalt.

Seavy Slack, Eastington High Moor.—700 O. D.—

Gneiss, Rhomb-porphyry.

Ainthorpe, near Danby, in field north of Schoolhouse.—500 O. D.—

Porphyrite, Lake District volcanic ash.

Great Ayton, Rye Hill Gravel Pit.—425 O. D.—

Porphyrite, very abundant and greatly preponderating over all other non-sedimentary rocks together. Millstone Grit (rare), Carboniferous limestone and chert (very rare), Lower and Middle Lias, Triassic sandstone, Jurassic grit, Magnesian limestone, flints (both black and brown).

Scugdale, Sparrow Hall—600 O. D.—

Grit, Carboniferous chert (one specimen), granite, green volcanic ash, porphyrite.

On Moor, near Harfa Bank Slack.—875 O. D.—

1 Carboniferous chert with crinoid stems.

Swainby, Scarth Nick—625 O. D.—

Many large blocks of basalt and Lake District andesite, pebbles of porphyrite.

Stanghow Ridge, near Smithy.—675 O. D.—

Shap granite.

Lockwood Hills.—850 O. D.—

Near peat-holes gravel composed largely (at least one-third) of porphyrite.

Hutton, near Guisborough.—Cod Hill Farm—800 O. D.—

Porphyrite.

Bold Venture.—825 O. D.—

Porphyrite and volcanic ash.

Carlton Bank.—On watershed, 925—950 O. D.—

Pebbles of Carboniferous grit, porphyrite and volcanic ash.

Whitby.—On beach—

Elæolite syenite, exactly resembling that of Kvelle, near Larvik.

Whitby.—In Upper Boulder-clay—

Coarse dolerite, resembling closely that of Crawford-John.

Caves at Uphill.—Report of the Committee, consisting of Professor C. LLOYD MORGAN (*Chairman*), Professor W. BOYD DAWKINS, Mr. W. R. BARKER, Mr. T. H. REYNOLDS, Mr. E. T. NEWTON, *and* Mr. H. BOLTON (*Secretary*), *appointed to excavate the Ossiferous Caves at Uphill, near Weston-super-Mare.*

THE Committee report that a large cave was opened and explored for some distance, but being unproductive was abandoned. A second cave was opened, and has been traced for a distance of 23 feet, when it opens upon a rock ledge somewhat similar in character to a rock shelter.

Fragments of mammalian bones, gnawed bones, hammer stones, and pot-boilers have been found, together with the long bones of birds and small mammals, which from their shape would seem to have been used as pins or borers.

At 7 feet from the entrance of the second cave a piece of black Roman pottery was found. The material shows abundant traces of water action, and would seem to have been carried from the rock shelter into the cave, and to have also come from higher levels, a search for which is now being made

Fossil Phyllopoda of the Palæozoic Rocks.—Fifteenth Report of the Committee, consisting of Dr. T. WILTSHIRE (*Chairman*), Dr. H. WOODWARD, *and* Professor T. RUPERT JONES (*Secretary*). *Drawn up by* Professor T. RUPERT JONES.

CONTENTS.

§ I. 1888.—IN the 'Memoirs of the Geological Survey of New South Wales, Palæontology,' No. I. pp. 1–8, and plate 1, figs. 1–10, Robert Etheridge, junior, treating of the Invertebrate Fauna of the Hawkesbury-Wianametta Series of New South Wales, describes and figures some *Estheriæ* obtained by deep borings in those strata, namely at the Moore-park, Port-Hacking, Dent's Creek, Heathcote, Narrabeen, and Moorbank Bores.

Estheria Coghlani, Cox, first described in the 'Proceedings of the Linnean Society of New South Wales for 1880 (1881),' vol. v. p. 276, is here figured in plate 1, figs. 1–5 (from Dent's Creek Bore); and some undetermined fragments, figs. 6, 8–10, from the same and from the Narrabeen Bore.

§ II. 1895–6.—In his memoir on the stratigraphic and faunal relations of the Oneonta sandstones and shales, the Ithaca and the Portage groups in Central New York, from the 'Fifteenth Annual Report of the State Geologist,' Mr. J. M. Clarke describes, at pp. 63–81, some sections in Chenango, Courtland, Schuyler, and Yates Counties. At Station VI., De Ruyter, Madison County (pp. 68 and 69), above the Tully Limestone come the Sherburne Sands, and herein were found three specimens of an interesting species of *Rhinocaris*, which Mr. Clarke names *bipennis.* Though not perfectly preserved, they show a low curved ridge on the valve, an optic and a mandibular node, three external abdominal segments, and caudal appendage. In one of the specimens a valve has been weathered away and exposes some obscure evidences of internal organisation.

§ III. 1897.—In the 'Thirteenth Report on the Palæozoic Phyllopoda' ('Report Brit. Assoc. for 1897,' pp. 343–346) reference was made at pages 343 and 344 to some of Dr. G. F. Matthew's minute Cambrian fossils from New Brunswick. In a letter dated November 5, 1897, he directs attention to 'Leperdilla' as misspelt for *Lepidilla*, and having no connection with *Leperditia*, but meaning 'double scale,' being bivalved. He adds: 'I wish to withdraw *Lepidilla*, as not being a crustacean. More perfect specimens seem to show a fanlike structure of internal tubes. There is only one species, the one you mention.' He adds: 'I have referred *Ceratiocaris pusilla* to *Rhinocaris* (see "Seventh Report," p. 64, and "Thirteenth Report," p. 344) as being the nearest genus, but it appears to have a fixed rostrum (attached to one valve), though possibly the suture may run through from the apex of the shield.'

§ IV. 1897.—In the 'Geological Magazine,' Dec. IV. vol. iv. (1897), pp. 197 and 198, a new genus of Palæozoic Phyllopods was recognised as *Estheriina* in the *Cardinia Freysteni*, Geinitz, and the *Estheria limbata*, Goldenberg; the distinctive features having been determined by the study of some Brazilian forms (of Cretaceous? age), *Ibid.* pp. 198 and 201. These have the umbonal area of each valve extremely exaggerated, the remainder being thin, flat, and marked with more numerous and more delicate concentric lines.

A Permian specimen, from Frankfurt-on-the-Maine (described and figured in the 'Geological Magazine,' September 1899, p. 394, pl. 15, fig. 7), found by Baron von Reinach, represents a highly swollen separate umbonal area (such as occurs isolated with those in Brazil), and has been named *Estheriina extuberata*, Jones.

§ V. 1898.—Mr. J. M. Clarke, State Geologist of New York, in the 'Fifteenth Annual Report of the State Geologist,' gave a series of 'Notes on some Crustaceans from the Chemung Group of New York State,' and therein described and figured (pp. 731–733, two figures) a singularly ornamented Phyllocarid Crustacean, found in the Chemung Sandstone at Alfred, N.Y. It is related to *Echinocaris*, but, besides other differences, it has a deep oblique sulcus on the valves, and these are fringed with long strong spines. Its name, *Pephricaris horripilata*, has reference to its extravagant decoration.

§ VI. 1899.—M. Canavari, in the 'Proc. Verb. Soc. Toscana Sci. Nat. Pisa,' 1899, pp. 150–153, noting the occurrence of Silurian Entomostraca in Sardinia, mentions some *Ostracoda*, such as *Beyrichia reticulata*, Bornemann, *B. simplex*, Jones, *Entomis migrans* and *dimidiata*, Barrande, and some undescribed species; also *Cypridina* and *Bolbozoe*. Of the *Phyllopoda* he mentions fragments of *Ceratiocaris* and *Aristozoe*, and several specimens of *Aptychopsis prima*, Barrande.

§ VII. 1899.—Dr. G. F. Matthew, in his 'Preliminary Notice of the Etcheminian Fauna of Newfoundland' ('Bull. Soc. Nat. Hist. New Brunswick,' XVIII. vol. iv. p. 189), describes and figures single valves of the minute *Aptychopsis Terranovica*, p. 194, pl. 3, fig. 5, and its 'mutation' *arcuata*, p. 195, pl. 3, fig. 6.

§ VIII. 1899.—In the 'Monograph of Dithyrocaris' ('Palæont. Soc.'), part iv. p. 183, we have determined that the Devonian valve from Saalfeld, pl. 22, fig. 2, is a *Calyptocaris*, not a *Chœnocaris* as at first placed, p. 133; also in the 'Fourteenth Report,' 1899, p. 521; and that it is allied to *Calyptocaris striata* from the Lower Carboniferous Sandstone of Scotland.

§ IX. 1899.—1. Two Lower Silurian specimens from Brittany, in M. Paul Lebesconte's collection at Rennes, were mentioned in the 'Seventh Report on Palæozoic Phyllopoda,' 'Report Brit. Assoc. for 1889 (1890),' p. 65. These, although pressed and distorted in the slaty schist, are certainly allied to, though not identical with, *Dithyrocaris*, and are evidently the oldest examples of the group. On the back of one of the specimens a single but damaged valve supports our determination of their characters and alliance. On one or other of these three individuals there are characteristic anterior and posterior denticules or spines, and longitudinal ridges and foldings, such as are common in the group. Combining the evidences given by these specimens, although somewhat obscure on account of imperfections, distortion, and imbedment, we conclude that they are the relics of a bivalved Phyllopod, and we name it *Lebescontia ænigmatica*, J. and W.

2. Subsequently from among the Carboniferous fossils of Linn Dalry, collected by Mr. John Smith, of Kilwinning, we have seen two counterparts of one valve, corresponding in general characters with *Lebescontia*. It is figured and described by Jones and Woodward in the Monograph of Palæoz. Phyllop. Pal. Soc., for 1899, as *L. occulta*.

§ X. 1899.—Related to *Cyclus*, which is a Phyllopod, a new genus *Hibbertia* has been established by Jones and Woodward, on a specimen long ago collected from the Lower Carboniferous series at Burdiehouse, Scotland. This has a nearly circular shield-like test, with a slight kink or crumple in front, and a concave hollow behind, about as wide as a third of the test. This indentation lies between the postero-ventral angles of the shield; and the median space above it is occupied by the obscured débris of the animal. The outer edge of the test shows an upturned narrow rim; and the sides of the buckler are much tuberculated, including the inner edges of its incurved posterior angles. Faint traces of some probably articulate limbs are discernible. It is concluded that this little fossil is related to *Cyclus*, but characteristic of a distinct genus, which is named *Hibbertia*, after Dr. Hibbert, whose discoveries in the Carboniferous strata at Burdiehouse are well known. 'Geol. Mag.,' September 1899, p. 390, pl. 15, fig. 4.

§ XI. 1899.—One of the two specimens of the rare *Echinocaris Whidbornei* recorded in the 'Thirteenth Report,' p. 346, is figured and redescribed in the 'Geol. Mag.,' September 1899, p. 393, pl. 15, fig. 6.

Registration of Type Specimens of British Fossils.—Report of the Committee, consisting of Dr. H. WOODWARD (*Chairman*), Rev. G. F. WHIDBORNE, Mr. R. KIDSTON, Professor H. G. SEELEY, Mr. H. WOODS, and Mr. A. S. WOODWARD (*Secretary*).

DURING the past year only one list of type specimens of British fossils has been published, namely, Mr. Bather's List of the Blastoidea in the British Museum. This is the second list of types issued by the Trustees of the British Museum, the Fossil Cephalopoda having been similarly treated in 1898. The list of type specimens in the Brodie Collection, prepared for the Committee by the late Rev. P. B. Brodie himself, has been lent to the Department of Geology, British Museum, and has been found of much value in identifying these fossils, which are now incorporated in the National Collection.

Ty Newydd Caves.—Report of a Committee consisting of Dr. H. HICKS (*Chairman*), Rev. G. C. H. POLLEN, S.J. (*Secretary*), Mr. A. STRAHAN, Mr. E. T. NEWTON, Mr. G. H. MORTON, *and* Rev. E. R. HULL, S.J., *appointed to investigate the Ty Newydd Caves, Tremeirchion, North Wales.* (*Drawn up by the Secretary.*)

IN addition to those mentioned in former reports on this exploration[1] as having given us assistance, we have to acknowledge the kindness of Mr. D. L. Paterson, of Aston Park, Birmingham, and of Mrs. Sutton, of Market Drayton, who gave us permission to excavate on their property, and of Mr. John Griffiths, of Mold.

The principal work done during the past winter and spring has been—

(1) In the eastern cave.
(2) In the northern portion of the western cave.
(3) A trial shaft was also sunk in a cave 200 yards S.-W. of Ty Newydd, on the same hillside.

(1) The eastern cave consists of a true cave tunnel with oval section, and a rock floor measuring, on the average, 8 ft. by 5 ft. in cross section, and extending 35 ft. at one level in the direction N. and S.

At the northern extremity there is a passage to the W. 8 ft. long and 6 to 8 ft. across, connecting it with an oval chamber 23 ft. by 8 ft. and 18 ft. to 24 ft. high. The entrance is situated in the upper portion of this chamber on the western side.

This cave has an outlet at its southern extremity, when it turns sharply to the N.-E. with a sudden dip of nearly 45°, which prevented further excavation.

At the top of the first chamber from the entrance there were some small beds of gravel, which are described and figured in the 'Q.J.G.S.' February 1898, p. 124. The lower part of this chamber, as well as the passage and tunnel beyond, was filled almost exclusively with laminated sandy clay, containing a few fragments of stalagmite. It is not therefore considered necessary to reproduce in this report any of the measured sections taken in this part of the work.

(2) The northern portion of the western cave runs in the direction of the gully separating these caves from those of Ffynnon Beuno and Cae Gwyn.

After passing across the old quarry floor behind the cottage of Ty Newydd, the cave runs under a garden on the northern slope of the hill.

For 6 ft. we found here a roof of rock, but beyond that distance there was only a fissure covered by boulder clay.

As we obtained permission to explore this part of the cave on condition of our doing no permanent injury to the surface, we endeavoured as far as possible to tunnel under the drift, which, however, proved a very unsafe roof to our excavations.

To the distance of 33 ft. the average width of the cave was 2 ft. to

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[1] *Q.J.G.S.* February 1898, p. 119. Report read at the Bristol Meeting of the British Association, 1898. Not published.

3 ft., but at this point it widened out and divided into two passages, one 3 ft. to 4 ft. wide, continuing due N., the other 1 ft. to 2 ft., turning 30° to the E.

We followed each of these passages for some distance, but they gradually became filled with large blocks of limestone; and as we found that one very large block formed a continuous floor 13 ft. below the surface, which would have prevented our exploring at a lower level, we thought it best to abandon this part of the work, and to sink a shaft at 25 ft. from the quarry entrance. This shaft was carried to a depth of 25 ft. from the surface, when the boulder clay above began to fall in, owing to the heavy rains in January. The expense required to shore up the roof and to make further working safe would have been very great, so we were reluctantly obliged to fill in all this part of the cave to prevent any further subsidence.

The material excavated consisted chiefly of clayey gravel, containing some sand, and also some stalagmite. A sample sent to Mr. Strahan for examination was found to contain striated stones. There was also some stalagmite adhering to the walls. As we passed to a lower level the sand disappeared, and the gravel became undistinguishable from the lowest clayey gravel found in former portions of the cave, but we could not clearly determine the line which separated the deposits. There were also a few thin beds of clay in the upper gravel.

These deposits had been cut through vertically in several places, and large beds of sand and of laminated sandy clay had been introduced. In one case the division between the gravel and the sand beds was concave.

At the 25-ft. shaft there was a funnel-shaped bed of sand which thinned off below into a long pipe with cross sections 1 ft. by 3 in. This extended nearly the whole depth of the shaft and then turned towards the N.

Besides having to abandon this part of the work without fully determining the correlations of the beds, we were also under the disadvantage of not knowing what the deposits may have been in the upper portion of the cave in the old quarry, and are thus unable to make out the exact connection between the northern and southern parts of the western cave with each other and with the eastern cave.

Twenty-two feet beyond our furthest work under the garden there is a cutting in the hillside to provide a level space on which some cottages have been erected. In the courtyard behind these cottages, after removing modern *débris*, we found a fissure cave, considerably wider than the former western cave fissure, being 4 to 5 ft. across. The direction in this part was nearly E. and W., but there were indications that it subsequently turned in a northerly direction. The undisturbed material consisted of a very deep bed of laminated clayey sand, containing large blocks of limestone and massive stalagmite fragments, one of the latter measuring over 18 in. in thickness. Below this there was a bed of gravel which had apparently been introduced from a small fissure, 1 ft. 6 in. wide, which runs in the direction of our former workings. Just opposite this fissure the gravel was at its highest level, and the dip to the N.-W. was so great that we thought it useless to excavate far, as there was no promise of a mouth by which animals could have entered the cave.

There was no true roof of rocks, but the sides were composed of a limestone breccia, with blocks of several tons weight, so that the excavation was a work of no little difficulty and danger. In the heavy rains of the early spring the work became too perilous, and we were obliged to refill the cave before a serious fall could take place.

(3) At a distance of 200 yards from Ty Newydd cave, on the same hillside, a trial pit had been made for lead about sixty years ago. The miners passed through 14 ft. of rock, and then came to an open cave, which they did not disturb. On removing the *débris* which filled this pit we found an open chamber 20 ft. by 12 ft., and 8 ft. high in the centre. From this chamber a tunnel, about 3 ft. wide, ran S., and another small passage 1 ft. wide extended W.; both of these were filled to the roof at a distance of 12 ft. and 5 ft. respectively from the chamber. The pit was over the extreme northern end of the chamber. Immediately under this opening in the rock we sank a shaft 14 ft. deep to the rock floor, and obtained the following succession :—

Sand, 4 ft., the surface rising a foot more in the chamber.

Laminated sandy clay, 6 ft., with many large blocks of limestone, and fragments of massive stalagmite, with stalactites 8 in. to 1 ft. in diameter.

Clayey sand, 4 ft.

There was no trace of gravel, nor could we see any indications of a natural outlet to the surface. The laminæ of the middle bed dipped to the N., showing that the cave continued in this direction.

General Summary of Results.

As this is the final report on the excavations, it will be convenient to give a general summary of the work done, and of the conclusions at which we have arrived.[1]

The excavation was commenced on December 23, 1896, and terminated May 6, 1899.

The following grants have been obtained towards the expenses :—

Royal Society Donation	£15.
Government Grant Fund, 1897	20.
,, ,, ,, 1898	30.
British Association, 1898	40.

In addition to these grants further sums have been obtained from private sources.

About 1,300 tons of material have been excavated, and as most of the exploration has been below the surface, the material was usually wound up in buckets and deposited at a higher level. All the original excavation of the caves has been done by the theological students of St. Beuno's College, although for a great part of the time one or two workmen have been employed to remove the *débris.*

The general direction of the cave fissures in this neighbourhood, including those of Ffynnon Beuno and Cae Gwyn, is N. and S. In the last two caves only have natural mouths been discovered, and they are consequently the only ones in which there are traces of occupation by animals and man.

In the longest portion excavated, the western cave, Ty Newydd, which

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[1] Papers frequently alluded to in this Report are: Dr. Hicks's reports on Ffynnon Beuno and Cae Gwyn caves, 1884, *Proc. Geol. Assoc.* 1; *Q.J.G.S.* 1886, p. 3, 1888, p. 56. Report on Ty Newydd caves by present writer, *Q.J.G.S.* 8198, p. 119. This last paper refers to other publications on Ffynnon Beuno and Cae Gwyn caves.

was explored for a distance of over 300 ft., no floor has been reached, although in some places 30 to 40 ft. vertical depth has been attained, and the total difference of level between the highest and lowest points is 74 ft. From the materials excavated we have obtained the following succession, commencing with the lowest deposit.

A. *Purely local gravel.*—Of the stones in this gravel Mr. Strahan writes: 'All have come from the immediate neighbourhood of Ty Newydd, and the proportion of silurian rocks suggests that the cave either leads to the silurian boundary underground, or was supplied by a stream running over these rocks and falling into a swallow-hole when it passed on to the limestone.' In this deposit we found our only two fossils, both waterworn fragments of molars, horse and rhinoceros sp., evidently introduced as pebbles with the gravel. These fossils show that the hills above the caves could at this time support large mammalia.

We could find no distinction between this material and the gravels from below the bone beds in Ffynnon Beuno and Cae Gwyn caves,[1] of which Dr. Hicks says:[2] 'The lowest deposits, consisting almost entirely of local materials, must have been introduced by a river' . . . He also writes in a recent letter: 'A critical examination, such as you have since made, did not seem at that time necessary, but the importance of the difference between this and the disturbed materials in the cave was at once recognised. We certainly had not discovered non-local stones, but it was thought better to qualify the expression until the gravel had been more thoroughly examined, especially as bits of quartz and sand grains may or may not have had a local origin. The pebbles examined were all from local sources.' In the western cave, Ty Newydd, this gravel had nearly filled the southern portions of the cave to the height of 450 ft. O.D.

B. On the floor formed by this gravel the bone beds of Ffynnon Beuno and Cae Gwyn were found. Although at the time of their discovery the majority of the fossils were no longer in their original positions, Dr. Hicks was able to show that a massive stalagmite floor had formed over them.[3] In one part of Ffynnon Beuno cave this floor was found intact, with the bones adhering to its lower surface.[4] A floor was also discovered in Ty Newydd cave, in contact with the earliest gravel, and presumably both were formed during the same period of rest.

C. *Stalagmite floor.*—In Ffynnon Beuno and Cae Gwyn this stalagmite attained a thickness of 10 inches to 12 inches, while in Ty Newydd we found a floor, *in situ*, extending for nearly 70 feet, and varying in thickness from 18 inches to over 3 feet. For the most part this floor was massive or with thin sandy partings. The northern portion, however, was in thin layers alternating with sand, showing that some of the latter was introduced at this epoch. We are unable to say whether the earlier matrix of the Ffynnon Beuno bone beds is to be ascribed to this or the next stage; probably both were represented before the disturbance of those caves.

D. Beyond the northern extremity of the floor in Ty Newydd we observed lines of stalagmite on the walls at the same level, showing that part of the floor had been broken up and carried to lower levels. We were able to trace the beds formed of the broken fragments mixed with

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[1] *Q.J.G.S.* 1898, p. 131.

[2] *Ibid.* 1886, p. 16.

[3] *Ibid.* pp. 12–14.

[4] *Proc. Geol. Assoc.* 1884, pp. 13, 14.

considerable quantities of sand and with the underlying local gravel. Whether the floor at Ffynnon Beuno was similarly broken through we cannot now tell, but the floods cannot have been very severe, as so small a portion of the Ty Newydd floor was taken away. Mr. A. Strahan detected some striated stones in the gravel belonging to this part of the series, thus indicating the presence of glacial conditions.

E. All these earlier beds in Ty Newydd were covered over by a thin bed of clay, which, although of no importance in itself, was of great use in providing us with a clear line of separation between the various formations. Above this clay bed, in the southern and middle portions of Ty Newydd, we found a deep deposit of limestone breccia in clay which reached nearly to the surface. In each place where this was present we also observed that the roof was wanting, and the abrupt termination of the cave walls implied that they formerly extended some feet higher before arching over. The removal of the roof must have been subsequent to the formation of the stalagmite, as it is absent over nearly the whole length of the floor.

The breccia was so compact that in several places it was difficult to distinguish it from rotten portions of the cave wall. Many of the blocks were over 2 cwt., and in no case was the appearance of the bed such as to imply a simple falling in of the roof, but it rather indicated that considerable force had been applied.

This powerful agent appears to have been identical with the force which disturbed the bone beds of Ffynnon Beuno and Cae Gwyn, breaking up the floor and redepositing the fragments with the fossils in a clay matrix.[1]

F. The succession hitherto discussed is chiefly founded on the deposits in the southern half of Ty Newydd western cave. The laminated sandy clay or clayey sand which followed was very poorly represented at the higher levels of this cave, but in the lower northern portion, in the eastern cave, and in the last excavation made under the old lead shaft this deposit was found in great abundance. Its true place in the succession is proved by the excavations at Cae Gwyn,[2] where it completely covers over the redeposited bone beds.

To this deposit we must add the sandy beds with marine shells discovered at the northern extremity of Cae Gwyn cave.[3]

G. Over all the deposits in the caves, and in several places in direct contact with them, there is spread over the valley a considerable thickness of boulder clay, containing the only local stones which have glacial striæ, and also having a large admixture of erratics.[4]

The above correlation, though only put forward as a suggestion, yet cannot be denied some probability, especially when it is remembered that only a few hundred feet separate all the excavations, and therefore the same agents must have been at work on each.

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[1] *Q.J.G.S.* 1886, p. 15.

[2] *Ibid.* 1888, p. 574, fig. 5.

[3] *Ibid.* p. 567. See also a paper in the same volume by Prof. T. M'Kenny Hughes, p. 119.

[4] *See Q.J.G.S.* 1898, p. 120. In the paper read before the British Association at Bristol, it was stated that the results of Mr. Strahan's examination show that about one half is local material, much of this being clearly striated. . . . Of the erratics the greater part consists of felsites, &c., whose source could not be determined, while the residue contains about equal proportions of felsites from the Snowdon area, and of granite from Cumberland or Scotland. With these are a few cretaceous flints, perhaps from the North of Ireland.

The scheme appended represents the order of events we have here sketched out in two parallel columns, the first representing some of the results obtained by Dr. Hicks at Ffynnon Beuno and Cae Gwyn; the second, the order of succession shown by our present exploration :—

<table>
<tr><th></th><th>Ffynnon Beuno, &c.</th><th>Ty Newydd, &c.</th></tr>
<tr><td>A.</td><td colspan="2">Local gravel, with a few waterworn fossils.</td></tr>
<tr><td>B.</td><td>Animals and man.</td><td>—</td></tr>
<tr><td>C.</td><td>Stalagmite floor over bones, which are in sand.</td><td>Stalagmite floor formed over gravel, some sand introduced.</td></tr>
<tr><td>D.</td><td>(?)</td><td>Floor broken through, redeposited with sand. Stones striated.</td></tr>
<tr><td>E.</td><td>Great disturbance, floor broken, fossil redeposited in clay.</td><td>Roof broken, blocks of limestone packed in clay.</td></tr>
<tr><td>F.</td><td colspan="2">Laminated clayey sand to sandy clay.</td></tr>
<tr><td>FA.</td><td>Sandy clay with marine shells.</td><td>—</td></tr>
<tr><td>G.</td><td colspan="2">Boulder clay, with Northern and Western erratics.</td></tr>
</table>

Canadian Pleistocene Flora and Fauna.—Report of the Committee, consisting of Sir J. W. DAWSON (*Chairman*), Professor D. P. PENHALLOW, Dr. AMI, Mr. G. W. LAMPLUGH, *and* Professor A. P. COLEMAN (*Secretary*), *reappointed to continue the investigation of the Canadian Pleistocene Flora and Fauna.*

IN last year's report of this Committee the results obtained from excavations in the Don Valley, Toronto, and from three wells or shafts sunk at or near the foot of Scarborough Heights, east of the city, were given in some detail. The Scarborough shafts were intended to determine whether the warm climate beds of the Don Valley underlie the cold climate beds of Scarborough, and whether the whole series is interglacial; and the results of the work done made it very probable that both questions should be answered in the affirmative. But the coming in of water from Lake Ontario put a stop to the work before solid rock (Hudson shale of the Cambro-Silurian) was reached, and so prevented the positive proofs desired.

As it was of great interest either to prove finally or to disprove the interglacial character of the great series of beds referred to, the sum of 30*l*. was granted at the Bristol meeting to carry the work farther, if possible to a conclusion. At the desire of the Chairman of the Committee, 5*l*. of the grant were devoted to the examination of Pleistocene beds of the Ottawa Valley, the work to be reported on by Dr. Ami. 25*l*. were therefore available for work near Toronto, and more than this amount has been expended in the sinking of shafts intended to settle the questions referred to above.

As last year's work had been rendered unsatisfactory through the incoming of water, it was decided to choose a new point for work near the river Don, where it was known that the Hudson shale rises above the river, so that good drainage might be looked for. It was also known that the Don beds are well shown in this region, since they are admirably exposed at Taylor's brickyard; but at the latter point the Scarborough clays, cold climate beds, are only doubtfully found to a thickness of from 8 to 13 feet. As characteristic Scarborough peaty clay had been traced at points some distance north of the brickyard, it was decided to begin a shaft at a point one-third of a mile to the north-east, where the conditions appeared favourable.

The place chosen is on the plain or terrace formed by ancient Lake Iroquois, with a deep ravine on each side, the one to the east cut by the Don, that to the west by a small tributary stream. The terrace rises 148 feet above the Don, which is here 12 feet above Lake Ontario as determined by aneroid, and Hudson shale crops out 30 feet above the river, leaving a thickness of 118 feet of 'drift' above it. Near the top of the steep slope above the Don an excavation made for obtaining potter's clay exposed about 40 feet of stratified bluish-grey clay, containing no peat or other fossils—probably of later age than the fossiliferous interglacial beds—making it unnecessary to commence the shaft at the top of the terrace.

The first shaft sunk on the slope towards the Don was unsuccessful, since at a depth of 17 feet water began to come in from a stratum of sand, putting an end to the work. The upper part of this shaft passed through grey clay, but the last 2 feet consisted of clay with boulders.

As another shaft started 100 yards to the south proved no better, it was decided to begin anew on the opposite side of the hill, an eighth of a mile to the west, on the slope towards the small tributary stream.

The third shaft was commenced 35 feet below the Iroquois terrace, and in the absence of the Secretary was taken in charge by Professor A. B. Willmott. He reports that sand was passed through for 32½ feet, followed by 2½ feet of gravel and a foot or two of clay, the whole depth being 38 feet. Here, however, water came in so rapidly that the work was stopped. No undoubted boulder clay was met with, though at 12 feet depth large Archæan boulders were found in the sand. Below this some layers of sand and gravel cemented with carbonate of lime occur, and in gravel beneath the cemented layers unios and pleuroceras were found, unfortunately too fragmentary to be determined.

Professor Willmott decided to sink another shaft lower down the hill, at a point apparently better drained, and this was successfully carried down 60½ feet, almost reaching the Hudson shale, the Secretary once more taking charge of the work.

The section disclosed 13 feet of sand and gravel like those of the previous shaft, but with no cemented layers and no shells; 30½ feet of stratified clay, with some wood, peaty layers, and hard thin sheets of greenish clay ironstone; 2½ feet of brown sand with some clay; 5 feet of bluish sand and clay; 6 inches of gravel with unios; 2 feet of brown sand and about 6½ feet of blue sand, and a little clay containing many shells. At this depth water put a stop to the work. By the side of the stream a few paces away a small scarp exposed the Hudson shale a foot or two below the bottom of the adjoining shaft, and resting on it was a sheet of typical boulder clay, from 6 to 18 inches thick, containing fragments of limestone and Archæan rocks, such as granite.

The section opened up by this shaft displayed characteristic Scarborough peaty clay overlying equally characteristic Don sands with unios, the lower boulder clay lying beneath the latter, but the upper boulder clay was not shown. To settle its position a fifth shaft was sunk just at the foot of the cutting for potter's clay near the Don, Professor Willmott again taking charge of the operations. He reports that the shaft, commencing 42 feet below the Iroquois terrace, goes through 13 feet of surface soil and stratified grey clay without fossils. At 15 feet boulder clay was met on the side towards the river, with numerous small angular pebbles of shale and an occasional one of syenite. At 16 feet stratified clay with some pebbles of shale replaced the boulder clay, going down 5 feet, when boulder clay again came in to the thickness of 2½ feet and of typical character, containing boulders of limestone and granite. Below this a little stratified clay was found, and then sand until the shaft was stopped at a depth of 27 feet.

An opening made on the hillside below showed about 6 feet of sand followed by 10 or 12 feet of gravel overlying stratified peaty clay. This shaft gives evidence that the upper boulder clay overlies the stratified sand and also the peaty clay as at Scarborough Heights, and so completes the proof that the cold climate beds and the underlying Don beds, with unios, leaves, and wood of a warm climate, lie between sheets of till, and are interglacial.

Summing up the work done, we have the following section near the tributary stream :—

	Feet.
Sand	11½
Sand with boulders	1
Sand with some cemented layers	20
Gravel with fragments of shells	2½
Peaty blue clay with sheets of clay ironstone	30½
Brown sand and clay	2½
Bluish sand and clay	5
Gravel with unios, &c.	½
Brown sand with shells	2
Blue sand and clay with unios, &c.	6½
Boulder clay	1
Hudson shale (Cambro-Silurian)	30
	113

The section near the Don, so far as worked out, is as follows :—

		Feet.
Stratified grey clay		57
Boulder clay		1
Stratified grey clay		5
Boulder clay		2½
Sand	about	6
Gravel		10 or 12
Don River to top of peaty clay	about	64
		147½

It is found that the top of the peaty clay is about 15 feet lower on the side of the hill towards the Don than on the western side near the tributary; but on both sides it is covered with interglacial sand and gravel as at Scarborough Heights, the latter point being unknown before the shafts here described had been sunk.

The thanks of the Committee are due to Professor A. B. Willmott for taking charge of the work during the absence of the Secretary, and to the Messrs. Taylor for their kindness in permitting the shafts to be sunk on their property.

A considerable amount of material, such as fossil leaves and wood obtained during the work and from Taylor's brickyard, has been forwarded to Professor Penhallow for identification, but time has been wanting for their determination. It is hoped, however, that this and other fresh material may be available for a final report next year, summing up the evidence as to the great series of interglacial beds commonly called the Toronto Formation.

Drift at Moel Tryfaen.—Report of the Committee, consisting of Dr. H. HICKS (*Chairman*), Mr. E. GREENLY (*Secretary*), Professor J. F. BLAKE, Professor P. KENDALL, Mr. G. W. LAMPLUGH, Mr. J. LOMAS, Mr. T. MELLARD READE, Mr. W. SHONE, *and* Mr. A. STRAHAN, *appointed to make Photographic and other Records of the Disappearing Drift Section at Moel Tryfaen.*[1] (*Drawn up by the Secretary.*)

Introduction.—In August, 1898, it became known that what is perhaps the clearest and most instructive section in the famous high-level drift deposits at Moel Tryfaen must in a short time be swept away in the course of the quarrying operations. There are two slate quarries on Moel Tryfaen, the 'Alexandra' and the 'Moel Tryfaen' quarries, excavated in the same line of strike of the slates. Gradually expanding, they had approached each other so nearly as to leave a narrow bank between them with no more than a yard or two of uncut turf upon it. Now the drift sections thus in danger of destruction are exceedingly important for the following reasons: 1. They are at right angles to the strike of the slates, and thus display the character of the underlying rock surface. 2. They show the nature and position of the junction of the shelly sands and gravels with the overlying boulder clay. 3. The false bedding and other structures in the sands

FIG. 1.—Map of part of Moel Tryfaen from Six-inch Ordnance Map.

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[1] Tryfan in New Ordnance Survey Maps.

and gravels are best seen along them. 4. They have been more accessible than the other sections in the quarries. A Committee was therefore appointed to preserve, by photography, supplemented by a written report, an impartial record of the phenomena displayed in these sections. The Committee have much pleasure in acknowledging their obligations to Mr. Menzies, the manager of the Alexandra Quarry, who, with a large-minded appreciation of scientific work for which geologists cannot be too grateful, offered to suspend operations in that part of the quarry for three months, besides showing the Committee every hospitality and facilitating their work by all means in his power.

Photographs.—Six whole-plate and five half-plate photographs were taken by Mr. John Wickens, F.R.P.S., photographer, of Bangor.

The views taken are :—

1. General view of section from W.N.W. end.
2. General view of section from E.S.E. end.
3. General view from W.N.W. of Moel Tryfaen Quarry, including neighbourhood.
4. Boulder clay by engine-house at E.S.E. end section.
5. Sands seen below boulder clay.
6. Junction, wedge of boulder clay in sand and gravel.
7. Base of sands and terminal curvature near W.S.W. end of section looking S.S.W.
8. Duplicate, showing a little more of slate.
9. Similar phenomena on N.E. side of quarry (third gallery) looking N.N.E.
10. Duplicate, a little nearer.
11. Rocks on summit of hill from N.W.

Description of Section.—The Chairman, Dr. Hicks, visited the section on September 26, 1898; and on November 5, 1898, Messrs. Kendall, Lamplugh, Lomas, Mellard Reade, Shone, and the Secretary examined it and recorded the facts embodied in this report. On July 1, 1899, the Secretary added items 1, 2, and 9.

As there has been serious difference of opinion as to the interpretation of the Moel Tryfaen phenomena, the Committee wish to emphasise the statement that this report is intended to be a record of observed facts only, without reference to any conclusions that may be drawn from these facts.

The observations are here arranged under thirteen heads. All the details were examined from the side of the Alexandra Quarry, which was the better and more accessible section of the two.

1. *Bearing and Distance of Section from Hill-top.*—About 800 ft. E.S.E. to the middle of the section.

2. *Length of Section.*—From 700 to 750 ft.

3. *Direction of Section.*—The sections are in curves concave to N.N.E. and S.S.W. in the 'Alexandra' and 'Moel Tryfaen' Quarries respectively, so that a tangent to both curves at their nearest point, about the middle of each section, is about W.N.W.–E.S.E.

4. *Height of Rock Surface.*—The floor of Gallery 'No. 1,' the highest in the Alexandra Quarry, is at 1,281 ft. above sea level. The surface of the rock emerges from below drift in the floor of this gallery a few yards

E.S.E. of the edge of the boulder clay, and rises gradually to W.N.W. The angle measured by Abney Level from opposite side of Alexandra Quarry is from 2°·5 to 6°·0 (average 4°·25) to E.S.E. (Photographs 1, 2, 3). But the surface undulates (Photographs 7, 8).

5. *Slope of Surface of Drift along Section* (Photograph 3).

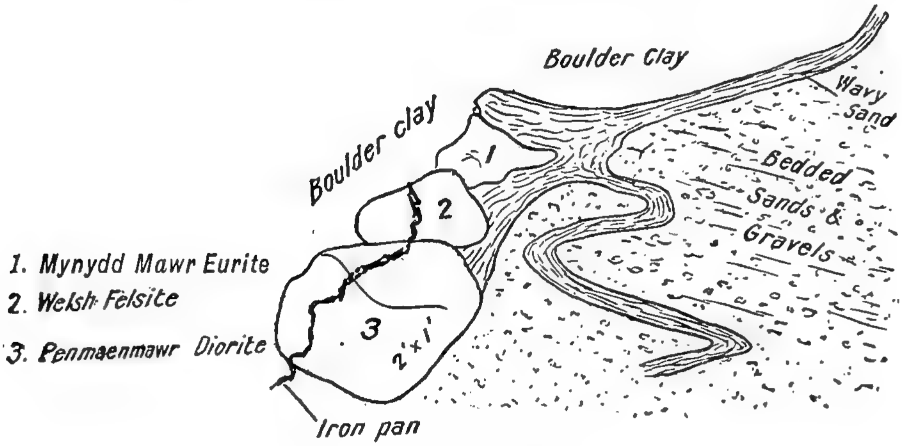
6. *Strike and Dip of Cleavage of Slates.*—N. 30 E., 95°–98° to S. of E. *Dip of Bedding of Slates.*—25°–30° S.S.E. or S., but undulating.

7. *Thickness of Drifts along Section.*—25 ft. maximum, thinning towards hill-top (Photographs 1, 2, 3, 4, 11). The sections which will remain at present will show the varying thicknesses in the quarries.

8. *General Nature of the Drifts.*—Their general characters have been often described. Towards the N.W. are sands, sandy loam, and gravel, with shells, boulder clay coming on above them towards the S.E. (Photographs 1, 2, 3).

9. *Position of Boundary of Sandy Group and Boulder Clay.*—The junction at the surface between the quarries is about 1,000 ft. from the hill-top.

FIG. 2.—Contortions in Sands below Boulder Clay.



Section at x (in fig. 3) on Elevation.

10. *Character of the Sandy Group.*—The beds may be described as sand and yellow loam with gravelly streaks and pockets containing shells. The shell fragments were found on November 5 only in the gravel, none but the finest crumbs having been seen in the sand and loam (α, p. 419). The bedding is very irregular, and even here and there curved (Photograph 1), but contortion has only been observed near the junction with the overlying boulder clay (β, p. 419).

11. *Characters of the Boulder Clay.*—This is a good, typical, tough, strong, unstratified till, such as is mostly found in mountain districts, dark grey in colour and full of stones (Photograph 4). The stones are for the most part of moderate size, but some up to 3½ and 3 ft. (the visible part) occur. They are subangular and well striated. There seems to be a general slight upward inclination of the longer axes of the stones to E.S.E. or E. The longer axis of the large boulder mentioned pointed W. 20 S.–E. 20 N., and its eastern end was a little lifted. Nearly all the stones observed were of N. Welsh origin, the riebeckite eurite of Mynydd Mawr being very abundant, but one pebble of a granite foreign to

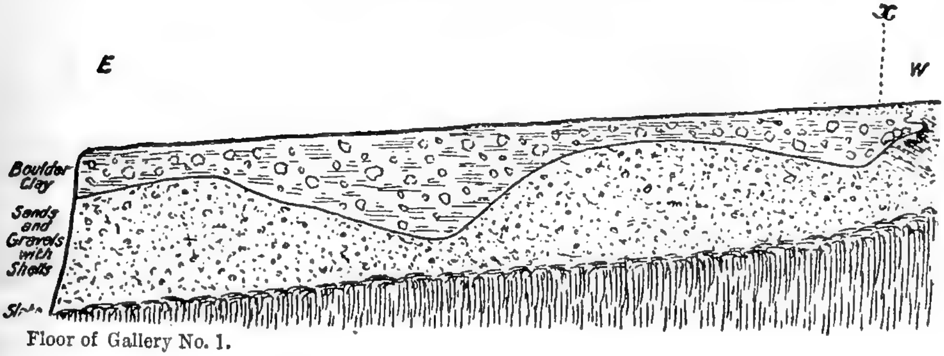
N. Wales was obtained on November 5 (γ, p. 419). Extensive sections will remain, in which all points not depending upon orientation can be observed.

12. *Nature of Junction of Sandy Group and Boulder Clay* (Photographs 5, 6).—In a general way the sandy group passes under the boulder clay to the E.S.E., as described by previous writers. The sandy beds in places dip W. at the junction, and are also contorted, a string of loamy sand two inches thick being bent into sharp folds (fig. 2). These contortions,[1] however, were not very clearly displayed on November 5 on account of slipping.

The boulder clay rests upon an uneven surface of the sandy beds, as shown in the annexed section (fig. 3), which was measured, and is drawn to scale.

The photograph No. 5 is taken close to the E.S.E. end of this section. The boulder clay is 'good typical stony till,' and the underlying beds the usual sand and yellow loam with gravelly streaks and pockets containing shell fragments. In the lowest layers are angular fragments of slate, below which is broken slate mixed with a small quantity of clayey matter resting on slate with terminal curvature.

FIG. 3.—Junction of Boulder Clay and Sandy Beds.



Scale 1 in. = 36 ft. Length of Section 144 ft. 6 in.

Evidence has been adduced by previous writers to show that the sandy group overlies as well as underlies the boulder clay, so that the two groups interdigitate. The section as seen on November 5 could not be said to be conclusive on this point; but it is shown in Photograph No. 6, of which fig. 4 is an explanatory diagram : (*a*) is very stony boulder clay, stones mainly of Welsh origin ; (*b*) yellow loam and sand bedded and contorted ; (*c*) bedded sand and gravel, 1 ft. to 2 ft.; (*d*) soil 6 in. The lower edge of the boulder clay dips downward into the exposed face rather steeply. BBB are boulders with angular ends projecting from the clay into the sand, the largest being apparently of Penmaenmawr diorite, and the other two of riebeckite eurite of Mynydd Mawr. There is no distinct evidence that the shelly sand and gravel anywhere overlie the boulder clay. A close examination showed a distinct line, probably of erosion, between that which passes above and that which passes beneath the boulder clay, in which last only were shell fragments found. The sand and gravel above the boulder clay may be altogether

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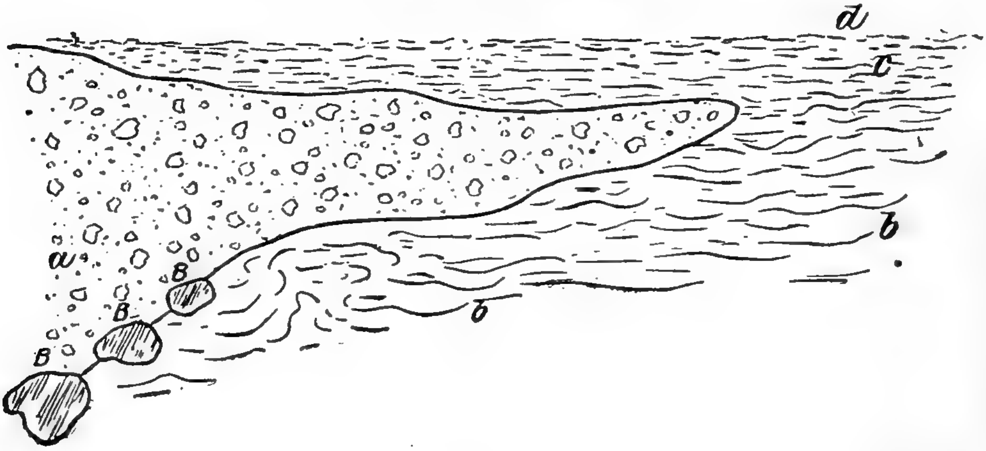
[1] Very well seen on September 26.—H. H.

newer than that in the lower part of the section containing the marine shells, and may possibly be merely hill-wash.

13. *Base of the Drifts and Nature of Underlying Rock Surface* (Photographs 7, 8).—The surface of the slate is seen in contact with the sandy group only, the boulder clay not reposing directly upon the rock in any part of the section. The surface of the slates is exceedingly shattered, the shattering affecting them to the depth of a foot or two. The shattered edges are, with (δ, p. 419) certain local exceptions, bent over in an E.S.E. direction, *i.e.* to the left of an observer looking along the strike of the cleavage to the S.S.W., the displaced laminæ retaining generally their original direction of strike. The displacement usually goes down to the first horizontal joint below the surface, and is a 'displacement' rather than a true curvature.

These terminally disturbed slates pass up into a band of slate breccia or rubble, composed of angular fragments (ε, p. 419). This forms a well-marked band all along the section, and is from 1 to 3 ft. thick. The fragments become smaller towards the top, and have at first a slight inclination upwards to the E.S.E., the upper layers, however, becoming horizontal. Where not obscured by slipping, the junction with the sandy drift above is usually well marked, but angular and subangular débris is mixed with the lowest layers of the gravel.

FIG. 4.—N.W. Termination of Boulder Clay in Section.



Conclusion.—The above description is not intended to be exhaustive, though the description of the section about to be destroyed has been made as full as seemed possible at the time. Incidentally certain details in other parts of the quarries were observed, and have therefore been included; but these form only a subsidiary and unessential portion of the report, and are therefore placed in a separate appendix (see Appendix C), because the sections in which they are displayed are in no danger of destruction. Generally, moreover, it will be observed that the report is confined to questions of structure, physical relations, and measurements; and that many matters of the highest importance, such as species, distribution, and state of preservation of the shells, the nature of the boulders in the sands and the clay, the character of the fine material of the drifts, are not dealt with. These are points which can be investigated as well as ever in extensive sections, which the quarrying will keep clear and open.

It must not be supposed that the Moel Tryfaen sections are being destroyed as a whole. It is the part specified only that is perishing; and the drifts of the quarries will continue to furnish ample scope for research into many matters of great importance to glacial geology for many years to come.

APPENDIX A.

Notes by Chairman and Members.

(α) §10.—Some of the best preserved specimens sent to me by Mr. Menzies from the drift in the Alexandra Quarry have adhering to them a fine loamy sand, and it is in such a material, interstratified with sand and gravels, that I have usually obtained the best specimens of shells in the Welsh sections. (H. H.)

(β) §10.—In addition to boulders of North Welsh rocks, they are full of far-travelled erratics from the Lake District and the South of Scotland.

(γ) §11.—This deposit, therefore, differs widely in regard to its included stones from the underlying sandy group, which contains many far-travelled erratics, as before stated; as it does also in the apparent absence of marine shells and of Foraminifera.

(δ) §13.—P. F. Kendall and J. Lomas would prefer to say that the general direction of displacement had only a few individual exceptions, which might indeed be due to quarrying operations.

(ε) §13.—This material was not observed by the Committee to contain any glacially striated fragments or any foreign stones—no fragments, indeed, but of the underlying slates.

APPENDIX B.

By T. MELLARD READE, *F.G.S.*

Specimens of the drift were taken by me at the meeting on November 5, 1898, in the positions shown on the following sections (figs. 5 and 6), and submitted to Mr. Joseph Wright, F.G.S., of Belfast.

He very kindly examined them for Foraminifera, and in all discovered twenty-three species. The results seem to show that the Foraminifera occur in the most abundance in the shelly sand. None were found in the overlying boulder clay (Specimen 4), and a few only in Specimens Nos. 1 and 2. In No. 3 the Foraminifera were more plentiful and of species common to the low-level boulder clay of Lancashire, Cheshire, and the Vale of Clwyd. As usual, *Nonionina depressula* was common, and far outnumbered the other species.

The high-level drift generally does not appear to have been searched much for Foraminifera. The only other published list from Moel Tryfaen that I can find is that given by Miss Mary K. Andrews.[1]

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[1] *Annual Report, Belfast Naturalists' Field Club*, 1894–95, pp. 209, 210.

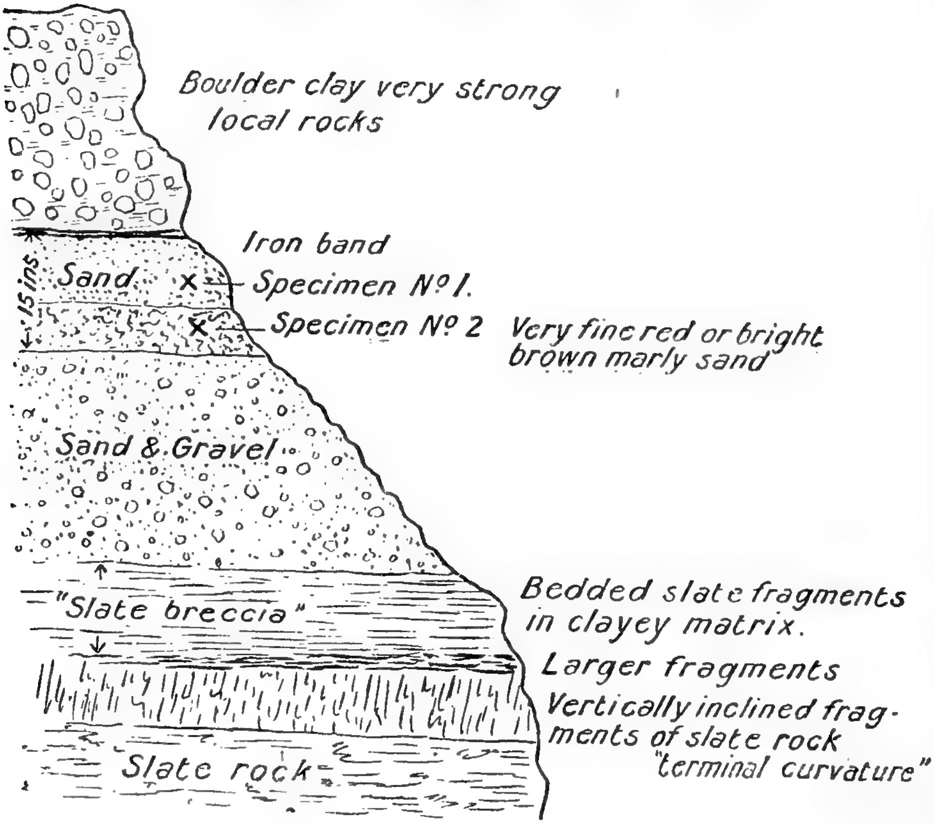
This list was also the result of Mr. Wright's examination of specimens collected by Miss Andrews. In all twelve species are enumerated, those common to this list being marked with an asterisk, and being eight in number.

Mr. WRIGHT'S LIST. *Foraminifera of Pleistocene Beds of Moel Tryfaen.*

No. 1. Weight of sand, 1 lb. 1·7 oz. troy. After washing, fine 10·8 oz.; coarse 1·5 oz. In this sample, as well as in all the others which I examined, the greater portion of the stones were more or less rounded, the others being angular.

Lagena semistriata (Will.), very rare.
*Nonionina depressula (W. and J.), very rare.

FIG. 5.—Section showing position of Foraminiferal beds.



No. 2. Weight of sand, 1 lb. 2·7 oz. troy. After washing, fine 7·3 oz.; coarse 2·2 oz. Very fine bright brown sand.

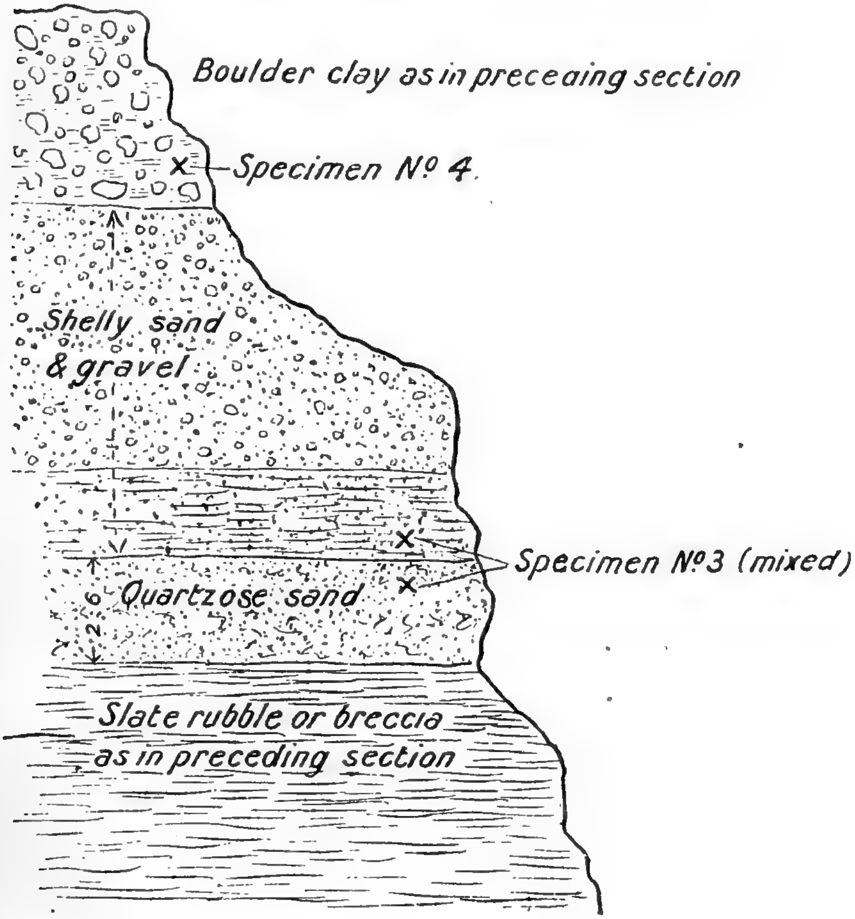
Lagena lineata (Will.), very rare.

No. 3. Weight of sand, 2 lb. 3·5 oz. troy. After washing, fine 1 lb. 8·2 oz.; coarse 5·4 oz. Fragments of shells.

Miliolina seminulum (Linn.), rare.
Bulimina pupoides (d'Orb.), very rare.
Bolivina punctata (d'Orb.), frequent.
*Bolivina plicata (d'Orb.), common.
*Cassidulina crassa (d'Orb.), common.
Lagena sulcata (W. and J.), very rare.
Lagena Williamsoni (Alcock), very rare.
Lagena semilineata (Wright), very rare.
*Lagena squamosa (Montg.), very rare.

Lagena marginata (W. and B.), rare.
Lagena quadrata (Will.), very rare.
Lagena clathrata (Br.), very rare.
Lagena Orbignyana (Seg.), very rare.
Lagena quadricostulata (Rss.), rare.
Uvigerina angulosa (Will.), very rare.
Globigerina bulloides (d'Orb.), very common.
Orbulina universa (d'Orb.), frequent, very small.
*Discorbina rosacea (d'Orb.), very rare.

FIG. 6.—Section showing position of Foraminiferal beds.



Discorbina Wrightii (Br.), common.
*Pulvinulina Karsteni (Rss.), rare.
*Nonionina depressula (W. and J.), most abundant.
*Polystomella striato-punctata (F. and M.), very rare.

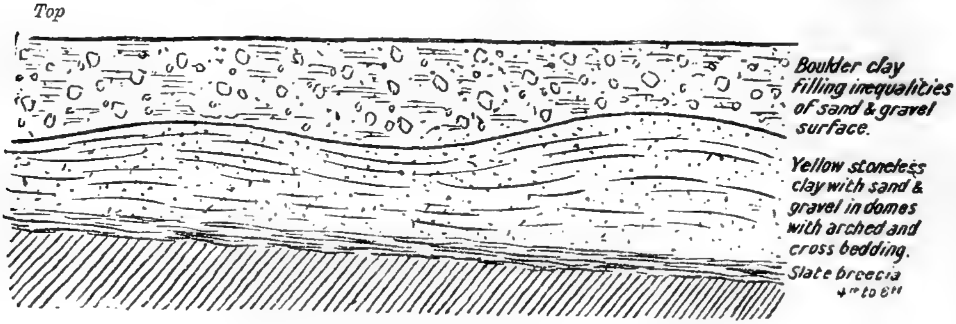
203 specimens of Nonionina depressula were obtained from this gathering, whilst the other twenty-one species numbered only 102.

No. 4. Weight of sand, 2 lb. 6·7 oz. troy. After washing, fine 6·6 oz.; coarse 1·3 oz. Sand very dirty, and having a large proportion of stones in it.

No Foraminifera.

APPENDIX C.

FIG. 7.—Diagram at N.E. side of Alexandra Quarry, showing dome-like arrangement of sand and gravel beneath Boulder Clay.



Length 50 to 60 yards. Height about 60 feet.

NOTE.—Much of the middle series consists of fine plastic reddish-yellow clay or silt without stones, the kind of material common in the stratified drifts of the Isle of Man. Shell fragments rather plentiful in the gravelly streaks, but none seen in the clay or sand.

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Pedigree Stock Records.—Report of the Committee, consisting of FRANCIS GALTON, *D.C.L., F.R.S. (Chairman),* Professor E. B. POULTON, *F.R.S., and* Professor W. F. R. WELDON, *F.R.S. (Secretary), appointed to promote the Systematic Collection of Photographic and other Records of Pedigree Stock. (Drawn up by the Chairman.)*

INQUIRIES made on behalf of the Committee have fully justified the belief that led to its appointment, namely, that few exact records exist of even the nearer ancestry of the members of any description of Pedigree Stock. The *names* of all their ancestry for many past generations are published in Stud-books, Herd-books, and other similar works, but in other respects those works afford scant means for obtaining that distinct presentment of each of the nearer ancestry which is needed for an exact study of the Art of Breeding. The information as to feature and form in the books mentioned above is almost wholly confined to colour, and, in the case of horses only, to height at the withers. Many details relating to appearance and action are, however, scattered over the pages of various volumes and periodicals, but these would require an excessive amount of labour in research before any complete families could be properly worked through for even three generations. As regards photographs, those of the more celebrated animals are now published in one form or another; nevertheless, it has been found very difficult to obtain the photographs of even a few of those genealogical *triads*, consisting of an adult subject, its sire, and its dam, which form the primary molecules of every pedigree. The authorities who were consulted on thoroughbred horses and on purely bred shorthorn cattle, were hardly able to indicate a single case in which photographs exist of all the seven individuals—the adult subject, its two parents, and its four grandparents—which form the secondary molecules of a pedigree. Thus the admirable opportunities enjoyed by breeders for making systematic records that would afford a solid basis for the advancement of the art of breeding, have been hitherto most inadequately utilised. The reason is not far to seek. Heredity is a comparatively new science, and few persons are as yet acquainted with the character of the records most suitable for its study, or are sufficiently impressed with the need for their exactness and persistence. The most important of those records which it seems feasible to obtain are photographs, not merely pretty and well worked-up productions satisfactory to an artistic eye, but rather such as are analogous to the portraits made of criminals, for storage at the central police office, to serve as future means of identification. The desired photographs need to be taken under such conditions as shall ensure their being comparable under equal terms, and shall admit of the accurate translation of measurements made upon them into corresponding measurements made on the animals themselves. There are a variety of ways by which the latter process may be performed, but it was only after many trials that a method was found capable of being used with extreme facility. It will be described later on; in the mean time, its existence may be taken for granted. The problem was thenceforward reduced to that of devising a self-working system by which the more important pedigree animals, say the prize-winners at great Shows, should be habitually photographed under standard conditions. Before this could be done certain doubtful questions had to be solved by an adequate experiment.

(1) Is it possible to make satisfactory photographs under standard conditions amid the hurry and under the necessary restrictions of a great Show? (2) If so, could they be made at a reasonable cost? (3) Is there any likelihood of such a system being self-supporting?

The desired experiment was permitted to be made, in response to a request of the Committee, by the Royal Commissioners on Horse-breeding at their Show held last March at the Royal Agricultural Hall. On this occasion 29 premium stallions were selected for service throughout England during the current season, who will become the sires of some 800 foals within the present twelvemonth. The Committee desire to express their grateful thanks to the Royal Commissioners for the assistance thus cordially given to them. The results were most satisfactory; they will be found in an Appendix to the Blue Book (C.—9487. *Price* $2\frac{1}{2}$*d.*) just issued by the Royal Commission. Reference should be made to this by those persons who desire fuller information than is given in this Report. Twenty-eight out of the 29 premium horses were photographed at the average rate of six minutes to each horse. Considered merely as portraits, they were very satisfactory, and they were of a size that gave, roughly, 2 inches or 50 millimetres for the height at the withers, being a little less than 1 millimetre to 1 inch of real height. Measurements made on them gave results that, in three-quarters of the cases, did not differ more than $\frac{3}{4}$ inch from those made by two veterinaries on the animals themselves. In the remaining quarter of the cases in which the differences ranged up to a single instance of $2\frac{1}{2}$ inches, it seemed from internal evidences and other considerations that the photographic method was the more trustworthy of the two. The experiment further showed that the cost of photography did not exceed what might be wholly or in part recouped by the sale of prints, and there was reason to believe that a highly skilled photographer might consent to take the photographs under standard conditions, at his sole charge, if he were permitted to sell authorised copies to newspapers and to private persons under such reasonable restrictions as might be thought proper by the authorities.

Should this hope be hereafter realised, it seems difficult to imagine that any serious difficulty would stand in the way of causing the photography of prize-winners to become a permanent feature in the larger Shows of Pedigree Stock. Of course, the uncertainties of weather have to be reckoned with, and the Shows held during the darker period of the year, in the smoky atmosphere of large towns, should be left out of consideration, unless artificial light could be used. But the more valuable animals are usually exhibited more than once, so that an occasional photographic mishap might be subsequently remedied.

Details relating to what has been said will now be given; they will be found stated at greater length in the Appendix to the Blue Book mentioned above.

Standard Conditions.—The arrangements now suggested are slight improvements on those under which the experiment was conducted. A wall, or solid vertical screen, is required for a background, and a hard and level pathway of 6 feet in width running alongside the wall for the horse to stand on. Two lines are to be made across the pathway at 2 feet apart, between which the fore-feet of the horse must stand while he is being photographed, his body being at the same time as nearly in the line of the pathway as possible, both of his hind feet being, at all events, upon it. The pathway should be rather light in colour, to show the feet clearly; it may be of flag-stones, concrete, or light-coloured bricks. Its curb, or edge, towards the camera must be sharp and clearly visible, because it is an important line of reference in the photograph. The wall should be painted of a light colour—bluish, not yellow. Fifteen small marks, each the size of a sixpence, arranged in three horizontal and five vertical rows, at the exact distance of 3 feet apart, should be made upon the wall, to give a scale to the photograph. They are indicated in fig. 1 by small crosses. The lowermost row should be well clear of the pathway, say 1 foot above its level. Some of these marks will be sure to be visible in the photograph, though most of them will be hidden by the body of the horse. Simple screens or hangings should shield the horse from distracting sights. An aperture in a screen will enable a person who is stationed for the purpose on the other side of it to momentarily arrest the attention of the animal when the photograph is about to be taken. The camera is to be firmly clamped to a solid stand opposite to where the horse is to be placed, and to remain undisturbed during the whole operation. Its object-glass is to be 5 feet above the ground, that the view from it of the pathway may not be too much foreshortened, and it is to be 30 feet from the wall. The equivalent focus of the lens should not be less than 9 inches, otherwise the photograph will be too small for convenient measurement; the lens used in the experiment was of 13 inches focus, with plates of $6\frac{1}{2} \times 4\frac{3}{4}$ inches, and proved exactly suitable. The most important point of all is that the plate-holder of the camera should be *strictly* parallel to the wall, as tested by the images of the marks on the wall forming squares of exactly equal sizes on its ground-glass focussing screen. As many of them as are visible in the photograph will, of course, do the same. A label should be fixed to the wall, well above the back of the horse, but within the field of the camera, on which the permanent data of the instalment should appear in bold letters, easily legible in the photograph. Lastly, the horse should wear a distinguishing number for after-identification. The photograph will thus bear internal evidence of the standard conditions having been observed, and will carry its own scale. An experiment succeeded perfectly of indicating the position of the prominence at the hip, which is easily to be felt but is not distinctly seen, by labelling it with a wafer of thin white paper the size of a shilling; *thick* paste which penetrated between the hairs was needed to make the wafer adhere. The mark was, however, unnecessarily large and conspicuous; one of the size of a sixpence would have been ample. It might, perhaps, be printed on the horse with water-colour. The question whether any, or what, points of anatomical interest might be treated advantageously in this way has not yet been fully considered.

Calculation from measurements on the Photograph.—Fig. 1 represents, on a scale of about one-third the actual size, the appearance of one of the photographs and of the measurements made upon it. SS is the line of junction between the pathway and the wall; the little crosses indicate the positions of the marks already described; qq is the curb, or edge, of the pathway opposite to the camera; p is any desired point on the ridge of the back of the horse, whose height above the ground it is desired to find. A measurement is made of the line that falls perpendicularly from p to qq; also of that from h to qq, h being the point where the perpendicular from p cuts a line so drawn on the pathway as to touch the sides of the shoes of the fore and of the hind foot that are nearest to the camera, and which may be called the *hoof line.* [Practically, the simplest way is to measure the heights of those two feet above *qq* and to roughly interpolate.] Measurements are also made between such marks on the wall as are visible, to furnish the scale of reduction at the distance of the wall from the camera. Fig. 2 represents a section of the installation on the same vertical scale as fig. 1, but the horizontal scale is much smaller and its internal proportions are not preserved, the primary object being to make a clear diagram. C is the object glass, D the point on the ground below it, *q* is the section of *qq*, here seen sideways, *h* is the projection of H upon the wall. Consequently C D=in reality 5 feet, D S=30 feet, S Q=5 feet, but the proportions are different in fig. 2 for the reasons just given. A line from C through Q determines the position of *q*, and *qh* being known by measurement, the position of *h* on the wall is known; then a line from C to *h* cuts the pathway at H, which gives the true position of the point where the vertical plane passing through C and *p* cuts the 'hoof line' on the pathway. Now M, the point on the pathway on which the vertical from P falls, lies in the same vertical plane as H, but a little further off from the camera, say 6 inches. This is a near enough estimate, as one or two inches of error here have no sensible influence on the result. So the position of H establishes that of M, and a line drawn from C through M determines that of *m* upon the wall as it would be seen in fig. 2, and consequently on the photograph as seen in fig. 1. *m* is not shown in the figure, as there is hardly room for it, and as it is not wanted in the simple way of working, which will immediately be explained. The height *pm*, as enlarged on the wall, has then to be reduced in the ratio of D M to D S, in order to obtain P M. The whole of this calculation is effected with the utmost ease by drawing the installation in its true proportions to a scale of $\frac{1}{10}$th, using paper ruled into squares of $\frac{1}{10}$th of an inch in the side, and converting the measurements made on the photographs into their corresponding values as projections upon the wall, reckoned in inches. The position of *q* is determined once for all on the paper by drawing a line from C through Q. A pin is inserted at C, and a loop made at one end of a thread is thrown over it. Q serves as the zero point both horizontally and vertically for all the working part of the diagram up to the line that represents the wall. But the zero point for this line is *q*. Then, the thread stretched through *h* determines H. M is marked off at six divisions further on. The thread is now stretched through *p*, and the value of M P is read off at once. It is unnecessary here to enter more particularly into details. All other measurements in the plane of the

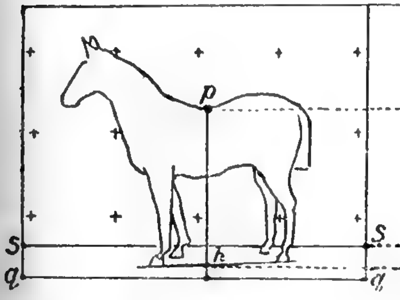


FIG. 1. Photograph. Its scale is about $\frac{2}{5}$ of that actually used.

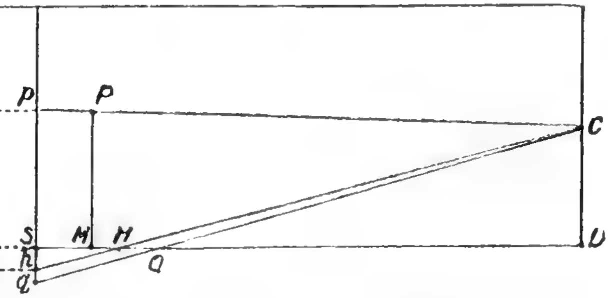


FIG. 2. Section of installation on the same vertical scale as fig. 1. The horizontal scale is much smaller.

photographic picture can be reduced to the corresponding real values in the same general manner. These are the diameters of the body and of the limbs, the length of the body, and the distances between any points of reference that may have been marked in the way described above, as seen in projection against the medium plane of the body.

Verification of the Results.—Numerous experiments have been made to test the exactitude of this photographic method of measuring living animals. The results of those made at the Show of the Royal Commission on Horse-breeding are given in the Appendix to the Blue Book. They are summarised as follows:—Two advanced veterinary students were deputed from the Royal Veterinary College to assist one another in measuring the animals that were photographed, for the purpose of controlling the photographic calculations. Each horse had its height above the ground measured at the withers, at the hollow of the back, and at the croup. Comparisons happened to be available in only twenty-six out of the twenty-nine premium horses, one of the latter having not been photographed, and two out of the remaining twenty-eight having been overlooked by the measurers. The comparison came out as follows:—

Sums of the Differences between Calculated and Observed Values.

No. of Cases	Heights at	Inches		
		—	+	Totals
26	Withers . .	7¼	13½	20¾
26	Back . . .	15	8¼	23¼
26	Croup . .	8	12¼	20¼
78	Totals . .	30¼	34	64¼

The approximate equality between the totals of the — and + differences, which are 30¼ and 34 respectively, testifies to the *average* correctness of the method and of the work. That between the summed results for the withers, back, and croup respectively, which are 20¾, 23¼, and 20¼, shows that each of these has been determined with about the same *degree* of correctness. It is therefore justifiable to treat all the 78 events on equal terms, in order to ascertain what that degree really is. This is done in the following table:—

Distribution of the Seventy-eight Differences without regard to their — or + signs.

Inches of Difference to nearest ¼ inch	No. of Cases	Sums from beginning	
		Totals	Per cents.
0	10	10	13
¼	11	21	27
½	20	41	52
¾	9	50	64
1	8	58	74
1¼	4	62	79
1½	5	67	86
1¾	4	71	91
2	6	77	99
2¼	1	78	100

It thus appears that in 52 per cent., or in one-half of the cases, the differences, when reckoned to the nearest $\frac{1}{4}$ inch, do not exceed $\frac{1}{2}$ inch, and that in 74 per cent., or in three-quarters of the cases, the differences do not exceed $\frac{3}{4}$ inch. In the remaining quarter of the cases the differences ranged upwards to a solitary instance of $2\frac{1}{4}$ inches. This summary does not, however, include one case where the veterinaries who entered their measures in 'hands' of 4 inches each, with the extra inches and fractions, obviously wrote down the wrong number of *hands*, 14 for 15. The entry assigned to the animal indicated an exceptionally hollow back, which the photograph showed not to be the case. So the erroneous entry of 'hands' was corrected, and then observation and calculation agreed. Considering the difficulty of measuring a restive, and often vicious, thoroughbred horse, whom it is somewhat dangerous to tickle with measuring apparatus, also that each animal was only measured once, while the photographs were measured at least twice, and again that one blunder of entry was detected as above, it seems reasonable to ascribe the larger differences of from 1 inch to $2\frac{1}{4}$ inches mainly to faults connected with measurement of the animals, and not to those connected with the photographs. An error in the latter of one millimetre, which corresponds to about $1\frac{1}{4}$ inch of actual height, is barely credible. This conclusion is confirmed by the more equable run of the statistical curve of photographic measures. It is further confirmed by some experiments made two years ago on behalf of the Chairman of the present Committee, on the degree of consistency between the measurements made (1) by the same veterinary student of the same horses on different occasions, and (2) between the means of the results of the several students. A discussion of these results showed that the probable error of a single measurement was considerable, and therefore that large errors might occasionally occur. Direct measures of the length of the body of a horse are considered by experts to be very untrustworthy, but the photographic method gives them with precision and simplicity. Owing to the roundness of the chest and buttocks, no correction seems necessary for the foreshortening of an animal that stands slightly askew.

Not a few inquiries and experiments have been made in relation to purely bred shorthorn cattle. Thirty-one *triads*, each consisting of one adult subject, its sire, and its dam—the 'subjects' being the offspring of 7 bulls and 26 cows—have been photographed for the Committee by Mr. John Patten, jun., under *quasi* standard conditions. The cattle were, for the most part, of the herd of the Duke of Northumberland, at Alnwick Park. The larger portion of the photographs were received too late to be properly dealt with in this Report. They seem to afford very valuable material for study.

Index Animalium.—Report of a Committee, consisting of Dr. H. Woodward (*Chairman*), Mr. P. L. Sclater, Rev. T. R. R. Stebbing, Mr. R. McLachlan, Mr. W. E. Hoyle, *and* Mr. F. A. Bather (*Secretary*), *appointed to superintend the Compilation of an Index Animalium.*

The examination of the literature published from 1758 to 1800 inclusive has been continued by Mr. C. Davies Sherborn, to whom facilities have, as heretofore, been granted by the authorities at the British Museum

(Natural History). Between July 1898 and June 1899 he has seen and indexed 1,528 volumes and tracts, and has now reduced the list of desiderata to about 500 items. Of these scarcely 100 are likely to be of any importance to the systematic zoologist; but every effort will be made to consult them, so as to be certain that everything has been recorded.

The Committee desires to express its grateful thanks for the loan of rare and valuable books, and for information concerning them, to the following:—The Hof-naturalien Kabinet of Vienna, Dr. Eduard Suess, and Dr. Steindachner; Dr. F. A. Jentink, of Leyden; Akademiker F. Schmidt, of St. Petersburg; the Stadt-Bibliothek of Zürich, Dr. Eschner, and Professor Renevier; the Hon. Walter Rothschild and Mr. Hartert; Sir Edmund Loder; Mr. Du Cane Godman and the late Mr. O. Salvin; Lord Walsingham and Mr. J. H. Durrant; Professor Amalitzky, of Warsaw; Professor Anton Fritsch and Dr. Jan Perner, of Prague; Professor Alfred Newton; Mr. W. E. de Winton; Mr. Gerrit S. Miller, of Washington; Mr. A. C. Seward, of Cambridge; and Professor H. A. Miers, of Oxford. Dr. Philippe Dautzenberg, of Paris, has also greatly aided the compiler in his efforts to obtain the loan of a rare catalogue. The editors of 'Nature' and 'La Feuille des jeunes Naturalistes' have lent valuable aid in publishing lists of desiderata. Of the generosity of the Vienna Kabinet, the Zürich Library, and Dr. Jentink, all of whom have sent over their treasures for inspection, the Committee cannot speak too highly.

Again the special and hearty thanks of the Committee are due to the Zoological Society of London for pecuniary assistance, which will, as in the past, greatly facilitate the work of procuring access to this rare literature.

The reference slips themselves are now in alphabetical order, and the work of checking previous reference books and of eliminating duplicate entries will be proceeded with as quickly as possible.

The following reports on dates of publication of various books have been published by Mr. Sherborn during the year:—

De Blainville, Ostéographie, 'Annals and Mag. Nat. Hist.' (7) ii., 1898.

Hübner, Samml. europäischer Schmetterlingen, 'Annals and Mag. Nat. Hist.' (7) ii., 1898.

C. d'Orbigny, Dictionnaire Universel, 'Annals and Mag. Nat. Hist.' (7) iii., April 1899.

Humboldt and Bonpland, Obs. de Zoologie, 'Annals and Mag. Nat. Hist.' (7) iii., 1899.

Lichtenstein, Catalogus rerum naturalium, 'Annals and Mag. Nat. Hist.' (7) iii., 1899.

The dates of the Paléontologie Française, 'Geol. Mag.,' 1899, pp. 223–225.

Temminck and Laugier, Planches coloriées, 'Ibis,' Oct. 1898.

It may also be mentioned that Mr. Sherborn has prepared an 'Index to the generic and trivial names of animals described by Linnæus in the 10th and 12th editions of the *Systema Naturæ*,' and the thanks of zoologists are due to the Manchester Museum, Owens College, for issuing this through Messrs. Dulau & Co., London, as its 'Publication 25.'

In the full belief that the first section of the Index (1758–1800) will soon be ready for publication as a tangible result of the compiler's labours, the Committee earnestly recommends its reappointment, with a grant of £100.

A Circulatory Apparatus for keeping Aquatic Organisms under definite Physical Conditions.—Interim Report of the Committee, consisting of Mr. W. E. HOYLE (*Chairman*), Professor S. J. HICKSON, Mr. F. W. KEEBLE, *and* Mr. F. W. GAMBLE (*Secretary*).

THE apparatus has been constructed, and Messrs. Keeble and Gamble have used it for making an investigation on the colour-physiology of *Hippolyte varians.* It is intended to submit a full account of these researches at the Bradford meeting next year.

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Professor W. A. HERDMAN (*Chairman*), Professor E. RAY LANKESTER, Professor W. F. R. WELDON, Professor S. J. HICKSON, Mr. A. SEDGWICK, Professor W. C. MCINTOSH, *and* Professor G. B. HOWES (*Secretary*).

THE table in the Naples Zoological Station hired by the British Association has been granted during the past year to Dr. H. Lyster Jameson, of Trinity College, Dublin, the Royal College of Science, London, and the University of Heidelberg, who occupied it from October 7, 1898, to April 17, 1899. He specially investigated the anatomy of certain Gephyrea and allied vermiform organisms, and has published a paper upon the leading species obtained, in the Naples 'Mittheilungen.' Other papers are in hand and ready for the printer, as set forth in his accompanying report.

Prior to Dr. Jameson's tenure of the table it was occupied but for a couple of weeks by Mr. Eliot, Secretary to the English Embassy in Constantinople. Mr. Eliot commenced work upon the Mollusca, with a view to certain economic considerations, but did not carry his enquiry far enough to justify the presentation of a report.

Your Committee have been informed by the resident officials at the Naples Zoological Station that the numbers of investigators who yearly make use of the institution are steadily on the increase, and that the material sent out during the year to workers and centres of instruction and research in all parts of the world has been greater than on any previous occasion. They would direct attention to this proof of the increasing utility of the Naples station, and to the thoroughly international character of the accompanying list of workers. In respect to the latter feature the Naples station stands alone among marine observatories, now numerous, and your Committee are of opinion that the advantages associated with the conference of distinguished workers of all nationalities, taken in conjunction with the richness of the Neapolitan fauna, present to the individual table-holder a combination not to be obtained elsewhere, which they regard as sufficient to justify the continued support of the British Association.

They therefore trust that the General Committee will sanction the payment of a grant of 100*l.*, as in previous years.

Applications have been received for the coming year from Mr. H. M. Kyle, M.A., B.Sc., who proposes to investigate the Anatomy of the Pleuronectidæ, and from Professor W. A. Herdman, F.R.S., to study the Compound Ascidians of the Bay of Naples.

APPENDIX.

I. *Report on the Occupation of the Table on Gephyrea and Allied Worms.*

By H. LYSTER JAMESON, *B.A.*, *Ph.D.*

During the period for which I had the privilege of occupying the Association's tables at Naples I confined my studies mainly to the Gephyrea and other worms.

I investigated and described in the Naples 'Mittheilungen' an example of the worm described by Della Chiaja as *Holothuridium papillosum.* Only three examples of this worm have been discovered, all of them in the Gulf of Naples.

In none of these examples was the proboscis preserved, so we have no idea of the form of this organ.

The only extant example had been in spirit for some years, and was kindly placed at my disposal by the authorities of the station. I found this worm to be an echiuroid Gephyrean, referable to the genus *Thalassema*, in which genus it occupies a position not far from *T. diaphenes*, described by Sluiter from Batavia. These two species agree in their continuous longitudinal musculature, simple anal vesicles, and single pair of nephridia. *Thalassema papillosum* may, however, be distinguished by its larger size and thicker body wall, as well as by its more highly papillated body. Fortunately a sketch of the living animal by Signor Merculiano, taken from an example which was subsequently lost, enables us to realise the natural colour of this worm. I have had this sketch reproduced in my paper.

I made some researches upon the sipunculoid Gephyrea, having had several collections placed in my hands for identification.

The rich supply of living Sipunculoids, placed at my disposal by Dr. Lo Bianco, was of great service to me in this work.

The results of these investigations are now ready for press.

I am at present describing a new giant, *Aspidosiphon*, sent to me at Naples, from Jamaica, by Mr. J. E. Duerden. I believe *Phascolosoma* (*Syrinx*) *granulosum*, of McCoy, will prove to be nothing more than a large variety of *Phymosoma granulatum.* I have been unable to find any difference between examples of the former from the west coast of Ireland, and of the latter from Naples, except in size.

Other subjects which I investigated, but have not yet sufficiently studied to warrant publication, are some questions relating to the peri-intestinal sinus in some worms, and alterations in the musculature of the intestinal wall which seem to bear a relation to the sinus.

In conclusion I must offer my hearty thanks to the Committee for permitting me to occupy their table, and to the authorities of the station for the excellent opportunities and encouragement they gave me.

II. *A List of Naturalists who have worked at the Zoological Station from July* 1898 *to the end of June* 1899.

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
1044	Dr. F. Capobianco	Italy	July 1, 1898	July 1, 1899
1045	Prof. F. S. Monticelli	„	„ 6, „	Nov. 8, 1898
1046	Mr. B. Schröder	Prussia	„ 18, „	Aug. 7, „
1047	Dr. A. Romano	Italy	Aug. 1, „	—
1048	Dr. V. Diamare	„	„ 1, „	—
1049	Dr. A. Russo	„	„ 1, „ Nov. 1, „	Sept. 30, „ Jan. 7, 1899
1050	Dr. F. Mazza	„	Aug. 4, „	Sept. 3, 1898
1051	Dr. P. Fuhrmann	Switzerland	„ 15, „	Oct. 6, „
1052	Dr. E. Hentschel	Bavaria	„ 20, „	„ 8, „
1053	Dr. S. Accorimboni	Italy	„ 18, „	Sept. 4, „
1054	Dr. G. Riccioli	„	„ 21, „	Oct. 7, „
1055	Miss Fl. Peebles	American Women's Table	Sept. 2, „	Nov. 19, „
1056	Prof. F. Röhmann	Prussia	„ 3, „	Oct. 15, „
1057	Mr. C. N. E. Eliot	British Association	„ 4, „	Sept. 17, „
1058	Prof. A. Coggi	Italy	„ 5, „	Nov. 2, „
1059	Prof. F. Apathy	Hungary	„ 5, „	Sept. 27, „
1060	Dr. R. Krause	Prussia	„ 5, „	Oct. 5, „
1061	Dr. S. Garten	Saxony	„ 12, „	Dec. 12, „
1062	Prof. Czokor	Austria	Aug. 30, „	Oct. 13, „
1063	Dr. H. C. Corning	Switzerland	Sept. 16, „	„ 7, „
1064	Dr. M. Bedot	„	„ 17, „	„ 20, „
1065	Mr. Ch. F. Hadfield	Cambridge	„ 25, „	Apr. 8, 1899
1066	Mr. R. C. Punnett	„	„ 25, „	May 9, „
1067	Dr. A. Bethe	Strasburg	„ 30, „	„ 26, „
1068	Dr. C. Saint-Hilaire	Russia	Oct. 1, „	Apr. 10, „
1069	Dr. H. Driesch	Hamburg	„ 4, „	May 18, „
1070	Dr. C. Herbst	Hesse and Prussia	„ 4, „	„ 18, „
1071	Dr. H. L. Jameson	British Association	„ 7, „	Apr. 17, „
1072	Dr. G. Bitter	Prussia and Saxony	„ 17, „	Mar. 21, „
1073	Dr. M. Nordhausen	Prussia	„ 17, „	„ 21, „
1074	Stud. H. Jordan	Zoolog. Station	Nov. 1, „	—
1075	Dr. F. H. Gerould	Smithsonian Instit.	„ 3, „	„ 2, „
1076	Dr. S. Metalnikoff	Russia	„ 10, „	Apr. 20, „
1077	Dr. G. Pastarini-Cresi	Italy	Dec. 1, „	—
1078	Dr. Th. Beer	Austria	„ 5, „	—
1079	Mr. T. F. Evans	Oxford	„ 18, „	—
1080	Dr. M. Siedleki	Austria	„ 20, „	—
1081	Prof. A. della Valle	Italy	Jan. 1, 1899	—
1082	Dr. G. Jatta	Zoolog. Station	„ 1, „	—
1083	Prof. S. Apáthy	Hungary	„ 7, „	Feb. 17, 1899
1084	Baron J. Uexküll	Baden	„ 21, „	—
1085	Dr. F. Hunger	Holland	Feb. 6, „	May 8, „
1086	Dr. R. Hoffmann	Prussia	„ 17, „	June 16, „
1087	Dr. E. Küster	„	Mar. 1, „	Apr. 17, „
1088	Dr. E. Zander	Bavaria	„ 6, „	„ 23, „
1089	Prof. K. von Bardeleben	Prussia	„ 6, „	„ 15, „
1090	Dr. R. Hesse	Würtemberg	„ 8, „	„ 15, „
1091	Prof. F. Francotte	Belgium	„ 9, „	May 17, „
1092	Dr. J. Sobotta	Zoolog. Station	„ 9, „	Apr. 27, „
1093	Dr. T. Pintner	Austria	„ 11, „	Mar. 31, „

II. A LIST OF NATURALISTS—*continued.*

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
1094	Dr. C. C. Schneider	Austria	Mar. 11, 1899	Mar. 31, 1899
1095	Mr. H. Vernon	Oxford	„ 18, „	Apr. 20, „
1096	Dr. F. Bancroft	Smithsonian Instit.	„ 20, „	—
1097	Prof. A. Beck	Austria	„ 23, „	„ 20, „
1098	Prof. E. B. Wilson	University Table	„ 31, „	May 27, „
1099	Dr. W. Lindemann	Russia	Apr. 5, „	—
1100	Prof. E. L. Mark	American Women's Table	„ 8, „	May 8, „
1101	Dr. F. Kopsch	Prussia	„ 9, „	June 2, „
1102	Dr. D. Carazzi	Italy	„ 27, „	—
1103	Dr. G. Mazzarelli	„	„ 27, „	—
1104	Cand. N. Bogoyavlensky	Russia	May 24, „	—
1105	Cand. A. Neirásoff	„	„ 24, „	—
1106	Dr. O. Carlgren	Zoolog. Station	June 1, „	—
1107	Prof. F. Raffaele	Italy	„ 10, „	—
1108	Prof. W. Schewiakoff	Russia	„ 15, „	—

III. *A List of Papers which were published in the Year* 1898 *by Naturalists who have occupied Tables in the Zoological Station.*

A. Bethe	Das Centralnervensystem von Carcinus mænas. Ein anatomisch-physiologischer Versuch. II. Theil. 'Archiv Micr. Anatomie,' Bd. 51, 1898.
K. Kostanecki	Die Befruchtung des Eies von Myzostoma glabrum. *Ibid.*
H. Driesch	Von der Beendigung morphogener Elementarprocesse. Aphoristische Betrachtungen. 'Arch. f. Entw.-Mechanik,' Bd. 6, 1898.
„	Ueber rein mütterliche Charactere an Bastardlarven von Echiniden. *Ibid.* Bd. 7, 1898.
H. E. Ziegler	Experimentelle Studien über die Zelltheilung, 1. und 2. Mitth. *Ibid.* Bd. 6, 1898; 3. Mitth. Bd. 7, 1898.
R. Hesse	Untersuchungen über die Organe der Lichtempfindung bei niederen Thieren. IV. Die Sehorgane des Amphioxus. 'Tübinger Zool. Arbeiten,' Bd. 2, 1898.
F. S. Monticelli	Sulla larva di Edwardsia Claparedii Panceri. 'Mitth. Zool. Station, Neapel,' Bd. 13, 1898.
N. Twanzoff	Ueber die physiologische Bedeutung des Processes der Eireifung. 'Bull. Soc. des Nat., Moscou,' 1897.
M. Siedlecki	Reproduction sexuée et cycle évolutif de la coccidie de la seiche. (Klossia octopiana Schn.) 'Comptes Rendus Soc. Biol.' 1898.
„	Étude cytologique et cycle évolutif de la coccidie de la seiche. 'Annales Institut Pasteur,' 1898.
A. Russo	Nuove osservazioni sulla morfologia degli Echinodermi. 'Monitore Zool. Ital.,' anno 9, 1898.
C. C. Nutting	The variostyles of the Plumularidæ. 'The American Naturalist,' 1898.
J. Heymans et O. van der Stricht	Sur le système nerveux de l'Amphioxus. 'Mém. Cour. et Mém. Sav. Etr. Acad. Belge,' 56, 1898.
A. H. Schmidt	Onderzoekingen betr. het Ovarium der Selachii, Proefschrift, Leiden, 1898, and in 'Tijdschr. Dierk. Ver.,' 1898.
L. J. Picton	On the heart-body and cœlomic fluid of certain Polychæta. 'Quart. Journ. Micr. Sc.,' vol. 41, 1898.

L. J. Picton	On the corpuscules of certain marine worms. 'Trans. Liverpool Biol. Soc.,' vol. 12, 1898.
O. van der Stricht	La formation des deux globules polaires, etc., dans l'œuf de Thyranozoon Brocchii. 'Arch. Biol.,' t. 15, 1898.
H. M. Vernon	The relations between marine animal and vegetable Life. 'Mitth. Zool. Station, Neapel,' Bd. 13, 1898.
„	The relations between the hybrid and parent forms of Echinoid Larvæ. 'Proc. R. Soc. London,' vol. 63, 1898, and 'Phil. Trans. R. Soc. London,' vol. 190, 1898.
J. Nusbaum	Zur Entw.-Geschichte des Mesoderms bei den parasitischen Isopoden. 'Biol. Centralbl.' Bd. 18, 1898.
A. Korotneff	Noch etwas über Auchinia. 'Mitth. Zool. Station, Neapel,' Bd. 13, 1898.
F. Doflein	Studien zur Naturgeschichte der Protozoen. 'Zool. Jahrb.,' Abth. 'Morphologie,' Bd. 11, 1898.
„	Studien zur Naturgeschichte der Protozoen. III. Ueber Myxosporidien. 'Zool. Jahrb.,' Abth. 'Anat. u. Ontog.' Bd. 11, 1898.
B. Solger	Zur Kenntniss der Chromatophoren der Cephalopoden und ihrer Adnexa. 'Arch. Micr. Anatomie,' Bd. 53, 1898.
C. Herbst	Ueber zwei Fehlerquellen beim Nachweis der Unentbehrlichkeit von Phosphor und Eisen für die Entw. der Seeigellarven. 'Arch. Entw.-Mech.,' Bd. 7, 1898.
J. Nusbaum und W. Schreiber	Beiträge zur Kenntniss der sog. Rückenorgane der Crustaceenembryonen. 'Biol. Centralbl.,' Bd. 18, 1898.
G. Dunker	Bemerkung zu dem Aufsatz von H. C. Bumpus. The variations and mutations of the introduced Lithorinæ. *Ibid.*
S. Orlandi	Maldanidi del Golfo di Napoli, etc. 'Boll. Musei Zool. e Anat. Comp. di Genova,' 1898.
Th. Beer	Vergleichend physiologische Studien zur Statocystenfunction. I. Ueber den angeblichen Gehörsinn und das angebliche Gehörorgan der Crustaceen. 'Arch. f. d. ges. Physiologie,' Bd. 73, 1898.
„	Die Accommodation des Auges in der Thierreihe. 'Wiener klinische Wochenschrift,' No. 42, 1898.
G. Mazzarelli	Bemerkungen über die Analniere der freilebenden Larven der Opistobranchier. 'Biol. Centralbl.,' Bd. 18, 1898.
„	Sulla persistenza del rene secondario nelle larve degli Opistobranchii, 1898.
H. Ludwig	Einige Bemerkungen über die mittelmeerischen Synapta-Arten. 'Zool. Anz.,' Bd. 21, 1898.
„	Brutpflege und Entwickelung von Phyllophorus urna, Grube. *Ibid.*
Ph. Bottazzi	Contributions to the physiology of unstriated muscular tissue. Part 4. The action of electrical stimuli upon the œsophagus of Aplysia depilans, &c. 'Journ. Phys. Lond.,' vol. 22, 1898.
W. Krause	Die Lichtempfindung des Amphioxus. 'Anat. Anz.,' Bd. 14, 1898.
G. Jatta	Sopra alcuni Cefalopodi della Vettor Pisani. 'Boll. Soc. Nat. Napoli,' vol. 12, 1898.
J. Sobotta	Die morphologische Bedeutung der Kupffer'schen Blase. Ein Beitrag zur Gastrulation der Teleostier. 'Verh. der Physic. Med. Ges. Würzburg,' N. F. Bd. 32, 1898.
V. Faussek	Ueber die Ablagerung des Pigmentes bei Mytilus. 'Zeitschr. Wiss. Zool.,' Bd. 65, 1898.
E. Goodrich	On the Nephridia of the Polychæta. Part II. Glycera and Goniada. 'Quart. Journ. Micr. Sc.,' vol. 41, 1898.
G. Brandes	Die Lorenzinischen Ampullen. 'Verh. Deutsche Zool. Ges.,' 1898.
G. Tagliani	Ueber die Riesennervenzellen im Rückenmarke von Solea impar. 'Anat. Anz.,' Bd. 15, 1898.

A. Fischel . . .	Experimentelle Untersuchungen am Ctenophoren Ei, II.–IV. 'Arch. Entw.-Mech.,' Bd. 7, 1898.
Th. Schaeppi . . .	Untersuchungen über das Nervensystem der Siphonophoren. 'Jen. Zeitschr. f. Naturw.,' Bd. 32, 1898.

IV. *A List of the Publications of the Zoological Station during the Year ending June* 30, 1899.

1. 'Fauna und Flora des Golfes von Neapel.'
   In print: 'Rhodomeleæ,' by Professor Falkenberg (Rostock).
2. 'Mittheilungen aus der zoologischen Station zu Neapel.' Vol. xiii. pts. 3–4, 2 plates.
3. 'Zoologischer Jahresbericht,' for 1897.
4. 'Guide to the Aquarium.' A new French edition has been published.

The Zoology of the Sandwich Islands.—Ninth Report of the Committee, consisting of Professor NEWTON (*Chairman*), Dr. W. T. BLANFORD, Professor S. J. HICKSON, Mr. F. DU CANE GODMAN, Mr. P. L. SCLATER, Mr. E. A. SMITH, *and* Mr. D. SHARP (*Secretary*).

THE Committee was appointed in 1890, and has been annually reappointed. During the past year it has received grants from the Royal Society and the Trustees of the Honolulu Museum for the publication of its results. Two parts (under the title of 'Fauna Hawaiiensis') have already appeared, one by Mr. R. C. L. Perkins and Professor Forel, on the Hymenoptera aculeata, the other by Mr. E. Meyrick, on the Macro-Lepidoptera. These two parts enumerate 490 species, 331 of which are new. The third and fourth parts (Orthoptera and Neuroptera) are in the press, and subsequent parts are in a more or less advanced state of preparation.

The Committee has been fortunate in being able to retain the services of Mr. Perkins, for which purpose the balance of the grant made to the Committee by the Trustees of the Honolulu Museum, and certain sums received from the British Museum for the preparation of specimens, have been appropriated. These resources are at present exhausted, and the Committee has no balance in hand except its publication fund.

The Committee considers it desirable that more complete evidence should be procured, and entertains the idea of again sending out Mr. Perkins to the islands. The fauna is being extirpated with increasing rapidity, and the natural conditions of the native animal life entirely upset; hence exploration, to be satisfactory, should be done at once.

The Committee has obtained a grant from the Government Grant Committee of the Royal Society, and the Trustees of the Honolulu Museum have signified their intention of again adding a proportional sum to any amount that may be raised in this country.

The Committee therefore asks the Association for a grant of 100*l.*, to be used either for the purpose of sending Mr. Perkins again to the islands or for continuing work in this country, as may seem most desirable.

Investigations made at the Marine Biological Laboratory, Plymouth.—Report of the Committee, consisting of Mr. G. A. BOURNE (*Chairman*), Professor E. RAY LANKESTER (*Secretary*), Professor S. H. VINES, Mr. A. SEDGWICK, Professor W. F. R. WELDON, *and* Mr. W. GARSTANG.

The Embryology of the Polyzoa. By T. H. TAYLOR.

BOWERBANKIA was found at the beginning of August to be breeding. Stones and shells with healthy colonies were dredged from the sound and placed in vessels of sea-water well supplied with suitable algæ, and larvæ were spawned in abundance. The larva is found in the parent polypide in the tentacle-sheath by the eversion of which it is passed to the exterior. Spawning generally takes place in the morning, only an occasional larva appearing after midday.

The larvæ are strongly influenced by light, and it is easy to cause them to migrate from side to side of the aquarium by altering the illumination. In order to test their response a beaker was wrapped round with black paper on one side of which a window was cut. On introducing the larvæ, they quickly appeared at the window, and remained there swimming about for some time. Eventually they disappeared, and were found to have settled on the floor of the vessel.

The free swimming period is very short. Of a batch spawned in the morning almost all have fixed by the early afternoon, and it is rare to find any left in the evening. The study of the free larva is greatly facilitated by its capacity for intra-vitam staining: toluidin blue was used for this purpose. After fixation the larva rapidly passes through its metamorphosis, and becomes a hemispherical cystide covered by a delicate cuticle, and containing the degenerated larval tissues. From one side a blunt process grows out as a stolon over the surface of the substratum, and is cut off by a septum from the cystide, which gradually develops into the primary polypide.

As the attachment of the cystide is very close, and cannot be loosened without injury, advantage was taken of the response to light in the larva to secure its fixation on a manageable substratum. Celloidin films were used according to the method adopted by Pronho for polyzoan and by Vosmaer for sponge larvæ. There is a great advantage in working with larvæ fixed on films, as there is no risk of losing them while they are being carried through the various reagents; and celloidin is very suitable, as it is quite transparent, and tears into convenient strips. After the larvæ had fixed the films were transferred to an aquarium and kept till required. In this way a series of stages was obtained. Flemming and a mixture of acetic and corrosive were used as fixatives.

I have to express my sincere thanks to the Committee of the British Association for their permission to occupy their table at the Plymouth Laboratory, and also to Mr. E. J. Allen, the Director, for his kind interest and many helpful suggestions.

The Rearing of Larvæ of Echinidæ. By Professor E. W. MacBride.

The problem which engaged my attention during the spring of 1898, when I occupied the Cambridge University Table, and during the present summer, when I held the Table belonging to this Association, was the rearing of the larvæ of echinoderms. Since the work done this year was only the completion of that commenced in 1898, the results of the two years may be considered together. The primary object which I had in view was the collection of sufficient material to enable me to undertake a thorough investigation of the formation of the organs in the Echinidæ, along similar lines to the researches already published on the development of *Asterina gibbosa*. The object was accomplished this summer in the case of one species, viz. *Echinus esculentus*; but as it will be some considerable time before the material can be worked up, I shall content myself with mentioning some points of general interest in connection with the rearing, since these may throw some light on the problem of the rearing of the eggs of marine animals in general.

So far as I am aware, the larvæ of the Echinidæ have heretofore been successfully reared only by two people, viz. Théel and Bury. Théel has already published his method, and the results of his work, so far as *Echinocyamus pusillus* is concerned; he has also told me that he has reared *Echinus miliaris*. Bury informed me some time ago that he had reared a few plutei of one of the Neapolitan species through the metamorphosis; but he experimented—to judge from his description—with only very few at a time.

Dr. Dohrn informed me that unsuccessful attempts had been made at Naples to keep larvæ living until they had metamorphosed by following Théel's directions; it may therefore be inferred that these directions have not fully described the difficulties which crop up in the course of the experiment.

There are three species of Echinus commonly found in Plymouth, viz., *E. miliaris*, *E. esculentus*, and *E. acutus*. The last two in colour and size closely resemble one another; *E. acutus* has, however, longer and sparser spines than *E. esculentus*; it is not so commonly found, and Mr. Allen informs me that it is an inhabitant of deeper water. *E. miliaris*, on the other hand, does not attain more than half the size of the other two species, and its predominantly green colour serves at once to distinguish it from them.

The eggs of *E. miliaris* and *E. acutus* are about the same size; that of *E. esculentus* is about double the size of either, and it was for this reason especially that I selected the last species as the most suitable. The size of the egg is, of course, conditioned by the amount of yolk; and the greater the amount of yolk, the greater, so to speak, is the initial velocity with which the development is launched: the longer the time before the larvæ has to depend exclusively on its own exertions for food.

Experiments were made also with *E. miliaris* and *E. acutus*; the larvæ of *E. miliaris* is strikingly different at all stages of development from that of *E. esculentus*, and in a forthcoming paper in the 'Quarterly Journal of Microscopical Science' these differences will be detailed. I only succeeded in rearing the larvæ of *E. acutus* for the first ten days of its existence, and during this time it strikingly resembled that of *E. esculentus*, but was in correspondence with the smaller size of the egg of about half the size of the larvæ of *E. esculentus*.

In order to obtain good results it is first of all necessary to use none but fully developed and thoroughly ripe males and females for the experiment. It is possible to get ripe eggs and spermatozoa from under-sized individuals, and also from ovaries and testes, the greater bulk of which consists of unripe sexual cells; but in no case did the larvæ produced from these live more than a short time. When the genital organ is ready at a touch to dissolve into eggs or spermatozoa, then and then only may success be anticipated.

The great essential condition for success is that the larvæ should be placed in pure sea-water, brought from some distance from the shore. In Plymouth the water must be brought from beyond the breakwater. And hence the success of any experimental work at Plymouth depends entirely on the possibility of procuring a continuous and abundant supply of this 'outside' water. Lest it should be thought that this is only necessary in the case of Echini, I may mention the fact that although *Asterina gibbosa* will live in the tanks and lay its eggs there, these invariably fail to develop. Nevertheless, in Naples every year crowds of the larvæ of this hardy species are obtained by simply throwing the adults into the tanks and leaving them there under the ordinary circulation.

Mr. Allen, the courteous director of the Plymouth Laboratory, strained the resources at his command in order to provide me with an abundant supply of pure water; but the only method of bringing it to the Laboratory at present available is carriage on the backs of the servants of the Laboratory from the shore to a height of over 100 feet, and it is obvious that under these conditions the amount available is very limited. One cannot help feeling that if Plymouth is to become successful as a centre of scientific work some capital expenditure must be incurred in order to provide for the better transport of 'outside' water to the Laboratory.

As soon as the eggs had reached the blastula stage and had become free-swimming, they were decanted off from the remainder which had developed abnormally or not at all. The blastulæ were then transferred to a number of two-gallon jars, each fitted with the plunger devised by Mr. Browne, of University College, London.

It is absolutely necessary that the jars should be protected from direct sunlight; for this purpose a sheet of blackened paper was attached to the exposed side.

If the action of the plunger be stopped, the larvæ, if healthy, will in a short time reach the top; it is then possible to siphon off the bottom water.

This, however, was not often done, and on one occasion some larvæ of *Echinus miliaris* lived for a month in one of these jars without progressing beyond the stage usually reached in seven days. The tendency of these larvæ to, so to speak, 'hang' in development without progressing, renders it impossible to make accurate statements as to the time they normally require to metamorphose. Even under the best conditions obtainable in a laboratory, it is probable that development is slower than in the open sea.

At the end of about a week it was usually found that in one jar (ten in all were used) the larvæ were particularly healthy and advanced. All the others were then discarded, and the healthy larvæ distributed over the remaining jars, which were, of course, filled up with fresh sea-water. After another week the most healthy were transferred to ten-gallon jars fitted with large plungers. About 200 were put in each jar, and they then commenced to develop the spines and tube feet of the adult Echinus.

It is necessary to change about two gallons of the water every day. At the end of 43 to 45 days some specimens were found on the bottom of the jar metamorphosed. For convenience of observation the remainder were transferred to a number of half-gallon jars which were immersed in one of the Laboratory tanks to keep them cool. About three larvæ were placed in each jar, but development did not go on as well or as quickly as in the large jar.

The reflection will occur to most people that the method I have described is a roundabout and cumbersome one. Why not, it may be urged, transfer at once 200 blastulæ to a ten-gallon jar? The answer to this is that I have tried this experiment, and that it failed. From my experience it seems as if it were necessary to allow Nature to select the healthiest larvæ; the experimenter cannot pick out the blastulæ which are fit to survive. At the end of 14 days a larva has a much greater hold on life, and if unhealthy conditions supervene, such as insufficient change in the water, it will often continue to grow without developing the organs of the adult.

Plenty of room is a cardinal condition for the success of all rearing experiments. When I had removed all the best larvæ to the half-gallon jars, I left behind in the ten-gallon jar a few of what I thought unhealthy larvæ. To my surprise and delight on the last day of my stay in Plymouth, I found practically all these either metamorphosed or just about to complete this process. To sum up, the necessary conditions for success are: (1) Selection of perfectly ripe full-grown males and females for fertilisation; (2) use of outside water; (3) action of natural selection for the first week; (4) the use of the plunger; (5) frequent change of water; (6) shading from excessive light; and (7) plenty of room.

This is not the place to enter into a discussion of the internal changes which go on in development, a subject which I reserve for a later paper, but it seemed to me that these observations of the conditions of successful rearing might be of interest to a wider circle than specialists in echinoderms. It was some time ago usual to regard the larvæ of echinoderms as the most difficult objects to rear. So far from this being the case, I believe that of all *true larvæ* they are really the easiest. I use the term 'true larvæ' advisedly, for comparative embryology has too long confined itself to the study of cases such as those of Æstacus amongst Crustacea, Pisidium and Cyclas amongst Mollusca, and *Asterina gibbosa* amongst Echinodermata, where the word 'larva' is only applicable to the young by a scarcely justifiable stretch of its meaning.

A larva is exposed to the struggle for existence with the environment, and depends on its own exertions for food, but this is not the case, as reflection will show, with most of the life-histories which, so to speak, have served as paradigms for comparative embryology. And yet, when one or two cases of true larval development have been successfully investigated, how full of meaning and interest they have shown themselves to be! I need only mention the instances of Lucifer and Penæus amongst Crustacea to prove this. The difficulty in such studies has always been the question of rearing.

I hope that the observations recorded above may be of assistance to any investigator who is attempting to make advances in this field, which seems to me to be one of the most hopeful for the future development of comparative embryology.

Zoology and Botany of the West India Islands.—Final Report of the Committee, consisting of Dr. P. L. SCLATER (*Chairman*), Mr. W. CARRUTHERS, Dr. A. C. L. GÜNTHER, Dr. D. SHARP, Mr. F. DU CANE GODMAN, Professor NEWTON, Sir GEORGE HAMPSON, *and* Mr. G. MURRAY (*Secretary*), *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.*

AT a meeting held on Wednesday, July 5, 1899, it was resolved to terminate the active work of the Committee by rendering a list of its publications to the Royal Society (Government Grant Committee) and to the British Association, and by presenting to the Trustees of the British Museum the remainder of the unworked-out material. This material, consisting mostly of Coleoptera, has remained undetermined owing to the dearth of expert naturalists, and there is no immediate prospect of the Committee obtaining the services of suitable naturalists.

The following list of papers represents the published work of the Committee since it was established :—

Zoology.

Vertebrata.

Sclater, P. L.	List of Birds collected by Mr. Ramage in Dominica, West Indies. 'Proc. Zool. Soc. Lond. 1889,' pp. 326, 327.
"	List of Birds collected by Mr. Ramage in St. Lucia, West Indies. 'Proc. Zool. Soc. Lond. 1889,' pp. 394, 395.
"	On a Collection of Birds from the Island of Anguilla, West Indies. 'Proc. Zool. Soc. Lond. 1892,' pp. 498–500.
Feilden, H. W.	The Deserted Domicile of the Diablotin in Dominica. 'Trans. Norfolk and Norwich Nat. Soc.' v. pt. 1, 1890, pp. 24–39.
Günther, A.	Notes on Reptiles and Frogs from Dominica, West Indies. 'Ann. and Mag. Nat. Hist.' ii. 1888, pp. 362–366.

Mollusca.

Smith, E. A.	On the Mollusca collected by Mr. G. A. Ramage at the Island of Dominica. 'Ann. and Mag. Nat. Hist.' ii. 1888, pp. 227–234, 419, 420.
"	On the Mollusca collected by Mr. G. A. Ramage in the Lesser Antilles. 'Ann. and Mag. Nat. Hist.' iii. 1889, pp. 400–405.
"	Report on the Land and Freshwater Shells collected by Mr. Herbert H. Smith at St. Vincent, Grenada, and other neighbouring Islands. 'Proc. Malac. Soc.' i. pt. 7, October 1895; pp. 300–322, with plate 21.

Arthropoda.

Pocock, R. I.	Contributions to our knowledge of the Crustacea of Dominica. 'Ann. and Mag. Nat. Hist.' iii. 1889, pp. 6–22, with plate 2.
Dollfus, A.	On West-Indian Terrestrial Isopod Crustaceans. 'Proc. Zool. Soc. Lond. 1896,' pp. 388–400.
Pocock, R.	On Isometrus americanus (Linn.), with a description of a new species of the genus. 'Ann. and Mag. Nat. Hist.' iv. 1889, pp. 53–59.

Peckham, G. W. and E. G.	On the Spiders of the family Attidæ of the Island of St. Vincent. 'Proc. Zool. Soc. Lond. 1893,' pp. 692–704, with plates 61 and 62.
Simon, E. . . .	On the Spiders of the Island of St. Vincent.' Parts 1–3. 'Proc. Zool. Soc. Lond. 1891,' pp. 549–575, with plate 42; 1894, pp. 519–526; 1897, pp. 860–890.
Pocock, R. I. . . .	Contributions to our knowledge of the Arthropod Fauna of the West Indies: Part 1. Scorpiones and Pedipalpi; with a Supplementary Note upon the Freshwater Decapoda of St. Vincent. Part 2. Chilopoda. Part 3. Diplopoda and Malacopoda, with a Supplement on the Arachnida of the Class Pedipalpi. 'Journ Linn. Soc. Zool.' 1893, Pt. 1, pp. 374–409, with plates 29 and 30; Pt. 2, pp. 454–473. 1894, Pt. 3, pp. 473–544, with plates 37–40.
" . . .	Contributions to our knowledge of the Myriapoda of Dominica. 'Ann. and Mag. Nat. Hist.' Pt. 2, 1888, pp. 472–483, with plate 16.
Waterhouse, C. O. . .	Observations on some Buprestidæ from the West Indies and other localities. 'Ann. and Mag. Nat. Hist.' xviii. 1896, pp. 104–107.
Matthews, A. . . .	Corylophidæ and Trichopterygidæ found in the West Indian Islands. 'Ann. and Mag. Nat. Hist.' xiii. 1894, pp. 334–342.
Grouvelle, A. . . .	Clavicornes de Grenada et de St. Vincent (Antilles) récoltées par M. H. H. Smith. 'Notes from the Leyden Museum,' xx. 1898, pp. 35–48.
Gorham, Henry S. . .	On the Serricorn Coleoptera of St. Vincent, Grenada, and the Grenadines (Malacodermata, Ptinidæ, Bostrychidæ), with descriptions of new species. 'Proc. Zool. Soc. Lond. 1898,' pp. 315–333, and part of plate 27.
" " . .	On the Coleoptera of the families Erotylidæ, Endomychidæ, and Coccinellidæ, collected by Mr. H. H. Smith in St. Vincent, Grenada, and the Grenadines, with descriptions of new species. 'Proc. Zool. Soc. Lond. 1898,' pp. 334–343, and part of plate 27.
Gahan, C. J. . . .	On the Longicorn Coleoptera of the West India Islands. 'Trans. Ent. Soc. Lond. 1895,' pp. 79–140, with plate 2.
Champion, G. C. . .	On the Heteromerous Coleoptera of St. Vincent, Grenada, and the Grenadines. 'Trans. Ent. Soc. Lond. 1896,' pp. 1–54, with plate 1.
" " . .	On the Serricorn Coleoptera of St. Vincent, Grenada, and the Grenadines. 'Trans. Ent. Soc. Lond. 1897,' pp. 281–296.
Jacoby, M. . . .	A list of the Phytophagous Coleoptera obtained by Mr. H. H. Smith at St. Vincent, Grenada, and the Grenadines, with descriptions of new species, Crioceridæ—Galerucidæ. 'Trans. Ent. Soc. Lond. 1897,' pp. 249–280.
Riley, C. V., Ashmead, W. H., and Howard, L. O.	Report upon the Parasitic Hymenoptera of the Island of St. Vincent. 'Journ. Linn. Soc. (Zool.), 1894,' xxv. pp. 56–254.
Ashmead, W. H. . .	Report on the Parasitic Hymenoptera of the Island of Grenada, comprising the families Cynipidæ, Ichneumonidæ, Braconidæ, and Proctotrypidæ. 'Proc. Zool. Soc. Lond. 1895,' pp. 742–812.
Forel, A. . . .	Formicides de l'Antille St. Vincent. Récoltées par Mons. H. H. Smith. 'Trans. Ent. Soc. Lond. 1893,' pp. 333–418.
Forel, A. . . .	Quelques Formicides de l'Antille de Grenada. Récoltées par Mons. H. H. Smith. 'Trans. Ent. Soc. Lond. 1897,' pp. 297–300.
Hampson, G. F., Sir .	On the Geometridæ, Pyralidæ, and allied families of Heterocera of the Lesser Antilles. 'Ann. and Mag. Nat. Hist,' xvi. 1895, pp. 329–349.

Hampson, G. F., Sir	The Moths of the Lesser Antilles. 'Trans. Ent. Soc. Lond. 1898,' pp. 241–260, with plate 17.
Walsingham, Lord	On the Micro-Lepidoptera of the West Indies. 'Proc. Zool. Soc. Lond. 1891,' pp. 492–549, with plate 41.
Williston, S. W.	On the Diptera of St. Vincent, West Indies (Dolichopodidæ and Phoridæ by J. M. Aldrich). 'Trans. Ent. Soc. Lond. 1896,' pp. 253–446, with plates 8–14.
Uhler, P. R.	An Enumeration of the Hemiptera-Homoptera of the Island of St. Vincent, West Indies. 'Proc. Zool. Soc. Lond. 1895,' pp. 55–84.
,, ,,	On the Hemiptera-Heteroptera of the Island of Grenada, West Indies. 'Proc. Zool. Soc. Lond. 1894,' pp. 167–224.
,, ,,	A list of the Hemiptera-Heteroptera collected in the Island of St. Vincent, by Mr. Herbert H. Smith, with descriptions of new genera and species. 'Proc. Zool. Soc. Lond. 1893,' pp. 705–719.
,, ,,	A list of the Hemiptera-Heteroptera of the families Anthocoridæ and Ceratocombidæ collected by Mr. H. H. Smith in the Island of St. Vincent, with descriptions of new genera and species. 'Proc. Zool. Soc. Lond. 1894,' pp. 156–160.
Kirby, W. F.	On some Small Collections of Odonata (Dragonflies) recently received from the West Indies. 'Ann. and Mag. Nat. Hist.' xiv. 1894, pp. 261–269.
,, ,,	Descriptions of new Species of Phasmidæ from Dominica, Santa Lucia, and Brazil (Theresopolis), in the Collection of the British Museum. 'Ann. and Mag. Nat. Hist.' iii. 1889, pp. 501–504.
Brunner v. Wattenwyl, C., and Redtenbacher, J.	On the Orthoptera of the Island of St. Vincent, West Indies. 'Proc. Zool. Soc. Lond. 1892,' pp. 196–221, with plates 15–17.
Brunner v. Wattenwyl, C.	On the Orthoptera of the Island of Grenada, West Indies. 'Proc. Zool. Soc. Lond. 1893,' pp. 599–611, with plate 52.

Botany.

Baker, J. G.	On the Vascular Cryptogamia of the Island of St. Vincent. 'Ann. Bot.' vol. v. 1891, pp. 163–171, with plates 10 and 11.
,, ,,	On the Vascular Cryptogamia of the Island of Grenada. 'Ann. Bot.' vi. 1892, pp. 95–102.
Wright, C. H.	Two New Cryptogams (Polytrichum nudicaule and Kantia vincentina). 'Journ. Bot.' xxix. 1891, pp. 106, 107.
Spruce, R.	Hepaticæ Elliottianæ, insulis Antillanis S^{ti} Vincentii et Dominica a clar. W. R. Elliott, annislectæ 1891–92. 'Journ. Linn. Soc. (Bot.)' xxx. 1895, pp. 331–372, with plates 20–30.
Gepp, A.	Additional Notes on Mr. W. R. Elliott's Hepaticæ. 'Journ. Bot.' xxxiii. 1895, pp. 53–54.
West, W.	On some Freshwater Algæ from the West Indies. Assisted by G. S. West. 'Journ. Linn. Soc. (Bot.),' xxx. 1894, pp. 264–280, with plates 13–16.
West, W., and West, G. S.	A further Contribution to the Freshwater Algæ of the West Indies. 'Journ. Linn. Soc. (Bot.),' xxxiv. No. 237, 1899, pp. 279–295.
Grove, E.	Diatoms of St. Vincent and Grenada. 'Journ. Bot.' 1899.
Wainio, E. A.	Lichenes Antillarum a W. R. Elliott collecti. 'Journ. Bot.' xxxiv. 1896, pp. 31–36, 66–72, 100–107, 204–210, 258–266, 292–297.
Massee, G.	Some West Indian Fungi. 'Journ. Bot.' xxx. 1892, pp. 161–164, 196–198, with plates 321–323 and 325.

Papers are in hand on the Musci, by Mr. A. Gepp; on the Hepaticæ (additional), by Dr. Stephani; on the Lichenes (additional), by M. Wainio; and on the Fungi (additional), by Miss A. Lorrain Smith.

Zoological and Botanical Publication.—Report of the Committee, consisting of Rev. T. R. R. STEBBING (*Chairman*), Professor W. A. HERDMAN, Mr. W. E. HOYLE, Dr. P. L. SCLATER, Mr. ADAM SEDGWICK, Dr. D. SHARP, Mr. C. D. SHERBORN, Professor W. F. R. WELDON, Mr. A. C. SEWARD, Mr. B. DAYDON JACKSON, *and* Mr. F. A. BATHER (*Secretary*).

THE Report of this Committee for 1897, specially addressed to the editors of academical and periodical publications, has now been sent to all the leading societies and journals that publish either zoological or botanical communications, or both—about 800 in all. A special slip was inclosed drawing attention to the fact that the recommendations of the Committee were applicable to botanical no less than to zoological publications.

The difficulty of finding many of the desired addresses suggests that the compilation of a list of publishing societies and of current periodicals with their postal addresses would be of much service to workers in science. Existing lists are as a rule deficient in regard to the addresses.

Circumstances have interfered with the task of reporting on the correspondence already received. To deal with this and with any further correspondence that may arise out of the circulars, your Committee respectfully requests its reappointment, without a grant of money.

Plankton and Physical Conditions of the English Channel.—First Report of the Committee, consisting of Professor E. RAY LANKESTER (*Chairman*), Professor W. A. HERDMAN, Mr. H. N. DICKSON, *and* Mr. W. GARSTANG (*Secretary*), *appointed to make Periodic Investigations of the Plankton and Physical Conditions of the English Channel during* 1899.

THE proposed investigations have been carried out at quarterly intervals during the year by Mr. Garstang, who was enabled by means of the grant to hire a steam tug for the work during February, May, and the first week of September. Except for a few small items for temporary apparatus at sea, the whole of the expended grant (95*l.*) has been devoted to the hire of a suitable steamboat for the periodic survey. A small balance (5*l.*) remains, but as two further cruises will be necessary to complete the investigation, the Committee desires its reappointment with a grant of 50*l.* (in addition to the unexpended balance).

The observations of temperature and salinity and the collections of plankton obtained will furnish data for a complete year's record of the periodic changes in the physical character of the water and in the quantity and character of the floating fauna and flora in the mouth of the English Channel—a standard record which will be of the highest value in many branches of marine biological and hydrographical inquiry.

Most of the apparatus used has been provided by the Marine Biological Association, which has borne all the expenditure required for the more costly nets and gear. The Committee is also indebted to the Royal Society Grant Committee for the loan of armoured hose and an extra deep sea thermometer.

The collections are deposited in the Plymouth laboratory of the Marine Biological Association, where the work of identification and quantitative determination will be carried out.

As the year's collections are not yet complete, the Committee confines its report on the present occasion to a description of the methods and apparatus employed, and hopes to present a final report at the Bradford meeting.

The route fixed for the Survey consisted of the following lines:—(1) from Plymouth to Ushant, with stations in mid-Channel (50 fathoms) and off Ushant (60 fathoms); (2) from Ushant in a westerly direction towards the 100-fathom line, with a station near Parson's Bank (75 fathoms); (3) from Parson's Bank northwards towards Mount's Bay, with a station in 50 fathoms; (4) from Mount's Bay to Plymouth.

The hydrographic apparatus employed consisted on all occasions of Negretti and Zambra's Deep-sea Reversible Thermometers, and of one of Dr. Mill's Water Bottles. Complete series of temperatures were taken on all occasions.

On the February cruise the biological apparatus consisted of a number of silk-gauze nets of various meshes for surface collections and of a semi-rotary hand-pump and 40 fathoms of armoured hose (having a diameter of one inch) for quantitative samples both of surface and deep-water plankton. Accessory apparatus for filtering the plankton and measuring the volume of water filtered was also provided.

The results obtained by pumping appeared to be quite satisfactory for quantitative determination of the more immobile elements of the plankton, such as diatoms and even the smaller copepods; but the vertical distribution of the plankton was found to be so variable, under the varying influence of darkness and light, even at a depth of 40 fathoms, that the length of hose, which alone was obtainable with the means at the Committee's disposal, was inadequate to provide a proper series of samples for comparative purposes in cases where the depth exceeded 50 fathoms. On returning from this cruise, therefore, Mr. Garstang determined to attempt a solution of the difficulties which have hitherto invested the problem of a simple but efficient opening and closing net for horizontal towing; as well as to construct a vertical net, after Hensen's pattern, for comparative estimation of the total quantity of plankton present at different places and at different seasons.

These nets were ready for use towards the end of May, and were employed with perfect success during the May and September cruises. As the closing net has proved to be a thoroughly reliable instrument, the principles of its construction are here briefly given, and the net itself will be exhibited and tried at sea during the Dover Meeting. (The trials took place on September 17 on board Mr. J. W. Woodall's yacht *Vallota*, in the presence of Sir John Murray, Mr. H. N. Dickson, and Mr. I. C. Thompson, and were completely successful.)

The principal obstacles to the use of closing nets for horizontal towing at definite depths have been (1) the tendency of the net to oscillate, during towing, through a thick stratum of water, depending on inevitable variations in the rate of towing; (2) the uncertainty of determining the actual depth of the net at any moment, owing to the curvature of the line produced by the resistance of the water; (3) the difficulty of ensuring the proper opening and complete closure of the net at the depth required.

It appeared that the first and second obstacles might be overcome by combining a minimum resistance of the towing line and net with a maximum weight of the net frame. The net was therefore designed to be towed by fine steel wire instead of a hempen line, and provision was made for a heavy net frame to support a small net, as well as for the voluntary addition of extra weight to any degree that might appear to be required. The wire employed was provided by Messrs. Latch & Batchelor, Limited, of Birmingham. They describe it as No. 16 G, and give its breaking strain as 790 pounds.

The essential parts of the frame are the same as in Giesbrecht's net, but the modifications introduced are in the direction of a much greater simplicity. A quadrangular jointed metal frame slides up and down a cylindrical axis, formed by a stout rigid metal tube, which is furnished with a guide. When the frame is opened, the aperture is diamond-shaped; when shut, the two upper limbs of the frame approximate tightly to the corresponding lower limbs. Both pairs of limbs can be supported in the closed position at the top of the tubular axis by metal springs, on the principle employed by Dr. H. R. Mill in his well-known self-locking water-bottle. Owing to the fact, however, that the releasing gear had to be doubled in the case of the net, the set of springs which support the *lower* limbs of the frame were attached *inside* the tubular axis, which is perforated at three points for the protrusion of the supporting edges of the springs. Release of the frame is effected in each case by the action of a metal cap which can be driven over the springs by the action of a messenger. The first messenger (a narrow one) drives down the inner cap and releases the lower limbs of the frame, which then descend by their own weight and open the net to its utmost extent; the second messenger (a broad one) is arrested by the outer cap, drives it down, and releases the upper part of the frame, thus closing the net again, but in this case at the bottom of the axis, instead of at the top. By means of messengers both movements are thus under the control of the operator on the deck of the ship, whatever be the depth to which the net is lowered.

Another important departure from the Giesbrecht net, whether in its original form, or as modified by the Prince of Monaco, consists in the method by which the proper orientation of the net is ensured. The wire, in fact, is attached to a central pivot upon which the tubular axis of the frame, which bears all the weight, is free to rotate. Friction is reduced to a minimum by means of ball bearings. In this way the possibility of any revolution of the net round a vertical axis, either during descent, towing, or ascent, as a consequence of the twisting of the wire, is completely avoided—a very important matter, for if the frame were to revolve during its descent, the gauze net attached to it would be wrapped round the axis or the horizontal limbs of the frame, and the opening of the net would be impeded, and probably quite prevented. On no occasion, however, has such an accident happened—a fact which bears witness to the efficiency of the means taken to prevent it. The net never failed to come up to the surface properly closed, so that the reliability of the results obtained by the net can be confidently assumed. Although on this occasion it is not proposed to go into any details, Mr. Garstang reports that the difference between the plankton of different levels as revealed by this new net were in many cases of a most conspicuous character, a fact which will be fully demonstrated in the final report of the Committee. The various hauls made by the net at different times of the day and night also show in a clear and convincing manner the effect of light and darkness upon the vertical movements of pelagic organisms in the Channel waters.

It is consequently proposed to continue the investigations until February 1900, in order to complete a full year's survey under identical conditions with the same apparatus.

Bird Migration in Great Britain and Ireland.—Second Interim Report of the Committee, consisting of Professor NEWTON *(Chairman), the late* Mr. JOHN CORDEAUX *(Secretary),* Mr. HARVIE-BROWN, Mr. R. M. BARRINGTON, Rev. E. PONSONBY KNUBLEY, *and* Dr. H. O. FORBES, *appointed to work out the details of the Observations of the Migration of Birds at Lighthouses and Lightships,* 1880–87.

YOUR Committee has to deplore the loss it has sustained by the recent death of its Secretary, Mr. Cordeaux, who, ever since the subject of the migration of birds was first brought before the Association at Swansea in 1880, when he was made Secretary of the Committee then appointed, has devoted an incalculable amount of time and labour to the work in hand.

If Mr. Cordeaux were not the first to suggest the employment of the light-keepers in obtaining observations, he was certainly the first to prove its practicability, and the success which attended the inquiry must be attributed almost wholly to his skilful conduct of it. All the complicated details of schedules, circulars, and other information supplied to the observers were carefully thought out by him, and he carried on the greater part of the necessary correspondence which, in the earlier years of this inquiry, was enormous, while raising by his own exertions the funds needed to defray its expenses, which amounted to at least twice as much as the grants from time to time received from the Association—though these have not been inconsiderable. Even a still greater service was performed by him in getting the men at the Lighthouses and Lightships to take a real interest in the business, for all depended on their cheerful co-operation, which was given voluntarily and was gratuitously rendered.

In continuation of the Interim Report of last year, your Committee has to inform the Association that Mr. William Eagle Clarke, of the Museum of Science and Art at Edinburgh, has continued working out the details of the collected observations, in accordance with the scheme before indicated; but that, as then stated, some two or three years will be needed to do this in a satisfactory way. The work is attended by some expense, and your Committee, while respectfully soliciting reappointment, begs also for a renewed grant of money. Your Committee has the satisfaction of presenting the following statement received from Mr. Clarke as to the progress he is making:—

'Considerable progress has been made since the last Report. The work of supplementing the data amassed by the Committee has been completed, with the result that no fewer than about 15,000 useful records have been added to the observations available. Most of these records have been tabulated, and incorporated with the original data, and the completion of this portion of the task is now receiving attention.

'In addition, all the information relating to the occurrences of the rarer species for *all years* has been amassed and will be utilised.

'I hope to proceed at once to treat of species, giving the results obtained concerning the migrations of each—a task which must necessarily take a considerable time to accomplish.'

Your Committee takes this opportunity of making known that one of its members (Mr. Barrington) has, on his own account, continued to collect observations from the Irish Lights since the year 1887, when they were discontinued by the Committee of the Association, and has printed the results, which contain many valuable records, up to 1896.

The Climatology of Africa.—Eighth 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 returns have reached your Committee, in the course of last year, from forty stations in Africa.

Niger Territories.—One year's observations from Old Calabar have been received from Mr. E. G. Fenton, the medical officer. We regret that no information respecting the interior of the country has become available.

British Central Africa.—The scientific department, under the zealous direction of Mr. J. McClounie, is now in full working order, and full reports have been received for two stations of the second order, namely, Zomba on the highland, and Fort Johnston on the Lake Level, as also reports, more or less complete, from twenty-two other stations. Mr. McClounie hopes to be able, in the course of the present year, to equip two more stations of the second order, namely, Chinde on the coast, and another station on the lake. He has attempted to make two-hourly observations on term days, but as the exposure in the morning air resulted in fever, he has given up the attempt.

We have, in addition, received three years' registers for Lauderdale, from our most faithful correspondent, Mr. John W. Moir, as also fifteen months' record from Kambola, a station of the London Missionary Society, near the southern extremity of Tanganyika. The observer at the latter place is Dr. James F. Mackay.

British East Africa.—Returns from eight Government stations have been received. These returns are, of course, most welcome, and they speak well for the zeal of Mr. Craufurd and the officers working under him; but considering the practical importance of meteorological work, it is much to be desired that something more should be done. Let us hope that the satisfactory working of a 'Scientific Department' in the South African Protectorate may induce the authorities to organise a similar institution for East Africa and Uganda. As a proof of the high value placed upon work of this kind in the neighbouring German Protectorate, we may state that a professional meteorologist has been appointed as inspector, and that there are now at work twenty-six stations, including two of the first and seven of the second order.

We are likewise in receipt of rainfall observations made by the Rev. R. M. Ormerod at Golbanti, on the Tana river.

The old Scottish Missionary Station at Kibwezi has been abandoned, and the missionaries have removed to a new station in Kikuyu, whence three months' observations have already been forwarded.

Uganda.—The valuable observations on the level of the Victoria Nyanza have been resumed since the suppression of the mutiny.

Mr. C. W. Hobley has forwarded two years' record of the rainfall at Mumia's, the headquarter station of Kavirondo.

Our earth thermometer has accompanied Captain Austin during his journey to Lake Rudolf, but no record of work done has hitherto been received.

Your Committee propose that they be reappointed. They do not ask for a grant.

Nyasaland.

Mr. J. McClounie, head of the Scientific Department of British Central Africa, has forwarded to the Committee the following remarks on the weather, dated Zomba, May 12, 1899 :—

The year of 1898–99 has not been marked by any extraordinary features. In the absence of any records for past years, 1898–99 may be taken as a good one all round. No lengthy damaging drought was experienced. No great rainfall was registered for the year, *i.e.* what may be termed zero to zero, and being the twelve months from October to September, both inclusive.

The rainy season practically commences in October and continues to May, during which time spring and summer prevail, autumn following on in the coldest months, and winter, antipodal to England with regard to temperature, as the temperature rises daily all over the country until the rains of October and the following months cool the atmosphere. Be it understood, of course, that in what is termed the 'wet season' there is no inference that rain falls continuously during these months, as this is not the case. Thunderstorms, though frequent, are of brief duration. From Zomba, the progress of thunderstorms can be seen forty miles away; they are seen to traverse the plain quickly, and rain may be seen falling at three or four different places simultaneously.

During the months of August, September, and October, and sometimes November, vegetation is at a standstill, the accumulating heat from the sun's southing having completely dried the grass and made hard and hot the paths. Bush fires are numerous, and soon there remains nothing but large blackened areas. On this the ground temperature is very great, and almost unbearable by the natives, whose bare feet get badly cracked. As a result of the great temperatures, whirlwinds may be observed long distances away speeding across the plain ; a long black column, small at the ground but widening out at the top, 150 feet to 200 feet high, is a frequent object of interest. Occasionally a whirlwind of more than usual violence may reach the dwellings at Zomba or Blantyre, and dangerously shake the iron roofs. Trees and shrubs are also very much blown about, and sometimes overthrown.

The sunshine during August, September, and October is almost continuous from morning till evening. High temperatures are the rule, and the atmosphere very dry. The bush fires continue, and a heavy haze hangs like a pall over the land until the copious rains in November extinguish the fires and clear the air. Two or three showers are looked for in September, and are called (locally) Kokalupsya, or the early rain, but these are slight. On them, however, the planting community base their hopes for the success of the next year's crop, by their bringing the coffee into flower and setting the fruit.

From Fort Johnston full and excellent returns have been received, observed by Mr. F. S. S. Wright, of the Naval Department.

Excellent climatological returns were received from Nkata Bay and Cholo, the observers being Mr. C. A. Cardew and Mr. Geo. Adamson.

Other climatological stations commenced during the year, and good registers are now being received. The way in which planters and missionaries have responded to the request for rainfall readings has been very encouraging, and these, together with administration stations, give rainfall readings for twenty-two places.

It is not my desire at the present time to go into the tables and make comparisons of the different stations, or point out any special feature, the object of this—the first Report—being to try in a way to illustrate the general nature of the climate of British Central Africa, and which, I hope, may be found compatible with the tables. The barometric and other reductions have been obtained from 'Smithsonian Meteorological Tables,' 1896 edition, and my thanks are due to Mr. Ravenstein for the courteous manner in which he has at times assisted and advised me.

Kambola, Tanganyika Plateau. Lat. 8° 50′ *S.*, *Long.* 31° *E.*, 4,880 *feet* (*by B. Pt.*). *Observer : James F. Mackay, L.R.C.P. Ed.*

Months	Mean Temperature					Temp. Extremes		Mean Temp. Wet Bulb		Vapour Pressure		Dew Point		Relative Humidity		Rain		
	7 A.M.	5 P.M.	Max.	Min.	Mean	Highest	Lowest	7 A.M.	5 P.M.	7 A.M.	5 P.M.	7 A.M.	5 P.M.	7 A.M.	5 P.M.	Amount	Days	Heaviest Fall
1897	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	Inch	No.	Inch
October .	70·90	73·23	84·10	57·90	71·00	90	52	62·42	63·26	·484	·490	58·2	58·5	64	60	1·35	4	1·00
November	68·73	69·56	78·11	52·13	65·12	86	54	63·60	65·10	·540	·577	61·2	63·1	77	80	7·67	16	1·27
December	66·97	63·78	78·19	57·06	67·62	85	53	62·84	64·81	·622	·575	65·3	63·0	95	82	6·17	18	2·18
1898																		
January .	64·11	67·70	76·25	57·22	66·74	82	55	63·38	64·74	·577	·583	63·1	63·4	97	85	12·64	25	2·68
February .	65·17	67·33	76·79	58·16	67·47	84	55	62·00	63·91	·535	·562	61·0	62·4	86	84	8·30	19	1·72
March .	69·09	69·74	82·16	58·00	70·08	88	56	63·53	65·38	·533	·585	60·9	63·5	75	81	9·06	16	1·56
April .	65·86	68·73	81·43	56·40	68·91	89	52	61·43	64·23	·502	·557	59·1	62·1	79	80	6·62	17	2·10
May . .	64·41	73·77	80·96	54·19	67·58	88	51	58·32	65·70	·431	·556	55·0	62·0	71	66	0·00	0	—
June .	59·03	70·73	78·96	49·33	67·14	85	45	52·00	60·17	·323	·424	47·1	54·5	65	56	0·00	0	—
July . .	58·59	71·92	80·70	43·66	62·19	85	42	57·86	58·14	·474	·355	57·6	49·6	97?	45	0·00	0	—
August .	62·14	73·42	82·39	40·57	61·48	88	45	52·07	56·45	·297	·308	44·9	45·8	51	37	0·00	0	—
September	68·80	77·86	86·70	57·76	72·23	90	53	56·26	60·43	·338	·361	48·3	50·1	48	37	0·14	2	0·07
October .	70·45	74·93	86·38	60·41	73·40	90	57	60·93	61·80	·447	·430	56·0	54·9	60	50	0·66	5	0·40
November	67·10	70·96	80·36	60·00	70·18	88	58	62·80	65·10	·531	·564	60·8	62·4	80	75	5·56	22	1·12
December	66·97	69·45	78·90	59·22	69·06	85	57	63·06	63·70	·541	·536	61·3	61·0	82	74	11·43	18	4·04
1898	65·05	71·37	80·83	55·41	67·79	90	42	59·46	62·5	·461	·484	56·3	57·6	74	64	54·41	124	4·04

The instrumental errors (if any) are not known. The mean is deduced from ½ (max. + min.) and are consequently too high.

Rainfall in Nyasaland.

Month	LOWER SHIRE[1]			CHOLO[2]			BLANTYRE[3]		ZOMBA[4]		MLANJE[5]						UPPER SHIRE[6]		NYASA LAKE SHORE[7]				CENTRAL ANGONI LAND[8]			
	Port Herald	Chiromo	Chikwawa	Nkawa	Matande Estate	Pamula Estate	Blantyre Mission	Myara Estate	Zomba	Domasi	Lauderdale	Dunraven Estate	Luchenya Estate	Fort Anderson	Fort Lister	Lukulesi Estate	Liwonde	Fort Johnston	Likoma	Nkata Bay	Deep Bay	Karonga	Dedza	Fort Mlangeni	Mkoma	KAMBOLA (Tanganyika Plain)
1898	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	4·65	—	—	11·77	—	7·45	8·69	—	11·62	10·19	13·28	13·34	8·94	14·91	—	—	8·26	7·54	—	10·64	10·40	7·76	—	—	—	12·64
February	8·29	—	—	15·11	—	3·54	8·74	—	15·42	13·61	34·64	26·21	25·90	32·37	—	—	10·20	8·68	—	23·30	—	11·19	—	—	—	8·30
March	4·76	—	—	7·88	—	11·27	7·28	—	7·60	5·57	10·49	9·84	8·62	—	2·27*a*	7·18*b*	3·92	6·89	—	14·10	—	13·83	—	—	—	9·06
April	—	—	—	10·91	12·81	12·50	5·48	4·14	11·74	5·51	25·12	17·60	22·86	19·82	5·51	1·67	—	6·15	2·00	21·93	—	—	7·16	—	1·15	6·62
May	3·66	—	—	1·56	1·23	2·69	0·07	0·52	0·37	1·31	10·79	2·83	2·04	1·55	0·25	0·32	—	0·11	0·00	1·88	—	—	0·00	—	0·00	0·00
June	1·13	—	1·82	5·01	2·39	5·29	1·24	1·37	2·55	1·62	7·84	7·35	3·78	7·00	0·94	0·76	0·41	0·47	0·00	5·03	—	—	9·07	—	0·00	0·00
July	0·00	—	0·39	2·11	1·06	2·60	0·00	0·52	0·87	0·38	8·16	5·07	4·32	8·16	—	0·00	0·00	0·02	0·00	1·27	—	—	0·00	—	0·00	0·00
August	0·72	—	—	2·26	1·03	1·96	0·21	0·44	0·15	0·17	4·57	4·09	2·41	4·18	—	0·00	0·50	0·27	0·00	1·49	—	—	0·00	—	0·00	0·00
September	0·27	—	—	0·73	0·98	0·69	0·00	0·00	1·80	0·61	6·59	1·14	1·16	13·30	—	1·08	0·00	0·04	0·00	1·22	—	—	0·00	—	0·00	0·17
October	0·03	2·23	—	1·72	1·00	0·92	0·40	0·27	0·95	1·02	4·86	2·23	1·45	4·07	0·08	1·23	0·00	0·42	0·00	0·00	—	—	0·84	—	0·00	0·66
November	0·30	1·92	—	2·30	3·88	3·47	3·18	3·78	0·35	—	8·62	9·89	12·64	7·96	—	2·48	0·78	2·06	1·59	1·60	0·86	—	2·40	2·78	1·18	5·56
December	2·43	5·89	—	13·70	16·82	10·16	12·10	14·32	8·81	8·34	24·04	22·49	21·25	20·30	11·07	8·58	—	9·36	6·16	8·26	—	—	14·12	7·80	—	11·43
1899																										
January	2·73	1·07	—	3·32	2·79	2·61	3·60	7·09	5·84	7·71	—	2·45	4·34	6·11	—	3·96	4·55	1·80	4·77	3·03	1·99	—	3·88	5·10	—	9·61
February	15·58	15·83	—	16·32	18·00	19·19	15·28	18·05	11·39	11·40	—	23·37	20·50	20·87	—	14·64	19·74	12·17	16·69	4·14	2·22	—	15·07	9·58	4·40	5·34
March	3·80	3·24	—	9·37	7·75	8·78	9·14	10·34	7·06	6·46	—	10·39	12·29	19·84	—	6·42	6·72	6·46	7·70	8·73	—	—	6·87	9·93	4·95	—
Year (April to March)	30·35	—	—	69·31	69·74	70·86	50·70	60·87	51·88	44·53	—	105·90	109·04	133·16	—	41·14	—	39·33	38·91	58·59	—	—	59·41	—	—	—

NOTES ON STATIONS.

[1] LOWER SHIRE.—*Port Herald*, on the west bank of the Shire, 16° 40′ S., 35° 15′ E., c. 120 ft.; observers, Ch. Ockenden and others. *Chiromo*, on the east bank of the Shire, 16° 31′ S., 35° 10′ E., c. 150 ft.; observer, Lewis O. Way. *Chikwawa*, on the east bank of the Shire, at the foot of the road leading to Zomba, 16° 3′ S., 35° 10′ E., c. 150 ft.; observer, A. W. Easterbrook.

[2] CHOLO HIGHLANDS.—Exact position of stations not known to me. Observers: at *Nkawa*, Geo. Adamson; at *Matande*, R. White; at *Pamula*, H. Kaisser.

[3] BLANTYRE.—15° 47′ S., 35° 5′ E.; observer, Jas. Reid. *Myara Estate*, near Blantyre; observer, T. H. Lloyd.

[4] ZOMBA.—*Domasi Mission*, 15° 18′ S., 35° 29′ E., to the north-east of Zomba, between Mount Zomba and Lake Shirwa; observer, Rev. Dr. H. E. Scott.

[5] MLANJE DISTRICT.—*Lauderdale*, 16° 2′ S., 35° 36′ E., 2,580 ft. south of Mount Mlanje; observer, J. W. Moir. *Luchenya*, 16° 3′ S., 35° 38′ E., estate of the Nyasaland Coffee Company, lies 4 miles to the south-east of it; observer, Moggridge. *Dunraven Estate*, 16° 4′ S., 35° 44′ E., 2,716 ft., 10 miles south-east, near Fort Anderson; observer, H. Brown. *Fort Anderson*, 16° 5′ S., 35° 44′ E.; observer, G. O. L. Ray. *Fort Lister*, 15° 50′ S., 35° 45′ E., lies to the north-east of Mount Mlanje; observer, Dr. Hallam Hardy. The *Lukulesi Estate* appears to lie to the north-west of Lauderdale; observer, D. B. Ritchie.

[6] UPPER SHIRE.—*Liwonde*, 15° 2′ S., 35° 16′ E., in Shire; observer, J. F. Whicker. *Fort Johnston*, 14° 28′ S., 35° 16′ E., 1,700 ft., lies on the western bank of the Shire, 2 miles above the old fort and station; observer, F. S. S. Wright.

[7] NYASA LAKE SHORE.—*Likoma*, 12° 5′ S., 34° 45′ E., 1,700 ft., station of the Universities' Mission, on an island near the eastern shore of the lake, where the rainfall is much less than along the western shore; observer, Rev. A. G. B. Glossop. *Nkata Bay*, 11° 36′ S., 34° 18′ E., on western shore; observer, C. A. Cardew. *Deep Bay*, 10° 26′ S., 34° 12′ E., on western shore. *Karonga*, 9° 56′ S., 33° 58′ E., near German boundary; observer, Jas. B. Yule.

[8] CENTRAL ANGONI LAND.—*Dedza*, 11° 50′ S., 34° 5′ E., near Mount Dedza, 7,000 ft. *Fort Mlangeni*, S. of preceding? *Mkoma*, 11° 30′ S., 34° E., station near Mount Mkoma, 7,000 ft.; observer, T. C. Vlok.

a. 11th to 31st only. *b*. 5th to 31st only.

Lauderdale, Mlanje. Lat. 16° 2′ *S., Long.* 35° 36′ *E.,* 2,850 *feet. Observers: John W. Moir* (1897 *and* 1898) *and Mr. Thomson* (1896).

Month	Aneroid			Mean Temperature						Temp. Extremes		Mean Temp. Wet Bulb			Dew Point			Vapour Pressure			Relative Humidity			Rain			Cloud (0–10)		
	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	Max.	Min.	Mean	Highest	Lowest	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	Amount	Days	Highest Fall	7 A.M.	2 P.M.	9 P.M.
1896	In.	In.	In.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	In.	In.	In.	p.c.	p.c.	p.c.	In.	No.	In.			
January . .	27·184	27·141	27·179	67·6	76·4	71·5	79·5	66·7	71·8	87·6	63·8	65·1	72·2	67·4	63·9	70·6	65·6	·593	·747	·629	88	82	81	16·29	27	2·46	6·0	9·0	5·7
February . .	·210	·147	·204	67·5	77·5	71·1	80·3	67·1	72·0	87·8	65·2	66·1	74·1	68·4	65·4	70·2	65·8	·626	·736	·633	93	78	83	25·87	23	2·49	6·7	8·4	5·1
March. . .	·240	·184	·244	66·7	77·3	70·8	80·2	66·3	71·6	85·2	62·2	65·0	72·7	68·7	64·2	71·0	67·8	·599	·756	·679	92	81	90	16·00	25	3·14	4·0	8·1	5·1
April . . .	·267	·226	·281	65·3	74·2	69·1	77·5	64·4	69·3	82·6	60·7	63·6	70·3	66·5	62·8	68·7	65·3	·570	·700	·623	92	83	87	17·54	19	3·66	3·4	7·7	3·9
May . . .	·346	·312	·377	64·8	73·0	65·4	75·9	60·1	67·7	82·1	57·9	57·8	67·2	61·5	53·4	64·5	59·4	·408	·607	·506	66	75	81	3·24	9	1·02	3·4	4·7	2·8
June . . .	·358	·358	·409	57·8	74·0	63·4	74·0	56·6	65·1	76·5	54·0	54·2	62·8	58·1	51·8	56·7	54·9	·384	·459	·430	80	54	74	0·65	3	0·59	1·5	3·0	1·5
July . . .	·443	·428	·469	57·0	68·2	61·3	70·5	55·4	62·2	78·2	51·0	53·4	62·0	57·2	50·9	58·8	54·7	·372	·493	·427	80	72	79	4·45	11	1·34	2·8	5·8	3·7
August . .	·420	·230	·440	—	—	—	76·2	59·6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2·13	6	—	—	—	—
September . .	·411	·260	·420	63·3	83·1	72·4	87·0	61·2	72·9	92·0	81·0	56·8	67·2	62·1	52·6	59·4	55·8	·396	·506	·444	69	44	56	--	—	—	0·5	1·0	0·0
October . .	·300	·280	·300	66·6	81·2	70·4	86·1	64·8	72·7	94·5	61·1	61·9	70·0	64·3	59·4	65·2	61·4	·506	·620	·542	77	59	75	2·74	7	1·45	0·5	5·0	1·1
November . .	·270	·130	·131	67·1	85·7	73·3	91·4	65·9	75·4	100·3	59·9	64·3	72·7	66·3	62·9	67·5	63·0	·573	·672	·575	86	55	70	6·08	5	5·07	1·3	3·4	2·0
December . .	·250	·180	·200	69·5	77·5	71·7	83·9	64·0	72·9	100·4	57·3	68·2	73·3	69·4	67·6	71·7	68·4	·875	·776	·694	93	82	89	13·16	26	1·80	4·4	8·2	7·2
Year . .	27·306	27·240	27·304	—	—	—	80·2	62·7	—	100·4	51·0	—	—	—	—	—	—	—	—	—	—	—	—	108·15	161*	5·07*	3·1*	5·8*	3·5*

Lauderdale—continued.

Month	Mean Temperature						Temp. Extremes		Mean Temp. Wet Bulb			Dew Point			Vapour Pressure			Relative Humidity			Rain			Cloud (0–10)		
	6 A.M.	2 P.M.	9 P.M.	Max.	Min.	Mean	Highest	Lowest	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	Amount	Days	Highest Fall	7 A.M.	2 P.M.	9 P.M.
1897	°	°	°	°	°	°	°	°	°	°	°	°	°	°	In.	In.	In.	p.c.	p.c.	p.c.	In.	No.	In.			
January . .	69·0	76·2	71·6	82·6	67·4	72·3	90·0	64·0	67·4	72·6	69·0	66·7	71·2	67·9	·654	·763	·681	92	85	89	18·17	20	3·67	5·6	8·0	8·0
February . .	68·4	76·9	71·5	83·3	66·6	72·3	86·8	63·0	66·3	73·7	69·6	65·3	72·5	68·8	·624	·798	·702	90	86	91	11·88	25	2·84	6·2	7·0	6·4
March. . .	67·2	79·6	72·1	83·9	66·0	73·0	88·2	60·5	66·2	76·9	70·9	65·8	76·0	70·5	·633	·896	·743	95	89	95	8·45	16	2·94	7·1	0·4	1·4
April . . .	64·3	75·0	67·8	77·9	63·2	69·0	84·8	58·4	63·9	72·1	66·3	63·7	71·0	67·1	·539	·757	·664	97	87	98	6·59	20	1·77	3·2	5·8	3·1
May . . .	62·9	75·3	—	78·9	60·2	66·9	81·5	57·1	60·9	68·4	—	60·3	65·2	—	·523	·620	—	92	71	—	1·27	8	0·69	2·5	3·6	5·0
June . . .	—	—	—	66·8	54·4	—	73·9	50·1	—	—	—	—	—	—	—	—	—	—	—	—	8·07	14	2·66	8·3	—	9·7
July . . .	—	—	60·6	71·6	54·7	—	78·0	47·3	—	—	55·1	—	—	51·4	—	—	·378	—	—	72	0·55	5	0·27	3·1	—	2·0
August . .	—	—	—	81·2	52·8	—	86·2	49·2	—	—	—	—	—	—	—	—	—	—	—	—	2·27	5	0·97	4·9	—	4·3
September . .	—	78·4	73·9	85·8	—	—	93·3	50·7	—	69·2	64·9	—	65·1	60·3	—	·619	·523	—	64	63	0·46	3	0·28	2·8	1·4	—
October . .	68·9	—	72·9	92·7	63·6	—	99·1	50·1	61·3	—	63·6	57·0	—	58·8	·464	—	·495	66	—	61	0·57	2	0·56	0·0	—	0·3
November . .	70·3	87·3	77·1	90·6	68·1	78·2	99·0	60·3	66·4	74·3	68·8	64·6	69·3	65·1	·608	·715	·619	82	55	66	2·85	13	0·75	6·1	7·1	3·6
December . .	69·3	79·9	73·3	84·6	68·2	74·2	95·9	59·7	67·1	73·5	69·7	61·1	71·1	68·2	·641	·759	·689	90	74	84	17·88	26	3·98	7·2	7·9	6·5
Year . . .	—	—	--	81·6	—	—	99·1	47·3	—	—	—	—	—	—	—	—	—	—	—	—	79·01	157	3·98	4·7	—	—

NOTE.—The observations have been taken as recorded. Several of the blanks are due to obvious errors in the Registers, due, possibly, to the copyists.

LAUDERDALE—continued.

Month	Mean Temperature						Temp. Extremes		Mean Temp. Wet Bulb			Dew Point			Vapour Pressure			Relative Humidity			Rain			Cloud (0-10)		
	6 A.M.	2 P.M.	9 P.M.	Max.	Min.	Mean	Highest	Lowest	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	6 A.M.	2 P.M.	9 P.M.	Amount	Days	Highest Fall	7 A.M.	2 P.M.	9 P.M.
1898	°	°	°	°	°	°	°	°	°	°	°	°	°	°	In.	In.	In.	p.c.	p.c.	p.c.	In.	No.	In.			
January . .	68·9	79·7	73·5	83·6	68 9	74·0	88·4	64·5	67·5	73·7	69·7	66·9	70·6	68·2	·658	·747	·689	92	74	83	13·28	28	1.43	5·0	4·7	3·8
February . .	67·3	76·1	70·7	79·3	66·4	71·4	85·0	62·3	65·2	71·7	68·0	64·2	70·0	67·1	·600	·731	·663	90	82	89	34·64	26	6·40	5·6	4·0	6·7
March . . .	67·3	77·4	71·2	80·1	66·9	71·9	85·3	62·3	65·6	72·8	67·9	64·8	71·1	66·4	·612	·759	·648	92	80	85	10·49	26	2·18	5·4	5·2	5·0
April . . .	64·4	80·3*	72·1*	76·2	63·1	72·3	86·4	56·9	61·7	72·8*	67·6*	60·2	69·9	65·6	·522	·730	·629	87	71	80	25·12	20	5·63	7·2	4·0*	2·0*
May . .	61·3	69·8*	64·4*	73·0	59·8	65·2	80·1	56·3	60·2	63·6*	60·7*	59·6	60·4	58·6	·510	·525	·493	95	72	81	10·79	15	6·74	7·6	6·6*	4·9*
June . . .	58·4	66·3	61·2	67·4	57·3	63·0	76·0	54·4	55·8	61·5	57·2	54·2	58·9	54·7	·419	·497	·428	86	77	81	7·84	19	2·45	5·5	6·7	5·7
July . . .	56·6	66·0	61·8	67·0	55·6	61·5	78·1	51·2	55·0	61·6	57·6	53·9	59·2	55·7	·416	·503	·443	91	78	81	8·16	20	1·52	4·7	6·9	5·3
August . .	55·4*	64·5	61·7	69·0	55·0	60·5	78·6	52·0	53·2	62·9	57·5	51·9	60·7	54·9	·383	·530	·431	88	88	79	4·57	13	1·54	3·5	6·0	5·0
September . .	61·7	79·1	69·1	79·5	61·0	70·0	87·6	54·4	56·3	66·4	61·1	52·9	60·2	56·6	·399	·520	·458	73	52	62	6·56	7	1·17	2·8	4·1	2·3
October . .	67·0	85·1	74·7	89·9	65·6	75·6	95·0	54·1	60·9	70·3	63·7	57·5	63·8	57·9	·473	·591	·479	71	49	56	4·86	6	3·09	1·3	4·2	1·2
November . .	69·3	85·8	74·1	89·3	67·3	76·4	95·0	61·1	65·9	75·0	67·2	64·3	71·0	64·0	·602	·758	·596	84	60	71	8·62	10	1·94	2·8	5·6	3·1
December . .	67·8	78·8	72·5	81·8	66·3	73·0	92·2	63·1	65·9	72·2	67·8	65·1	73·6	64·8	·617	·828	·612	91	84	77	24·04	17	9·67	7·3	7·3	4·8
Year . . .	63·8	75·7	68·9	78·0	62·8	69·5	95·0	51·2	61·1	68·6	63·8	59·6	65·3	61·2	·518	·643	·547	87	72	77	158·87	207	9·67	4·9	5·4	4·1

NOTE.—The observattions have been taken as recorded. Several of the blanks are due to obvious errors in the Registers, due, possibly, to the copyists.

* Returns incomplete.

Nkawa Estate, Cholo. *Lat.* 16° 3′ *S.*, *Long.* 35° 10′ *E.*, 3,400 *feet.* *Observer : Geo. Adamson.*

1898	Mean Temp.			Rain				Cloud (0-10)			Bright Sunshine
	7 A.M.	2 P.M.	9 P.M.	Amount	Days	Heaviest Fall	Thunder-storms	7 A.M.	2 P.M.	9 P.M.	
	°	°	°	In.	No.	In.	No.				Hours
January .	69·3	77·0	69·9	11·77	17	2·81	12	3·7	6·7	5·7	130
February .	65·2	74·3	67·0	15·11	13	2·14	1	6·5	7·7	6·1	79
March . .	67·1	77·6	67·7	7·88	13	2·10	8	5·0	5·8	4·3	127
April . .	63·9	74·7	67·2	10·91	8	3·02	—	4·8	4·1	1·9	[135]
May . . .	59·1	73·2	61·3	1·56	5	0·49	—	4·6	3·6	1·6	196
June . .	54·8	66·1	57·7	5·01	10	1·32	—	5·8	6·1	6·0	101
July . . .	54·7	67·6	56·2	2·11	6	0·79	—	5·1	6·0	4·8	115
August . .	51·1	71·3	56·8	2·26	4	1·54	—	5·4	4·2	4·4	177
September .	59·3	85·7	63·4	0·73	2	0·48	—	2·4	2·6	2·0	261
October . .	66·5	87·2	69·3	1·72	3	0·91	2	3·0	2·5	1·8	245
November .	68·9	88·3	71·7	2·30	7	0·78	9	2·5	5·4	3·1	230
December .	67·5	81·4	69·6	13·70	15	4·27	9	3·7	6·7	3·8	180
Year . .	62·3	77·0	64·8	75·06	103	4·27	41	4·4	5·1	3·8	1,976

The observations have been freed from instrumental error. *Winds.*—Southerly (S.) from February to September; Northerly (N.E.) from October to January.

Nkata Bay, Nyasa. *Lat.* 11° 36′ *S.*, *Long.* 34° 18′ *E.*, 1,700 *feet.* *Observer : C. A. Cardew.*

1898	Mean Temp.			Rain				Cloud (0-10)			Bright Sunshine
	7 A.M.	2 P.M.	9 P.M.	Amount	Days	Heaviest Fall	Thunder-storms	7 A.M.	2 P.M.	9 P.M.	
	°	°	°	In.	No.	In.	No.				Hours
January . .	71·6	81·2	75·2	10·64	21	2·59	7	6·8	4·3	5·6	215
February . .	70·0	76·8	73·1	23·30	19	3·69	9	8·6	5·8	6·6	150
March . .	71·0	83·2	75·2	14·10	18	2·33	3	5·6	3·0	4·8	242
April . . .	69·2	83·2	72·5	21·93	25	4·90	7	7·2	5·2	4·9	202
May . . .	67·1	79·8	67·9	1·88	9	0·79	—	6·1	3·5	3·0	298
June . . .	62·4	75·9	64·3	5·03	10	1·15	—	6·6	3·6	4·4	245
July . . .	62·5	75·5	63·7	1·27	7	0·60	—	5·7	3·0	3·6	233
August . .	60·8	75·7	63·4	1·49	5	0·65	—	5·5	2·6	2·2	290
September . .	65·6	82·4	70·5	1·22	4	1·15	—	4·8	2·1	1·4	242
October . .	64·4	85·4	74·3	0·00	0	—	—	3·1	1·4	1·0	316
November . .	73·2	87·1	79·2	1·60	3	0·60	3	4·7	2·8	2·8	290
December . .	72·3	84·0	78·0	8·26	14	3·37	7	3·7	5·9	5·8	230
Year . .	67·5	80·90	71·4	90·72	135	4·90	36	5·3	3·6	3·8	2,983

The observations have been corrected for instrumental errors. A few estimates have been introduced for days when, owing to the absence of the observer, no entries were made.

Wind.—At 7 A.M. S.W. throughout the year; at 2 P.M. N.E. in January and February, S.E. in March and April; S.W. from May to August; and again S.E. and N.E. to the close of the year. At 9 P.M. S.W. or W. throughout the year.

Zomba. Lat. 15° 22′ *S., Long.* 35° 18′ *E., Alt.* 2,948 *feet. Observers: J. McClounie and J. Mahon.*

Months	Barometer (Reduced to Sea-level)			Mean Temperatures						Temp. Extremes		Mean Temp. Wet Bulb			Dew Point			Vapour Pressure			Relative Humidity			Rain			Thunderstorms	Cloud (0-10)			Bright Sunshine
	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	Mean Max.	Mean Min.	Mean	Highest	Lowest	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.	Amount	Days	Heaviest Fall		7 A.M.	2 P.M.	9 P.M.	
1897	In.	In.	In.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	In.	In.	In.	p.c.	p.c.	p.c.	In.	In.	In.	Dys.				Hrs.
November . .	29·704	29·553	29·657	72·2	85·8	75·6	88·5	67·6	77·3	93·8	64·0	65·1	67·9	65·5	61·5	59·2	65·5	·545	·502	·526	67	41	60	4·19	10	1·82	8	4·0	4·5	4·1	204
December . .	·692	·581	·637	69·8	78·7	70·6	76·9	64·4	72·4	92·2	61·0	67·4	70·1	67·2	66·4	67·7	67·2	·646	·678	·631	89	69	84	9·02	22	0·99	21	8·3	7·6	8·0	83
1898																															
January . .	29·678	29·548	29·646	69·8	78·4	71·0	81·2	65·9	72·3	86·0	63·2	67·4	73·0	65·1	66·4	70·9	65·1	·646	·756	·559	89	78	73	11·62	27	2·28	22	7·0	7·0	7·0	193
February . .	·692	·606	·591	66·7	74·4	67·9	77·6	63·7	69·2	84·0	60·5	64·8	68·3	65·4	63·9	66·1	65·4	·593	·640	·600	90	74	89	15·42	20	3·40	3	7·0	7·6	5·1	129
March . .	·690	·591	·679	67·7	78·4	69·0	78·9	64·7	71·0	83·5	61·3	65·5	69·3	66·3	64·5	65·3	66·3	·605	·624	·618	90	90	87	7·60	23	1·26	4	8·1	7·0	5·6	122
April . .	·788	·698	·888	64·4	73·1	66·4	75·4	61·7	67·6	84·5	56·0	62·3	67·6	63·8	61·3	65·1	63·8	·540	·619	·565	90	76	87	11·74	14	4·67	2	7·2	6·7	5·3	139
May . .	·864	·757	·845	61·1	72·0	63·2	76·9	58·0	64·9	82·0	53·8	57·9	63·9	59·2	56·0	59·7	59·2	·448	·512	·463	84	65	79	0·37	7	0·18	0	4·3	5·0	3·7	194
June . .	·970	·903	·990	57·1	66·4	59·2	68·4	54·4	62·9	76·2	50·0	54·3	59·1	55·8	52·4	54·7	55·8	·393	·428	·411	85	66	82	2·55	12	0·76	0	6·6	5·8	6·1	128
July. . .	·942	·907	·981	55·0	65·3	58·5	68·8	52·9	59·3	79·0	46·8	53·0	57·8	54·5	51·6	53·1	54·5	·382	·403	·384	88	65	79	0·87	6	0·44	0	5·7	6·4	5·0	156
August . .	30·052	·860	·899	55·4	69·2	59·5	71·4	52·3	60·9	79·0	46·0	51·5	57·6	54·1	48·5	50·0	54·1	·341	·359	·363	77	51	72	0·15	4	0·07	0	3·5	5·2	3·3	219
September .	29·877	·719	·812	62·7	77·1	64·0	79·0	58·1	66·9	85·0	50·5	57·4	62·3	58·2	54·1	53·7	58·2	·418	·413	·397	74	45	60	1·80	4	0·91	0	2·8	2·7	1·7	269
October . .	·777	·589	·697	68·5	83·6	75·9	85·4	62·6	75·9	92·8	54·0	62·7	70·0	65·0	61·8	64·0	65·0	·551	·596	·507	80	53	58	0·95	4	0·75	2	2·2	2·5	1·7	301
November .	·731	·482	·632	72·0	84·4	75·6	88·3	67·5	76·9	93·4	61·0	66·1	70·7	67·6	63·3	64·9	67·6	·581	·613	·594	75	53	65	0·35	4	0·16	7	4·0	5·3	4·7	234
December .	·684	·550	·628	73·2	79·9	70·4	83·6	65·1	73·5	89·5	62·3	66·8	70·3	66·8	63·8	67 5	66·8	·592	·673	·620	72	66	84	8·81	19	1·50	16	6·1	7·1	6·3	133
1898. . .	29·812	29·684	29·774	64·5	75·2	66·7	77·9	60·6	68·4	93·4	46·0	60·8	65·8	61·8	58·9	61 2	67·9	·508	·553	·507	83	65	77	62·23	144	4·67	56	5·4	5·7	4·6	2227

NOTES.

All observations have been corrected for instrumental error, with the exception of those of the barometer, the Kew verifications being only down to 27·5 in. The barometrical readings have been reduced by Mr. McClounie to 32°, to mean gravity in lat. 45°, and *to sea-level*, on the assumption that the cistern is 2,948 ft. above sea-level, the difference between Chiroma (assumed to lie only 125 ft. above the sea) and Zomba having been ascertained by spirit-levelling. This assumed altitude yields a mean pressure at the sea-level of 29·757 in. (January, 29·624 in.; July, 29·973 in.). The corresponding values, according to Buchan ('Scientific Reports of the Voyage of H.M.S. *Challenger*'), are 29·95 in., 29·80 in., and 30·10 in., and according to Dr. Hann ('Berghaus' Phys. Atlas') 30·00 in., 29·76 in., and 30·08 in. It should, however, be remembered that this assumed height of Zomba is merely an approximation. The observations have been reduced by Mr. McClounie, and since the beginning of this year this reduction is being made for each separate reading, and not from the means of the months—a most commendable practice, more honoured in the breach than the observance.

Abstracts of Sunshine and Wind observations, &c., have been made in London.

The most frequent wind blows from the E. (239 observations, total force 607, average 2·54), and next to it is the N.E. (55 observations, total force 170, average 3·09). The strongest wind blows from the N.W. (average force 3·25). The mean force of all the winds is 2·45 (compare 'Report' for 1897 for Mr. Moir's wind observations at Lauderdale).

Haze, usual in the plains, was observed twice in September, twice in October, and once in November.

Solar Radiation: February, 142·5; March, 142·2; April, 135·2; May, 133·9.

The STATION is situated on the southern slope of Mount Zomba, and is open on the south, east, and west, with an unobstructed view extending nearly fifty miles across the Shirwa Plain. The ridge of Mount Zomba rises behind it about 4,500 ft., and completely protects it from the north wind.

The thermometers are placed under a grass hut or roof open on all sides. The rain-gauge is in the open, and is uninfluenced by trees or houses. The barometer is hung in a verandah room used as an office, and of very equable temperature.

ZOMBA—*continued.* *Direction and Force of Wind.*

Month	North-east						East						South-east						South						South-west						West					
	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.		7 A.M.		2 P.M.		9 P.M.		7 A.M.		2 P.M.		9 P.M.	
	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force	No.	Total Force
1897																																				
November .	1	1	2	7	5	10	29	56	28	55	24	19	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
December .	2	7	—	—	—	—	14	9	15	22	11	6	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	4	8	5	3
1898																																				
January .	—	—	4	13	2	5	16	17	19	41	8	5	—	—	—	—	—	—	—	—	—	—	2	0	1	0	1	0	—	—	1	3	4	4	1	5
February .	—	—	1	2	1	1	4	9	6	14	2	4	4	4	5	10	—	—	—	—	1	2	—	—	2	2	9	10	3	7	1	2	—	—	—	—
March . .	—	—	—	—	—	—	3	3	13	32	1	2	1	1	1	2	—	—	—	—	—	—	—	—	—	—	2	3	1	1	—	—	1	3	—	—
April . .	—	—	—	—	—	—	3	9	10	22	3	6	—	—	—	—	1	2	—	—	—	—	—	—	2	5	—	—	3	7	—	—	—	—	—	—
May . .	—	—	1	3	—	—	2	5	5	13	—	—	—	—	2	10	—	—	—	—	—	—	—	—	1	2	1	2	2	4	1	2	—	—	—	—
June . .	—	—	4	21	—	—	2	5	—	—	2	7	—	—	1	2	—	—	—	—	3	8	1	2	1	2	3	6	—	—	2	4	2	7	—	—
July . .	—	—	—	—	—	—	3	7	8	22	1	2	—	—	1	2	—	—	—	—	—	—	1	2	2	4	4	7	1	2	3	3	2	3	5	10
August .	1	2	1	2	2	2	6	14	10	26	—	—	1	3	3	6	—	—	—	—	—	—	—	—	3	9	2	2	—	—	—	—	1	2	—	—
September .	7	22	12	37	6	18	5	16	7	24	3	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
October .	3	12	1	3	4	9	20	52	26	63	5	8	1	2	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
November .	—	—	1	4	1	3	2	67	21	66	4	8	1	2	1	5	—	—	—	—	—	—	—	—	—	—	2	2	—	—	—	—	2	3	—	—
December .	1	2	2	9	—	—	8	17	11	19	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2	1	2	—	—	2	4	5	11	2	4
1898 . .	12	38	27	94	16	38	74	221	136	342	29	48	8	12	15	39	1	2	—	—	4	10	4	4	13	26	25	33	10	21	10	18	17	33	8	14

Zomba—continued. Direction and Force of Wind—continued.

Month	North-west						Calms		
	7 A.M.		2 P.M.		9 P.M.		7 A.M.	2 P.M.	9 P.M.
	No.	Total Force	No.	Total Force	No.	Total Force			
1897									
Nov.	—	—	—	—	1	6	—	—	—
Dec. .	5	9	8	18	5	3	9	4	10
1898									
Jan. .	4	24	3	10	4	10	9	—	14
Feb. .	1	2	1	0	—	—	16	5	22
Mar.	—	—	—	—	—	—	26	13	28
April	—	—	—	—	—	—	25	20	23
May .	—	—	—	—	—	—	27	22	29
June	1	4	2	5	—	—	24	15	27
July .	2	4	1	2	—	—	21	15	23
Aug.	—	—	—	—	—	—	20	14	29
Sept.	—	—	—	—	—	—	18	11	21
Oct. .	—	—	—	—	—	—	7	3	22
Nov.	—	—	—	—	—	—	8	3	25
Dec. .	1	4	—	—	—	—	18	12	29
1898	9	38	7	17	4	10	228	137	302

Takaungu. Lat. 30° 41′ *S., Long.* 39° 52′ *E. Observer : G. H. L. Murray.*

Month	Rain		
	Amount	Days	Heaviest fall in 24 hours
1898	In.	No.	In.
May . .	2·62	9	0·65
June . .	2·96	9	1·40
July . .	4·75	17	1·13
August . .	1·20	6	0·33
September .	1·54	6	0·90
October . .	0·00	0	—
November .	2·34	7	1·65
December .	0·21	2	0·15

Fort Johnston. Lat. 14° 28′ *S., Long.* 35° 15′ *E.,* 1,700 *feet. Observer: Francis S. S. Wright.*

Months	Barometer (as read)			Mean Temperature						Temp. Extremes		Mean Temp. Wet bulb			Dew Point			Vapour Pressure			Relative Humidity			Rain (0–10)			Thunderstorm	Cloud (0-10)			Bright Sunshine	Force of Wind (1-12)[1]	Mist or Fog[2]
	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	Mean max.	Mean min.	Means	Highest	Lowest	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.	Amount	Days	Heaviest Fall		7 A.M.	2 P.M.	9 P.M.			
1898.	In.	In.	In.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	In.	In.	In.	P.c.	P.c.	P.c.	In.	No.	In.	Days				Hours		
January .	28·323	28·235	28·293	75·6	84·3	75·7	88·0	71·7	77·8	92·9	67·5	72·8	76·3	74·0	71·7	73·4	73·4	·776	·821	·821	87	70	92	7·54	23	2·75	3	7·0	6·6	6·4	185	6·1	3
February .	·338	·255	·305	72·5	84·0	74·1	86·0	69·2	76·2	91·9	66·8	70·1	73·7	71·4	69·1	69·6	70·3	·710	·722	·740	89	62	87	8·68	14	2·23	2	8·0	7·0	5·0	213	3·0	7
March .	·325	·263	·316	73·4	82·8	74·0	87·9	69·5	76·0	94·5	65·5	71·4	75·5	71·8	70·6	72·8	70·9	·748	·805	·755	90	72	90	6·89	18	1·77	3	7·5	7·5	4·8	241	2·8	4
April .	·405	·324	·382	69·6	81·1	71·0	84·6	65·9	73·2	94·7	60·0	67·8	72·3	68·6	67·0	68·6	67·5	·661	·699	·643	92	68	89	6·15	13	3·46	1	6·2	5·7	4·4	228	2·8	—
May . .	·467	·394	·444	64·6	82·5	67·3	84·2	60·2	69·6	90·9	54·6	62·6	69·5	63·6	61·6	63·4	61·7	·547	·583	·549	90	52	82	0·11	1	0·11	0	3·6	4·3	1·3	269	3·0	—
June . .	·571	·516	·563	61·0	76·4	64·6	78·4	57·7	66·7	89·7	51·4	56·0	65·3	61·0	52·7	59·4	59·0	·398	·506	·499	74	56	82	0·47	6	0·14	0	6·4	6·2	5·9	189	3·0	—
July . .	·607	·500	·546	59·9	76·2	64·6	79·4	56·7	66·3	87·5	51·8	57·7	63·9	59·4	56·4	57·0	56·2	·454	·464	·452	88	52	74	0·02	2	0·01	0	5·9	5·9	4·4	194	2·4	1
August .	·588	·448	·558	57·9	79·1	65·9	81 3	56·2	67·2	90·0	49·7	56·9	63·4	59·3	56·3	54·1	55·2	·453	·418	·436	95	42	69	0·27	3	0·15	0	5·2	6·0	3·4	247	3·0	—
September	·467	·353	·413	68·6	87·3	71·7	89·7	61·7	74·9	96·0	53·5	63·3	70·4	65·9	60·5	62·4	63·2	·526	·564	·576	76	43	75	0·04	1	0·04	0	3·6	6·0	1·9	252	3·6	—
October .	·379	·277	·326	74·7	94·0	77·9	96·9	65·4	81·1	105·9	60·0	67·8	75·9	71·3	64·2	68·8	68·6	·597	·702	·697	70	45	72	0·42	2	0·41	0	2·0	4·5	2·6	312	2·5	—
November	·325	·181	·267	78·7	94·6	79·2	99·3	71·8	82·9	105·8	66·8	70·5	75·9	73·6	66·9	68·5	71·5	·658	·696	·769	66	43	78	2·06	7	0·81	1	6·4	7·7	6·0	227	1·9	—
December	·315	·233	·286	75·7	92·0	77·9	93·6	69·0	80·1	105·0	64·0	71·7	76·1	72·1	70·1	69·6	69·8	·735	·722	·726	83	49	76	9·36	17	1·72	1	7·5	8·2	6·3	157	1·7	—
1898	28·426	28·332	28 392	69·3	84·5	72·0	87·4	64·7	74·3	105·9	49·4	65·7	71·5	67·7	63·9	64·8	65·6	·605	·642	·639	83	54	80	42·01	107	3·46	11	5·8	6·3	4·4	2,714	2·9	14

All observations have been corrected for instrumental error. The bulbs of the thermometers are 4 feet above the ground; the rim of the rain-gauge 1 foot.

Earthquake.—It occurred on September 24, at 1.18 P.M., lasting 10–15 secs.; direction from the South.

[1] A whirlwind on November 15 at 1.45 P.M.

[2] Haze ('smoke') is only put down for four days in October, but the first half of September is described as 'smoky.'

Kisimayu. Lat. 0° 22′ *S., Long.* 43° 33′ *E. Observers: R. G. Farrant and J. W. P. McClellan.*

Months	Atmospheric Pressure		Mean Temp. 9 A.M.	Rain		
	9 A.M.	3 P.M.		Amount	Days	Heaviest fall in 24 hours
1898	In.	In.	°	In.	No.	In.
January .	29·876	—	81·2	·00	0	—
February .	·836	—	80·8	·00	0	—
March .	·803	—	82·6	·00	0	—
April .	·827	—	84·2	0·45	2	0·35
May .	·862	30·050	81·8	7·83	9	3·44
June .	·963	·139	79·4	1·13	8	0·42
July .	·946	·121	77·6	1·15	5	0·30
August .	·974	·168	77·7	0·34	5	0·20
September	·941	·114	78·9	0·01	1	0·01
October .	·912	·102	80·2	0·00	0	—
November.	·830	·008	82·2	0·00	0	—
December.	·852	·012	82·1	0·00	0	—
1898	29·885	—	80·8	10·91	30	3·44

The readings have been corrected for instrumental errors.

The barometrical readings at 9 A.M. have been reduced to standard temperature of 32° and standard gravity in lat. 45°, but those for 3 P.M. are given as recorded, as no temperature observations were made prior to November. The corrected pressure for November is 29·779 inches, for December 29·786 inches.

In the course of November the wind shifted steadily round, and on the 30th was blowing due N.E., and all dhows had ceased coming from the south.

Fort Smith, Kikuyu. Lat. 1° 14′ *S., Long.* 36° 44′ *E.,* 6,400 *feet. Observers: D. C. T. Macpherson, Francis C. Hall, & Ch. Wiese.*

Month	Mean Temp. 9 A.M.		Humidity 9 A.M.			Rain		
	Dry	Wet	Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest fall in 24 hours
1898	°	°	°	In.	P.c.	In.	No.	In.
January .	65·19	62·22	60·9	·533	86	1·47	3	0·70
February .	68·28	63·05	60·8	·532	77	2·22	3	1·82[1]
March .	64·77.	61·97	60·7	·531	87	3·70	8	1·06
April .	66·40	63 28	62·0	·554	86	6·76	11	2·35
May .	63·87	61·84	60·9	·533	90	5·63	14	1·34
June .	58·63	56·66	55·7	·444	90	6·01	10	1·26
July .	59·70	57·16	56·0	·447	88	0·61	2	0·37
August .	57·99	55·95	54·2	·419	85	0·27	1	0·27
September	61·19	58·12	56·5	·456	85	0 85	[3·]	—
October .	64·03	61·00	59·6	·510	85	2·13	7	0·59
November	62·40	60·00	58·9	·496	88	4·92	16	1·61
December.	63·80	59·55	57·3	·470	82	1·62	7	0·42
1898	63·02	60·07	58·6	·497	86	36·19	85	2·37

NOTE.—The readings have been corrected for instrumental error. In computing the Dew Point, &c., a pressure of 23·6 inches has been assumed.

At the station of the East African Scottish Mission, within 2½ miles of Fort Smith, the rainfall was 2·21 inches (on 10 days) in October, 6·91 inches (19 days) in November, 5·07 inches (8 days) in December. (Observer: Rev. T. Watson.)

[1] A very heavy thunderstorm, with hail, began at 3 P.M. on February 28, and ceased at 3.30 P.M., during which time 1·51 inches fell.

Mombasa. 4° 4′ *S.*, 39° 42′ *E.*, 60 *feet.*
Observer: C. R. Craufurd.

Month	Pressure of Atmosphere 9 A.M.	Temperature Extremes		Mean Temperatures, 9 A.M.					Daily Range	Humidity, 9 A.M.			Rain		
		Highest	Lowest	Dry	Wet	Mean Max.	Mean Min.	Mean		Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest fall in 24 hours
1898	In.	°	°	°	°	°	°	°	°	°	In.	P.c.	In.	No.	In.
January .	29·936	86·3	71·9	82·9	80·8	86·3	73·4	79·8	12·9	80·1	1·026	91	—	—	—
February .	·854	86·3	71·9	81·8	79·0	86·3	72·7	79·5	13·6	78·0	·958	88	—	—	—
March .	·823	86·8	72·9	84·0	80·5	86·3	73·3	79·8	13·0	79·4	1·001	86	0·52	4	0·20
April .	·825	86·3	68·9	85·2	80·6	85·1	73·5	79·1	11·6	79·1	·992	82	1·03	4	0·73
May . .	·909	86·3	76·4	83·2	80·0	85·1	78·6	81·8	6·5	78·9	·987	88	4·30	5	1·65
June. .	·816	86·3	74·9	80·0	77·2	83·8	77·3	80·5	6·5	76·2	·901	88	2·55	2	2·50
July . .	·966	84·3	73·9	77·4	74·5	82·3	74·4	78·4	7·9	73·4	·820	87	5·27	6	2·00
August .	·977	82·3	74·9	78·3	75·5	81·5	75·9	78·7	5·6	74·4	·850	88	0·75	1	0·75
September	·983	82·3	75·9	79·6	76·7	82·3	76·5	79·4	5·8	75·8	·885	88	5·18	6	1·70
October .	·874	84·3	75·9	79·1	76·3	83·0	78·0	80·5	5·0	76·3	·904	91	0·70	2	0·50
November	·863	87·3	78·9	82·5	80·2	85·9	79·1	82·5	6·8	79·5	1·004	91	1·80	3	1·00
December .	·853	87·3	77·9	83·5	80·9	86·3	80·5	83·4	5·8	80·0	1·023	89	—	—	—
1898 . .	30·889	87·3	68·9	81·4	78·5	84·5	76·2	80·3	8·4	75·9	·946	88	—	—	—

NOTE.—All readings have been corrected for instrumental errors, except those of the barometer and its attached thermometer, the corrections for which are not known.

The barometrical observations have been reduced to 32° F. and Lat. 45°, but not to sea-level.

The mean temperature is assumed to be the mean of all max. and min., and is therefore too high.

No observations were made on Sundays, but the rain was allowed to collect in the rain-gauges.

Shimoni (Wanga). 4° 38′ *S.*, 39° 21′ *E.*
Observers: J. W. Tritton, H. B. Comyn, and H. H. Carvalho.

Month	Atmospheric Pressure		Mean Temp. 9 A.M.		Humidity			Rain			Prevailing Wind at 9 A.M.								
	9 A.M.	3 P.M.	Dry	Wet	Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest Fall	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Cal.
1898								In.	No.	In.									
January .	29·778	—	83·2	83·0	82·9	1·125	99	0·30	2	0·29	2	1	15	10	1	1	—	1	—
February .	·760	—	85·1	81·4	80·2	1·029	85	0·14	4	0·10	—	1	27	—	—	—	—	—	—
March .	·763	—	85·6	83·6	83·0	1·127	92	1·60	5	0·50	—	6	10	5	2	8	—	—	—
April .	·853	—	83·4	82·2	81·8	1·085	95	3·83	8	2·80	—	—	—	3	8	19	—	—	—
May . .	·903	29·849	80·2	79·2	78·8	·984	95	3·90	11	1·51	—	—	—	—	21	9	1	—	—
June . .	30·000	·921	76·9	75·3	74·7	·857	93	4·50	17	0·85	—	—	—	3	5	22	—	—	—
July . .	·021	·976	75·3	73·9	73·4	·821	94	7·47	17	1·50	—	—	—	—	6	10	15	—	—
August .	·003	·955	75·0	74·0	73·6	·827	95	1·30	8	0·41	—	—	—	—	10	21	—	—	—
September	29·985	·934	77·6	75·9	75·3	·874	92	1·13	5	0·70	—	—	—	—	12	9	6	3	—
October .	·977	·908	79·0	77·6	77·1	·929	94	0·42	2	0·41	—	—	—	—	4	19	5	3	—
November	·901	·896	81·6	80·4	80·0	1·022	95	2·71	6	0·97	—	—	1	4	3	20	—	2	—
December .	·867	·814	85·1	82·5	81·7	1·080	89	0·00	0	—	8	4	16	—	—	—	—	3	—
Year . .	29·901	—	80·7	79·1	78·5	·974	93	27·30	85	2·80	10	12	69	25	72	138	27	12	—

NOTE.—All instruments used have been corrected for instrumental errors (see 'Report for 1898,' p. 4).

The barometer readings have been reduced to 32° F. and lat. 45° N., but not to sea-level.

Machako's, Lat. 1° 31′ *S., Long.* 37° 18′ *E.,* 5,400 *feet. Observers: J. Ainsworth, R. Crawshay, and W. Maclellan Wilson.*

Month	Mean Temp. 9 A.M.		Humidity 9 A.M.			Rain			
						Amount			
	Dry	Wet	Dew Point	Vapour Pressure	Relative Humidity	Day 6 A.M. to 6 P.M.	Night 6 P.M. to 6 A.M.	Days	Heaviest fall in 24 hours
1898	°	°	°	In.	P.c.	In.	In.	No.	In.
January	67·38	62·75	60·2	·527	79	0·40	0·97	4	0·67
February	70·23	66·00	64·2	·600	81	0·29	1·70	4	1·19
March	67·93	65·94	65·1	·618	90	0·71	2·32	9	0·65
April	68·53	67·07	66·6	·650	93	0·17	3·55	11	0·51
May	68·20	64·10	62·3	·560	81	1·25	2·17	11	2·37
June	63·53	59·92	58·0	·481	82	0·59	0·26	5	0·72
July	62·70	54·62	49·5	·353	65	0·00	0·02	1	0·02
August	63·03	59·57	56·8	·478	80	0·02	0·00	1	0·02
September	65·41	60·88	58·7	·493	79	0·32	0·42	3	0·32
October	68·47	64·17	62·3	·560	81	0·015	0·625	4	0·340
November	66·47	61·97	59·6	·515	78	3·305	4·273	18	1·499
December	66·95	61·10	58·3	·486	74	0·750	0·161	11	0·540
1898	66·57	62·34	60·2	·527	80	7·820	16·499	72	2·37

NOTE.—The readings have been corrected for instrumental error.

Up to the end of September no observations were made on Sundays, except as to rainfall; the observations for September only embrace 17 days.

Since October Mr. W. Maclellan Wilson is also recording Clouds and Wind.

In computing the Dew Point, &c., a mean pressure of 24·5 inches has been assumed.

Lamu. Lat. 2° 16′ *S., Long.* 40° 54′ *E. Observers: A. S. Rogers, W. B. Comyn, and K. Macdougall.*

Month	Mean Temp. 9 A.M.		Humidity 9 A.M.			Rain		
	Dry	Wet	Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest fall in 24 hours
1898	°	°	°	In.	P.c.	In.	No.	In.
January	83·4	79·6	78·3	·967	84	0·00	0	—
February	83.3	80·3	79·3	·999	88	0.00	0	—
March	83·5	80·4	79·4	1·001	87	0·00	0	—
April	84·8	79·3	71·3	·939	78	0·00	0	—
May	82·9	78·9	77·5	·942	83	3·17	8	1·47
June	81·3	78·3	77·2	·933	87	5·37	8	2·14
July	78·2	75·1	73·9	·835	86	2·14	8	0·79
August	78·1	75·8	75·0	·865	90	0·30	2	0·23
September	79·2	76·1	75·0	·865	87	0·50	3	0·31
October	81·9	76·5	74·5	·852	77	0·31	0	0·31
November	82·9	78·5	77·0	·925	82	0·60	2	0·50
December	84·1	79·1	77·4	·937	80	0·00	0	—
1898	82·0	78·2	76·8	·922	84	12·39	31	2·14

NOTE.—All observations are corrected for instrumental errors.

Mumia's, Kavirondo. Lat. 0° 20′ *N., Long.* 34° 30′ *E.,* 4,000 *feet. Observers: C. W. Hobley and H. J. Moody.*

Month	Rainfall 1897			Rainfall 1898			Heavy Dews	
	Amount	Days	Heaviest fall in 24 hours	Amount	Days	Heaviest fall in 24 hours	1897	1898
1897	In.		In.	In.		In.	Days	Days
January	3·53	10	1·02	2·67	4	1·28	—	1
February	4·41	10	2·13	2·18	5	0·77	2	—
March	5·92	18	1·50	3·52	9	0·99	4	—
April	8·88	25	1·29	11·88	17	2·12	3	1
May	5·92	22	0·96	8·00	31	1·30	1	13
June	12·64	27	2·81	11·47	30	2·17	5	2
July	6·18	29	1·04	8·29	31	1·39	8	15
August	10·76	30	1·86	4·59	30	1·20	7	13
September	15·97	29	7·45	4·69	27	·95	7	2
October	10·92	31	2·99	4·16	30	·98	13	3
November	7·03	21	1·38	6·98	29	1·93	4	10
December	1·35	8	0·33	0·67	25	·28	2	19
Total	93·51	260	7·45	69·10	268	2·17	56	79

Rain-gauge: M.O. 364; diam. 8 inches. The rains usually occur between 3 and 7 P.M., with E. or N.E. winds, and are attended with thunder and lightning. The extraordinary fall of 7·45 in. took place on the evening of September 24, 1897. The storm only lasted two hours, and the rainfall was really more than recorded, as the collecting jug of the gauge overflowed.

Golbanti, on the Tana River. Lat. 2° 47′ *S.,* 40° 4′ *E.,* 50 *feet. Observer: Rev. R. M. Ormerod.*

Month	Rainfall			Depth of River		
	Amount	Days	Heaviest fall in 24 hours	Mean	Greatest	Least
1897	In.	No.	In.	ft. in.	ft. in.	ft. in.
September	1·08	6	0·78	9 7	10 3	8 9
October	0·40	4	0·16	9 11	11 7	8 10
November	0·70	4	0·42	11 9	13 0	10 3
December	0·00	0	0·00	10 4	12 3	8 0
1898						
January	0·28	3	0·15	6 10	7 9	5 8
February	0·00	0	0·00	4 10	5 7	3 7
March	0·15	1	0·15	3 8	5 6	2 10
April	0·41	2	0·28	4 6	7 2	3 6
May	0·95	6	0·26	12 2	13 6	7 3
June	1·58	5	0·80	12 2	13 0	11 0
July	1·48	9	0·62	9 0	11 9	7 3
August	0·51	5	0·30	6 5	7 6	5 6
September	1·77	9	0·90	6 9	7 6	6 6
October	2·90	7	2·10	6 9	9 6	5 9
November	2·09	4	0·90	9 6	12 6	7 3
December	0·21	2	0·19	8 7	12 6	7 0
1898	12·33	53	2·10	11 1	13 6	2 10

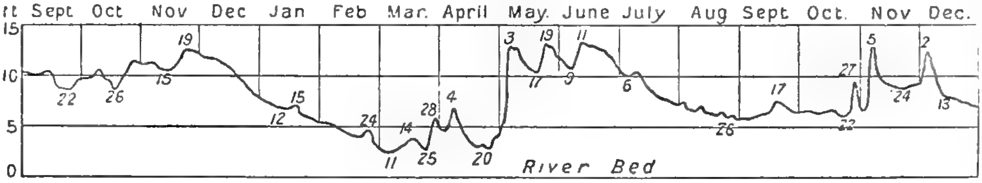
NOTES.

The rain-gauge was supplied by the Committee, and has a diameter of 5 inches. Its rim is 1 foot above the ground. The rain was collected at 7 A.M.

Mr. Ormerod remarks that the period covered has been unusually dry, the few rains being distributed over the whole year instead of being grouped into two regular rainy seasons. No crops were raised, except where water supply was available from the river or swamps.

Mr. Ormerod has likewise supplied data on the depth of the Tana River, measured by a 'fixed standard at the riverside.' From the diagram which I have drawn from his data, it will at once be seen that the river floods reflect two rainy seasons, but these rains are not the rains on its lower course, but rains far away in the Kenya district. The Tana, in fact, is a miniature Nile, and irrigation works, such as have converted Egypt into one of the most productive regions of the earth, would have a similar effect here. Mr. Ormerod points out that the success of the rice-fields depends upon the two annual floodings of the river, and where they fail to rise high enough the rice-fields suffer, and in many cases fail to produce any crops. Mr. Ormerod suggests that the setting in of the rains in the interior might be telegraphed to the Tana, so as to enable the people to get their fields ready for the flood.

Level of the River Tana at Golbanti, Sept. 1897 to Dec. 1898.



Malindi. Lat. 3° 13′ *S., Long.* 40° 7′ *E. Observers: K. Macdougall, G. H. L. Murray, and James Weaver.*

Month	Mean Temp. 9 A.M.		Humidity			Rain		
	Dry	Wet	Dew Point	Vapour Pressure	Relative Humidity	Amount	Days	Heaviest fall in 24 hours
1898	°	°	°	In.	P.c.	In.	No.	In.
January	81·6	77·6	76·5	·911	85	0·03	2	0·02
February	81·5	76·6	74·8	·860	81	0·83	1	0·83
March	83·7	79·8	78·4	·972	84	0·61	1	0·61
April	85·7	80·2	78·4	·968	79	0·20	1	0·20
May	81·6	79·4	78·7	·978	91	3·40	7	0·87
June	79·8	77·2	76·5	·913	90	2·60	9	0·40
July	77·9	74·5	73·2	·815	86	2·62	16	0·38
August	78·7	73·4	71·2	·763	77	0·76	7	0·25
September	80·5	74·8	72·5	·798	77	1·24	6	0·80
October	82·9	75·6	72·7	·804	70	0·20	1	0·20
November	83·8	78·2	76·2	·901	78	1·95	2	1·65
December	84·0	78·3	76·2	·903	77	0·00	0	—
1898	81·7	77·1	75·4	·882	81	14·44	53	1·65

Variations in the level of Victoria Nyanza.[1]

Decades	Lake Level		
	Port Alice	Lubwa's	Port Victoria
1898			
September, I. .	+4·00	+1·22	+1·87
II. .	3·87	1·34	2·32
III. .	3·25	1·02	2·67
October, I. .	2·22	·52	2·57
II. .	2·87	1·00	3·17
III. .	2·61	·58	2·15
November, I. .	1·97	−0·11	2·27
II. .	4·40	+1·22	3·27
III. .	5·74	1·19	3·07
December, I. .	6·29	1·79	3·07
II. .	6·35	1·00	3·52
III. .	4·97	0·40	2·15
1899			
January, I. .	3·00	−0·66	1·27
II. .	2·62	−1·03	0·67
III. .	2·67	+2·22	+0·42
February, I. .	3·67	−2·81	−1·18
II. .	3·17	−2·56	−0·78
III. .	2·66	−1·85	+0·22
March, I. .	3·04	−2·36	−0·13
II. .	2·72	−2·98	−1·98
III. .	2·47	−3·55	−2·21
April, I. .	1·72	−3·73	−2·53
II. .	1·82	−3·68	−1·78
III. .	3·97	−2·48	−0·38
May, I. .	3·64	−2·48	−1·08
II. .	4·54	+0·32	+3·02
III. .	4·22	+3·22	−4·65

Old Calabar. Lat. 4° 58′ N., Long. 8° 17′ E. Observers: E. G. Fenton, H. Ormsby, R. Allman, and S. W. Thompstone.

Month	Rainfall			Mean Temperature		Extremes of Temperature		Prevailing Wind	Harmatans	Tornadoes
	Amount	Days	Heaviest fall	Maximum	Minimum	Highest	Lowest			
1898	In.	No.	In.	°	°	°	°			
February .	0·32	1	0·32	89·6	72·3	92	69	N.W.	14	—
March .	7·78	15	1·98	88·6	74·6	93	69	S.W.	—	7
April .	9·73	20	1·76	85·8	75·6	92	70	S.W.	—	11
July . .	17·64	21	6·30	83·3	72·1	89	64	S.W.	—	—
August .	20·48	26	2·80	80·9	72·5	86	70	S.W.	—	—
September	13·86	27	2·92	82·7	72·5	87	70	S.W.	—	3
October .	20·24	23	5·45	84·3	72·5	89	68	S.	—	3
November	14·27	15	3·75	86·6	74·4	92	71	S.W.	—	6
December.	4·03	10	2·40	86·8	71·6	90	62	S.W., S.	18	1
1899										
January .	0·00	0	—	87·4	73·4	92	65	N.W.	22	—
February .	1·48	5	0·91	92·2	77·3	96	70	N.W.	3	3
March .	3·44	14	1·01	91·6	77·1	97	71	S.W.	—	6

The observations are published as recorded. Hour of observation, probably 9 A.M.

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[1] All observations are referred to the mean lake-level at each station during 1896, and cannot be reduced to a common datum level until the stations shall have been connected by lines of spirit levelling.

No observations were made between August 1897 and September 1898.

Victoria Lake.

Months	Mean Lake Level			Fluctuations[1]			Rainy Days		
	Port Alice	Lubwa's	Port Victoria	Port Alice	Lubwa's	Port Victoria	Port Alice	Lubwa's	Port Victoria
1898	In.	In.	In.	In.	In.	In.	No.	No.	No.
September . .	+3·72	+1·19	+2·29	1·7	2·5	2·5	—	—	13
October . .	2·57	·69	2·62	2·0	2·5	3·5	—	—	14
November . .	4·04	·77	2·87	5·2	3·0	4·0	22	—	17
December . .	5·86	1·04	2·89	3·2	4·2	5·0	6[2]	4	5
1899									
January . .	2·76	−1·04	0·74	1·5	2·5	3·5	—	3	3
February . .	3·20	−2·42	−0·63	5·0	3·0	3·5	—	5	8
March . . .	2·64	−2·95	−1·47	3·2	2·5	4·5	—	6	8
April . . .	2·50	−3·30	−1·56	5·0	4·5	6·5	12	10	18
May . . .	4·14	+0·10	+2·27	3·5	7·7	9·0	—	7	19[3]

[1] That is, difference between the lowest and highest level during each month.

[2] Rainfall 1·63 in.

[3] Rainfall, *P. Victoria*, March, 1·03 in.; April, 3·38 in.; May, 4·85 in.

Exploration of Sokotra.—Report of the Committee, consisting of Dr. J. SCOTT-KELTIE (*Chairman*), Professor I. B. BALFOUR, Professor W. F. R. WELDON, *and* Dr. H. O. FORBES (*Secretary*), *appointed to explore the Island of Sokotra.* (*Drawn up by the Secretary.*)

THE present report is preliminary to a fuller illustrated account of the results of the expedition to be issued as a special publication of the Liverpool Museums, edited by the Secretary, who is Director of that Institution.

The members of the expedition were Dr. H. O. Forbes, Director of Museums to the Corporation of Liverpool; Mr. W. R. Ogilvie-Grant, of the Ornithological Department of the British Museum; and the Taxidermist of the Liverpool Museums. The expedition was aided by a contribution from the Government grant of the Royal Society, by a vote of money and of instruments from the Royal Geographical Society, and by a grant of 35*l.* from the British Association made at its meeting last year at Bristol. The Trustees of the British Museum and of the Liverpool Museums also contributed generously to the expenses and the outfit of the expedition.

The party left England on October 28, 1898, and arrived in Aden on November 18. The entire voyage out was utilised in making a collection of the minute organisms which abound in the sea, by sieving the water through very fine silk nets attached to the discharge pipe of pumps, which, by the courtesy of the owners and the captain of the *Manora*, were allowed to work uninterruptedly day and night.

The members of the expedition, who on their arrival in Aden were immediately received by the Political Resident, Brigadier-General Creagh, V.C., were deeply disappointed to learn from him that, owing to political difficulties which had arisen between the Indian Government and the Sultan of Sokotra, it would be impossible for them to proceed to their destination. The Resident had, before their departure from England, cabled to the India Office in London that they should be advised to postpone their visit, but, through some unexplained cause, that information was not conveyed to them. Their arrival in Aden was, therefore, naturally a surprise to the Political Resident, who, in the fullest sympathy with the position in which they found themselves, the same day despatched an urgent message to the Indian Government, explaining the situation, and urging some speedy arrangement of the difficulty which had arisen, so as to enable the expedition, if possible, to proceed to Sokotra.

It is impossible to express fully the grateful thanks of the members of the expedition to General Creagh for his personal hospitality and for his great kindness in doing everything possible to make the days of the enforced stay of the expedition in Aden of profit to it. The Government bungalow at Sheik Othman, some twelve miles north of Aden, was generously lent to the expedition by him, and later, through his recommendation, an invitation was received from the Sultan of Lahej, in South Arabia, for the expedition to visit his dominions. His Highness met the members of the party at his boundary, conveyed them to the capital, hospitably entertained them, and assisted them in every possible way during their stay.

The Committee have to express their obligations to the military authorities in Aden in lending the expedition for this journey baggage- and riding-camels from the garrison establishment, and also the attendance upon them as a guard of a native officer (jemadar) and one sowar. The helpful aid of the First Political Assistant, Captain Jacob, in all these arrangements must also be very cordially acknowledged. A most profitable stay could undoubtedly have been made at Lahej, which is a very little-explored region, had the expedition been eventually prevented from visiting Sokotra. It had only, however, begun what was proving to be a very interesting collection when intimation was received from General Creagh that authority had been obtained from the Government of India for the expedition to proceed to its destination. A speedy return having therefore been made to Aden, where eight Somali servants were engaged to accompany it in various capacities, the expedition embarked on December 1, 1898, with its stores and baggage, on board the Royal Indian Marine steamer *Elphinstone*, which the Indian Government had very generously placed at its disposal to carry it to and from the island. Authority had also been obtained from General Creagh to break the voyage for several days at Abd-el-Kuri, an island lying between Sokotra and Cape Guardafui on the Eastern Horn of Africa. This islet had never before been scientifically examined; and during the short stay made there several species of animals and plants new to science were discovered, among them a very notable species of Euphorbia (*Euphorbia abdelkuri*), belonging to a family of plants of which many singular forms occur in Sokotra. The geological structure of the island was found to present many points of similarity to that of Sokotra. It has suffered great denudation, however, for the limestone, which is of both Cretaceous and Tertiary age, has disappeared everywhere except on one or two summits. Volcanic rocks abound, and from the high peak—1,750 feet in height—overlooking the anchorage they resembled a number of papillæ rising from a desert of sand. The island has but few inhabitants, who are very poor and miserably housed. Some of them are fishers and divers for pearl-shell. Numerous chelonian carapaces strewn about near their huts indicated that the hawk's-bill turtle was a common frequenter of their coasts. The most notable feature of the vegetation was the absence of those characteristic plants of Sokotra, the dragon's blood (*Dracæna*), myrrh (*Balsamodendron*), and frankincense (*Boswellia*) trees, though Abd-el-Kuri lies nearer to the African coast than the main island.

'The geological collections made on Abd-el-Kuri,' as Dr. Gregory in a preliminary note reports, 'show that the island consists of a block of Archæan rocks similar to those of Sokotra, and it contains dykes of the coarse pegmatite common in Somaliland. Above the gneiss series is a limestone of Cretaceous date which occurs on the highest point of the island, so that the whole of it was submerged at a time when Sokotra was probably a land area. The most recent limestone in the island is a low-lying Pleistocene reef containing *Goniastrea retiformis*.'

The poverty of the fauna and flora of the island is, therefore, in agreement with its geological history.

Two new species of birds, only slightly differentiated from species occurring both in Sokotra and Somaliland, indicate the comparatively recent separation of Abd-el-Kuri from the mainland.

On December 6 the *Elphinstone* left Abd-el-Kuri, and on the 7th anchored off Hadibu, the capital of Sokotra. On the 8th Dr. Forbes, accompanied by the commander of the *Elphinstone*, landed and was received by the Sultan, to whom he presented letters of introduction from the Government. Permission was readily granted by the Sultan to visit all parts of the island. The next day the expedition went ashore and camped in the mountain-girt plain in which Hadibu stands. A week was spent there investigating the northern slopes of the Haghier Mountains. On the 18th of the month the camp was moved to Dahamis, at an elevation of 1,500 feet, where the Europeans of the party were all unfortunately very soon laid down by a most pernicious form of malaria. Excellent collections were, nevertheless, obtained in their convalescent intervals. On the 26th, however, it was decided to move to Kamahanu, a hill in the Garieh Plains, where it was hoped a more salubrious camping-ground would be found. But the continued sickness of the party—among whom for several days there was not a single undisabled member—made it necessary, after a few days' trial of this camp, to seek a still higher altitude on the Haghier range. The tents were consequently struck on December 30 and transported to Jena-agahan, where, notwithstanding that fever was still very prevalent and the expedition was practically deprived, during the greater part of the time of its stay there (owing to his serious illness), of the services of the taxidermist, many of the most interesting specimens in the collection were secured, the most notable perhaps being the beautiful wild ass, of which large herds roamed the plains below the camp. On January 15 the camp was moved a two days' journey to the high plateau of Homhil, which proved to be a most successful collecting station. The health of the expedition rapidly improved, the climate and scenery were invigorating, with an abundant flora and fauna. There were here obtained roots and seeds of the shrubby gentian (*Exacum cœruleum*), one of the most lovely species both in flower and foliage of a beautiful family, and of a fine broad-leaved amaryllid (*Hœmanthus grandifolius*), whose flowering is awaited with much expectation.

On January 27 a move was made from Homhil to Adho Dimellus, in the heart of the Haghier Mountains, at about 4,000 feet above sea-level—one of the most salubrious and beautiful spots imaginable. There over a fortnight was spent with great profit to all departments of the collection. Numerous butterflies were captured, some of great rarity, such as *Papilio benetti*, of which only one broken specimen was previously known, as well as roots and seeds of some of the most remarkable of the plants of the island, whose alpine flora has all the marks of great antiquity. On February 18 the expedition had to make its way back to the plain of Hadibu to await the return of the *Elphinstone*, which on the 21st of the same month anchored off the town, and took on board the members of the expedition and the collections. The same evening the despatch-boat sailed for Abd-el-Kuri, where it was decided to supplement the collections already obtained there by a few days' further exploration. From Abd-el-Kuri the *Elphinstone* brought the expedition direct to Aden, arriving there on the night of February 26, 1899. The party left Aden on March 2, and sixteen days later arrived in London.

The results of the expedition may be summarised as follows: Of mammals there are examples of one or two species of rat, of one species of civet cat, of one species of bat, and of a beautiful wild ass, which may perhaps prove to be a new species. Of birds there are some 300 specimens, 250 in skin and fifty in spirit, out of which seven species have been described by Mr. Grant and Dr. Forbes as new to science. A large series of reptiles, described by Mr. Boulenger, was acquired, which contains one genus and eight species new to herpetology. Of the scorpions, millepedes, and spiders obtained, Mr. Pocock has described one new genus and seven new species in the former group, and one new genus and four new species in the latter. Of the land-shells (numbering several thousands), Mr. Edgar Smith has described eight species as new to his department of zoology. Of insects there are several thousands, and Mr. Ogilvie-Grant has described three new butterflies, one of them a very beautiful and large charaxes (*C. velox*), while Sir George Hampson has diagnosed one new genus and fourteen new species of moths. Mr. Burr, who has examined the Orthoptera, describes two new genera and six new species; while Mr. Kirkaldy has described the whole of the species of Hemiptera as new to science. Professor B. Balfour, F.R.S., of Edinburgh, reports that the plants, of which living specimens or ripe seeds, over 200 in number, have been brought home, are of great scientific interest. Their cultivation is being kindly undertaken by him in the Royal Botanical Gardens at Edinburgh. Among the most interesting may be mentioned species of *Dorstenia*, *Adenium*, *Begonia*, *Crinum*, *Exacum*, *Ruellia*, *Dendrosicyos*, *Hæmanthus*, *Helichrysum*, with *Punica protopunica* and *Dracæna cinnabari*.

The true Sokoteri of the mountains, the Mahri, were found to be a light-complexioned Mahomedan people only poorly civilised, living in caves or rude cyclopean huts, who possess but few utensils, implements, or ornaments, and almost no weapons. The ethnographical collections are consequently very small; still, there have been brought back specimens of their pottery, of their primitive quernlike mills, of their basket-work, and of their weaving apparatus. The expedition has likewise brought back and deposited in the British Museum two large blocks of stone inscribed with an ancient script, which may perhaps throw some light on the language of the people who occupied the island in a past age, and of whose cyclopean remains interesting photographs have been obtained.

In addition to the biological collections—in which six new genera and sixty-seven new species have been already described—a number of geological specimens were brought together, which have been examined by Dr. Gregory, whose report will shortly be published.

Every day also a meteorological register was kept, and trigonometrical and astronomical observations conducted by Dr. Forbes. From the latter a new map of the island will be constructed.

The results of the expedition, in regard to the question of geographical distribution, add little to what the investigations of Balfour, Schweinfurth, and Riebeck have established; but several of the zoological species confirm the presence of a distinct American element in the biology of the island, which appears to have reached this now isolated area by way of an antarctic land, the existence of which is greatly confirmed by the recent discovery in Patagonia of *Meiolania*, originally described from Lord Howe's Island.

It will not be out of place here to place on record the liberality and public-spirited action of the Museums Committee of the Liverpool City Council in taking part in the exploration of Sokotra, and the great credit which unquestionably belongs to it of having been the first in the provinces to recognise that it was within the duty of a great corporation to further in this way the advancement and increase of knowledge by actively sharing in the investigation of little-known regions.

The full report on the results of the expedition, shortly to be published as a special volume at the expense of the Liverpool Museums, will contain a Narrative of the Expedition, and complete lists, with coloured figures of all the new species, of the fauna and flora of the islands visited, with notes on their Geology and Anthropology.

Small Screw Gauge.—Report of the Committee, consisting of Sir W. H. PREECE (*Chairman*), Lord KELVIN, Sir F. J. BRAMWELL, Sir H. TRUEMAN WOOD, Major-Gen. WEBBER, Col. WATKIN, Messrs. CONRAD W. COOKE, R. E. CROMPTON, A. STROH, A. LE NEVE FOSTER, C. J. HEWITT, G. K. B. ELPHINSTONE, T. BUCKNEY, E. RIGG, C. V. BOYS, *and* W. A. PRICE (*Secretary*), *appointed to consider means by which practical effect can be given to the Introduction of the B.A. Screw Gauge.*

IN 1882 a Committee was appointed by the Association to determine a gauge for the manufacture of the various small screws used in telegraphic and electrical apparatus, in clockwork, and for other analogous purposes. This Committee reported to Section G in the succeeding years 1883, 1884, and proposed that a certain system of screw-threads, since known as the British Association screw-threads, should be recommended for adoption by users of small screws in this country. The system is identical except in one small point with that used in Switzerland and associated with the name of Professor M. Thury. The series consists of 26 threads, numbered 0–25, having diameters from 6mm. down to ·25mm., and is so closely graduated that only in exceptional cases can any size be required intermediate between two of the set. The form of the thread has proved to be well adapted for practical purposes, and screws made on this system have come into extensive use among English manufacturers of small mechanical apparatus. It has been adopted by several Government Departments, who have imposed its use upon their contractors.

In the year 1895 representations were made to the Section, and some correspondents of the Technical papers urged, that the value of this system was prejudiced by the fact that purchasers of British Association screws and screwing-tools could not rely on obtaining from manufacturers goods which were interchangeable with one another. This raised at once a question which had not been closely considered by the 1882 Committee—viz., the mode of determining whether any given screw of a particular number is or is not a fair representation of the form laid down by the British Association specification. The present Committee were appointed at the Ipswich Meeting to deal with this point, and with some additional members have sat at intervals up to the present time.

In 1896 an interim report was presented to Section G at the Liverpool Meeting, in which the problem of the mode of gauging small screws was discussed at length. The principal conclusion reached at that time was that as no means exists of examining a nut or female screw, the efforts of the Committee should be directed to obtaining accurate plug or male screws for use as gauges, and combs or chasers.

During the three years that have elapsed since this report was made the Committee have been in communication with different firms, and principally with the Pratt and Whitney Company of Hartford, U.S.A., a firm enjoying the very highest reputation for work of the kind the Committee desired to secure. Finding that this firm were prepared to undertake the production of gauges and tools for the British Association screw-threads on the same lines as they have adopted with the American and Whitworth threads, the Committee have been satisfied to leave the matter in the hands of the Company till they should ascertain whether they could produce the desired result, and have given them all the information, specifications, &c., that were possible. Within the last two months the Pratt and Whitney Company have submitted to the Committee specimens in hard steel of male and female gauge pieces of threads Nos. 3, 7, and 13. The three male screws of these sets have been photographed by Colonel Watkin on a large scale, and have been measured by Mr. H. J. Chaney, Superintendent of the Standards Department of the Board of Trade. Their two reports are printed below.

The Committee believe these gauges to be sufficiently accurate for practical requirements. The material of which they are made—hardened steel—should enable them to stand much use without injury. Their finish and general workmanship are exceedingly good.

The Committee, through their Secretary, have expressed to the Pratt and Whitney Company their satisfaction with these gauges, and have been informed in reply that a higher degree of accuracy may be expected in the future. They are still in correspondence respecting the specifications of limits of error and other details concerning their production on the commercial scale. The manufacture and sale of these gauges by the Pratt and Whitney Company appear to realise the object set before themselves by the Committee—viz., to assist the extension of the use of the British Association system of screw-threads by making generally available accurate means for their verification.

While recognising the excellence of the form of the British Association screw-thread for mechanical purposes, the Committee feel strongly that the difficulty of producing the form to the degree of accuracy desirable for the best class of work, and especially for gauge pieces, is a serious drawback to its value. Colonel Watkin's photographs show very clearly that the best appliances in the most experienced hands that the Committee could find have failed to produce even single specimens of first-rate accuracy. The letters addressed to the Secretary of the Committee by Mr. George M. Bond, manager of the standards and gauge department of the Pratt and Whitney Company, as well as the high reputation of his firm, leave no room for doubt that very great care has been taken to secure accuracy in these specimens. A considerable number of gauges made by English firms of good standing have been examined by the Committee, and have in every case shown errors of the same character as, though usually to a much greater degree than, the specimens submitted by the American firm.

From several sources, and especially in Mr. Bond's letters, it has been urged on the Committee that although the difficulties of constructing these gauges of a very high degree of accuracy are practically insuperable, screw-threads of a flat-ended form can be produced with great exactness. A photograph taken by Colonel Watkin of a fine screw taken from an instrument made by Messrs. Brown and Sharpe shows that this is certainly the case.

The American, or flat-ended, form of thread appears to be rapidly establishing itself in France and Germany, judging from the reports we have received of the French and Zurich Conferences, and we understand that it is entirely employed by the French Admiralty and by several of the French railway companies. These reports refer, it is true, to screws of larger sizes than are included in the range of the British Association and Professor Thury's systems. The conclusions of the recent Conference at Zurich, which adopted the flat-ended thread, were expressly limited to screws of more than 6 mm. diameter, the extreme upper limit of our system. But so far as the easy production of accurate form is concerned, arguments which apply to large screws apply with greater force to small screws; while a form which is suitable for all screws above 6 mm. cannot be wholly unsuitable for screws below that limit. The Committee, moreover, were informed by one of their number that he has used screws of the American form in sizes corresponding with some of the smaller numbers of the British Association series, and has found them perfectly satisfactory.

Current conceptions of the possible and desirable limits of accuracy in mechanical construction are rapidly advancing, and while we recognise the value of the work of the Committee of 1882 in establishing a generally accepted thread, we are dissatisfied with a standard form for a piece so important as a screw which is open to the serious objection referred to above.

We recommend that this Committee shall be reappointed for the purpose of considering whether the British Association form of thread for small screws should be modified.

APPENDIX.—REPORTS ON SCREWS MADE BY THE PRATT AND WHITNEY COMPANY.

I.—*Report by* COLONEL WATKIN, *R.A.*, *C.B.*

The Wilderness, Woolwich: July 11, 1899.

The Secretary British Association. Screw Gauge Committee.

I have now taken photographs of the screws sent by the Pratt and Whitney Company for the Committee, prints of which I enclose.

I find the general forms of these screws are better than those we have obtained heretofore, which is satisfactory, taking into consideration the fact that they are constructed of hard steel.

As in former cases, the larger sizes conform more nearly to the British Association pattern thread, the rounding in the smaller sizes being not quite so satisfactory.

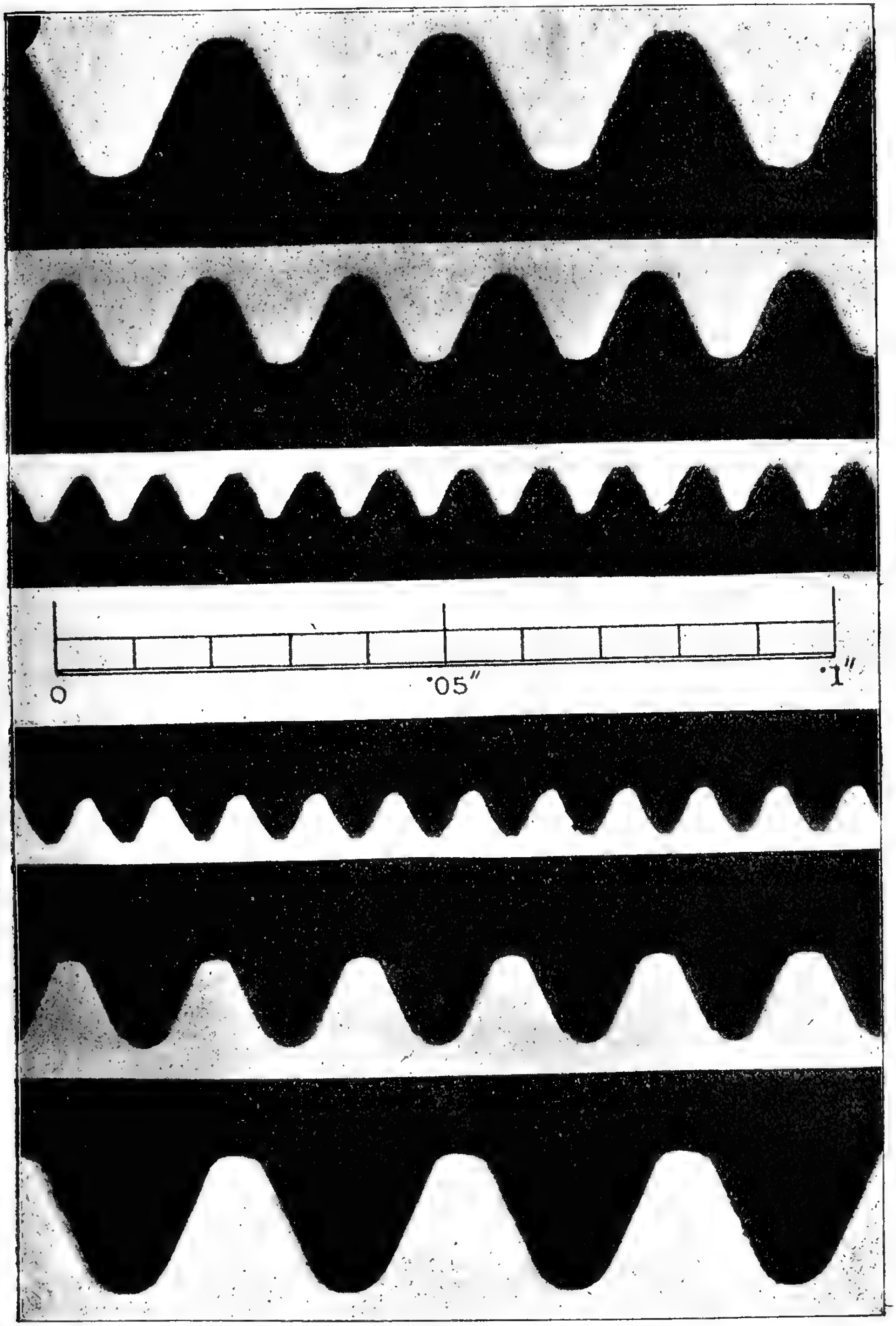
The angle of the thread in the two large sizes is about 49°, but considerably more in the No. 13 size.

As regards linear dimensions, all the screws are nearly perfect, as will be seen by the measurements given on the back of the photographs.

The diagonal scale accompanying the photographs was constructed from the scale photographed at the same time as the screws.

The gauges may, I think, be accepted as sufficiently correct for all practical purposes as standard gauges for British Association pattern screws. (Signed) W. WATKIN.

FIG. 1.—Reproduction of three photographs referred to in Colonel Watkin's Report, superimposed on one another.



II.—*Report from* Mr. H. J. Chaney, *Superintendent of the Standards Department of the Board of Trade.*

Standards Department, Board of Trade: July 10, 1899.

My dear Sir,—I have now the pleasure to enclose, for the information of Sir William Preece, a statement showing the external dimensions of the three male screws which you forwarded to me on Thursday last, and which have been returned to-day by registered post. The dimensions were determined by contact comparisons (made by independent observers) of the screws with Board of Trade Standard cylindrical gauges, plane gauges, and wire gauges; and in the case of the smallest screw (C), by microscopic comparison with a linear standard.

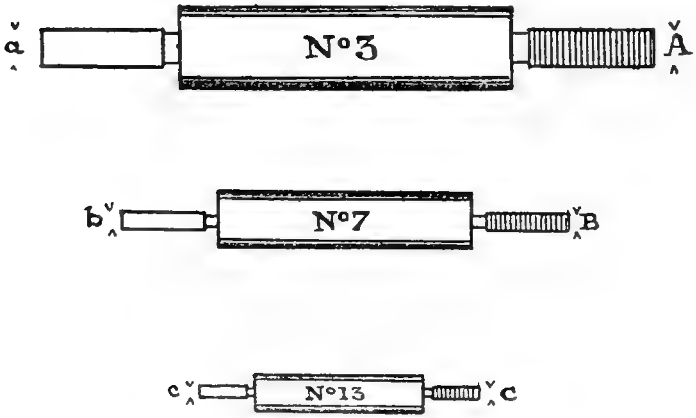
Had time allowed, a more exhaustive examination of the three screws might have been made; but the present comparison may, I suggest, be relied on to ± 0·0001 inch. The dimensions given in the enclosed paper (4·1023 mm., 0·16151 inch, &c.) are in each case the mean external diameter of the whole length of the screw, and show that although A and C have perhaps appreciable errors, the required dimensions have generally been closely followed by Mr. Bond. The screw-threads are in fact, in our opinion, of excellent workmanship; but it is doubtful whether the screws are always perfectly cylindrical. For instance, the mean external diameter of the last eight threads of screw C (or the point of the screw) is 0·008 mm. greater than the external diameter of the fifteen middle threads of C. The external diameter of the seven last threads (shoulder of the screw) of C agree in measurement with the diameter of the point of the screw.

I should much like to see a copy of Colonel Watkin's photographs.

Yours faithfully,
(Signed) H. J. Chaney.

W. A. Price, Esq.

Fig. 2.—British Association Screw Threads.



DIMENSIONS SPECIFIED.

A . . 4·1 mm. = ·16141 inch.
a . . 3·224 „ = ·12693 „
B . . 2·5 „ = ·09842 „
b . . 1·924 „ = ·07575 „
C . . 1·2 „ = ·04724 „
c . . ·9 „ = ·03543 „

Screws Nos. 3, 7, 13	Value in Millimetres			Value in Inches		
	Nominal	Observed	Difference	Nominal	Observed	Difference
3 A . .	4·1	4·1023	+0·0023	0·16142	0·16151	+0·00009
a . .	3·224	3·2304	+0·0064	0·12693	0·12718	+0·00025
7 B . .	2·5	2·5048	+0·0048	0·09843	0·09862	+0·00019
b . .	1·924	1·9273	+0·0033	0·07575	0·07588	+0·00013
13 C . .	1·2	1·2015	+0·0015	0·04724	0·04730	+0·00006
c . .	·9	·9048	+0·0048	0·03543	0·03562	+0·00019

(Signed) H. J. CHANEY,
July 10, 1899.

On the Erection of Alexander III. Bridge in Paris.
By M. AMÉDÉE ALBY.

[Ordered by the General Committee to be printed *in extenso.*]

IT will be observed, on consulting a plan of the Exhibition of 1900, that Alexander III. bridge is situated on the line of the Great Avenue which will connect the Champs-Elysées with the Esplanade des Invalides. Like the Palaces of Fine Arts along the same Avenue, it will outlast the Exhibition, and perpetuate the remembrance of it by a durable embellishment of Paris. Æsthetical considerations have therefore been of great importance in the plans which the engineers have prepared ; the technical details are also somewhat unusual and interesting in several respects, though they are not to be recommended for an economical solution of the problem of bridging a river about 500 feet wide.

The first condition which the engineers attended to was not to injure in any way the scenery of the Seine on either side of 'Pont de la Concorde ;' it was obvious at once that the low-arched form of bridge was the only acceptable one in these circumstances.

Two other facts had to be borne in mind : these are, preservation of the view of Les Invalides, and absolute symmetry of the plans. It was considered of the utmost importance that there should be a possibility of seeing over the bridge the whole monument of Les Invalides from the Champs-Elysées.

The decision of the authorities of the Exhibition of 1900 concerning this view of Les Invalides had been already successfully enforced in the year 1828 by the Municipal Council of Paris, when they obtained the demolition of a suspension bridge constructed on the very site of the new bridge by the well-known engineer Navier, who had purposely gone to England to study the Norhamford and Menai suspension bridges. The presence of the columns of the suspension bridge was considered as an intolerable obstruction to the view of Les Invalides.

The Palace of Industry (now demolished) was situated between the Champs-Elysées and the Esplanade des Invalides; hence during about forty-five years Parisians walking along the Champs-Elysées dispensed with the view of Les Invalides without complaint, proving that it is much better to hide entirely a fine view than to spoil it.

In addition to the foregoing æsthetical considerations, the engineers were aware it was the wish of people navigating the Seine that there should be no pier in the river bed, the widest possible fairway under the bridge, and that consequently the least thickness admissible must be selected for the central part of the frame of the bridge.

General Dimensions of the Bridge.—The bridge consists of a single very flat arch, the flooring of which is prolonged over either bank by small viaducts, the total length of the bridge between the parapets of the banks being 155 metres (509 feet). The abutments of the central arch are 109 metres (357 feet) apart.

The longitudinal axis of the bridge coincides with the axis of the new avenue crossing the Seine at an angle of 83° 38′. Its width, 40 metres (131 feet), had to harmonise with that of its approaches, the widest bridge in Paris up to the present being only 30 metres (98 feet); London Bridge is 54 feet, the Tower Bridge 60 feet, and Brooklyn Bridge 86 feet in width.

The whole width of the bridge is divided into a central roadway of 20 metres in width, and into two equal pavements of 10 metres each.

The gradient of the roadway is 1 in 50, and the highest part of it is situated at such a level that an observer standing near the Champs-Elysées in the prolongation of the axis on the right bank will be able to see the base of the Hôtel des Invalides.

For reasons which have been already mentioned, the coefficient of rise and the thickness of the central cross-section have been reduced to the least possible dimensions. The rate of rise to span is 1 to 17. The thickness of the central cross section from the bottom flange of the arch to the top of the wooden paving on the part of the roadway nearest the pavement is no more than 1·02 metres (3 feet 4 inches).

The conditions obtained for navigation, in consequence of the extreme flatness of the arch, though they do not fulfil the wishes of those most interested, and are in fact not quite satisfactory at the present time, must be considered as acceptable. The width of the fairway left is no less than 65 metres (213 feet) in the ordinary state of the river, and 34·4 metres (113 feet) at high-water time; the height of free passage being 5·50 metres (18 feet) above the water level. Moreover the practical inconveniences of the present situation may be corrected in the future by the suppression of one of the piers of the Invalides Bridge, through the arches of which tugs and barges going down the river cannot pass without some difficulty.

The characteristic features of the new bridge when compared with existing bridges may be expressed in these few words: Alexander III. Bridge is the widest, the flattest, the thinnest skew-arch bridge ever constructed in France. By what means have the engineers provided for the stability of such a bridge, and how have they erected it without interfering with the navigation? These two elements of the problem are so intimately connected, that it is not possible to separate them; both had an equal influence on the choice of the type of the arch.

The bridge consists of fifteen equally distant three-hinged arches, the elements of which have been made of cast steel connected by screw-bolts. The flooring rests either through the medium of upright pillars, or directly on the top of the arches.

The peculiarities of the triple-hinged arch appeared at once to be obviously adequate to the various conditions of the problem. The moments of flexure being almost independent of the temperature in such arches, and only becoming a little important near the articulations, it is possible to reduce the thickness of the section in the central part, more than in any other system, without any inconvenience. It is equally possible, by a judicious distribution of the metal, to prevent changes in the direction of the stresses, which are always well known in this system, and to obtain a sort of steel vault in which every part of the metal is compressed under all circumstances. The joints of the elements of the arches or voussoirs have not to be riveted, and may be made with screw-bolts. There is, moreover, no objection to the use of cast steel, so that the operations left to be carried out on the works for mounting the ribs are very few, provided sufficient preparatory care has been taken.

It was easy, on account of the suppression of riveting, not only to erect each rib in a short time, but also to erect them successively with the help of a moving system so as to secure the fairway wanted for navigation during the whole time of erection.

Foundations.—On account of the flatness of the arches the thrust is very considerable, though it is not greater in proportion than in many arch bridges made of masonry. It amounts to 288 tons for each metre in length of the abutments—about 12,700 tons for each abutment.

The subsoil of the valley of the Seine is not to be compared with the regular subsoil of the Thames in London, where engineers are sure to find an excellent water-tight, hard, uniform clay. The strata in the subsoil in the southern part of Paris have a general gradient towards the hills at Meudon, so that the bridges over the river have been built with all kinds of subsoil for foundations. Whilst, for example, the 'Pont Neuf,' the 'Pont de la Concorde,' and other bridges of the centre of Paris have been erected on the solid calcareous bed-rocks belonging to the Lutetian strata, the 'Pont des Invalides' stands on sand, the 'Pont de l'Alma' on soft clay, the 'Pont de Jéna' and the 'Passerelle de Passy' on hard clay, the 'Pont Mirabeau' on chalk.

When foundations are laid upon calcareous rock or on chalk, engineers agree on their being perfectly stable, but when the foundations are to rest upon the intermediate strata of sand or clay, precautions must be taken, because these strata lack regularity in depth and, in the case of the clay, in firmness, so that works resting on it run the risk of settlement.

It was decided that the foundations should be built as if they were to be supported by the worst strata of Parisian subsoil. Therefore the pressure on the bottom ground was limited to three kg. per square centimetre (about 40 lb. per square inch), and the weight of each abutment was fixed at such an amount that it could resist the thrust by the friction of the ground alone, without depending in any way on the earth backing.

It is easy to see that no result satisfactory for both conditions could be obtained without developing to a great extent the surface of the abutments, the back parts of which were carried to a distance of 33·50 metres (110 feet) from the front part in the river bed.

Each abutment consists, in consequence, of an enormous block of solid masonry in the form of a parallelogram 44 metres (144 feet) in length (along the river) and 33·50 metres in width, its surface area being 1,474 square metres (15,850 square feet).

The right abutment has been sunk to a depth of 8·25 metres (27 feet) under the regular water level, and the left abutment to a depth of 7·50 metres (24½ feet) according to indications from soundings.

The rear part of each one was left hollow and filled with sand.

Foundations of such a size are quite beyond the proportions commonly used even for bridges over very large rivers ; but the unfavourable conditions have been so great, namely, width of the bridge, flatness of arches, and character of subsoil, that the foundations of this modest 350 feet single span come into comparison for size with those of its older brothers, the Brooklyn Bridge, the Forth Bridge, and the magnificent Tower Bridge.

Surface of Foundations at the Bottom.

	sq. m.		sq. ft.
Brooklyn Bridge (single caisson)	1,716	=	18,450
St. Louis Bridge (single caisson)	520	=	5,590
Forth Bridge (largest caissons)	about 350	=	3,760
Tower Bridge (each pier)	about 1,510	=	16,200
Pont Alexandre III. (each abutment, single caisson) .	1,474	=	15,850

Each abutment was put in place by means of a single pneumatic caisson. The frame of the caisson, entirely made of mild steel, consisted of a vertical water-tight wall 3·68 metres (12 feet) in height, encircling the whole surface of the foundation, and of a horizontal equally water-tight partition at about 1·90 metres (6 feet 3 inches) above the lowest level of the wall.

This partition was the roof of the working space. As it was designed to sustain a heavy load of masonry while the caisson was sinking, the steel sheets (5 millimetres thick) which form the water-tight ceiling of the caisson were reinforced by two systems of girders perpendicular in direction.

Below the ceiling four partitions or supporting girders divided the working space into five sections or rooms, communicating with each other through the central latticed parts of the girders.

These four partitions and the walls were fitted with solid edge cutters at the bottom, and with angle brackets.

Above the roof a set of twenty-seven latticed beams 1·60 metres (5 feet 6 inches) in height were laid at right angles to the girders just described.

These beams were arranged to support the load of concrete while the space between them was being filled, and to contribute to the rigidity of the roof after the concrete had turned into a solid mass.

Each of the five rooms of the working space was furnished with two entrance wells, provided with air locks and engines for lifting excavated materials.

The contractors, in order to save time, erected these wells or shafts at the start with the total length which would be required at the end of the sinking, and so they were forced to erect a wooden scaffolding twenty-five feet in height over the whole surface of the caisson.

The caissons were rapidly and successfully sunk. The contractors received orders to commence work in April 1897 ; the sinking was begun on the first day of August, and finished at the beginning of November on the right bank ; begun in January 1898 and finished in the middle of March on the left bank. The work with compressed air lasted seventy-nine days on the right bank, and seventy-one on the left one.

It would be fruitless to deny that in spite of the great abilities of the contractors, Messrs. Letellier and Boutrinquieu, in spite of the intelligence displayed by the inspectors, who had great experience of compressed air work (especially in connection with the late Pont Mirabeau), the engineers were somewhat anxious about the success of the operation of sinking the caissons, never attempted before in such conditions and on such a scale.[1]

Great precautions were taken to insure regularity. Among the other difficulties encountered were those due to the variable resistance of the soil and to the presence in it of stones and piles belonging to the old demolished suspension bridge and to the foundations of the quay.

Frequent observations on the flexure of the metallic frame were considered to be the most convenient means to prevent the caisson from breaking. For this purpose a general water-level pipe was placed in the working space, so fitted that at every instant the inspector could state the flexure of walls and main girders. Moreover, daily observations were made in the open air to ascertain the true situation of the caisson.

When the caisson reached the proper depth the surface beneath it—consisting of large calcareous flagstones on the right bank and of sand on the left one—was cleaned and levelled and the working space was filled with concrete. The five rooms of each caisson were successively filled, the men retreating from one to another so that electric lighting could be maintained to the end.

The caissons were sunk and filled with concrete, and the backing constructed of heavy stone masonry laid in cement. The facings of the abutments on the river side were made of courses of hammered ashlar of cut granite stones; lastly, five granite courses were put behind the sockets perpendicular to the direction of the thrust, their surface increasing in size, so that the ordinary masonry in connection with the last one bears a crushing stress only of about 18 kilogrammes per square centimetre (252lb. per square inch), while the granite-bearing stones in connection with the sockets have to resist about 48 kilogrammes per square centimetre (780lb. per square inch).

Temporary Works Rolling Bridge.—The moving system designed for the erection of the arches consisted really of a steel riveted bridge of 120 metres in length supported above the level of Alexander III. bridge by framework of pyramidal shape, the whole forming a gigantic travelling crane rolling on double sets of rails fixed on the upper part of the abutments.

This apparatus was arranged to support the load of centreings and arches, and also to carry the centreings to their successive situations and to secure a convenient platform for handling the arch pieces.

As the necessities of navigation did not require a temporary passage more than 50 metres (164 feet) in width, the contractors for the metallic part of the work were allowed to mount the side parts of the arches near the springings on wooden centreings supported by piles in such a manner that they could be moved by slipping with the central part of the centreings fixed to the rolling bridge. In this way it was possible to relieve this temporary bridge of a large part of the load, and also to sustain its trusses at two intermediate points by metallic columns resting on rows of piles while the arches were being erected. The rolling bridge had generally in consequence three spans, two of 33·50 metres (110 feet)

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[1] The engineers to the Port du Havre, encouraged by this success, have projected to sink caissons of more than 22,000 square feet, through the bad soil they have to deal with.

in length for the side spans, and one of 53 metres (174 feet) for the centre. It had a single span of 120 metres (410 feet) only while being moved.

The structure of the temporary bridge was erected on the right bank of the river and launched so that the channel left for boats was never encumbered and navigation not once interrupted. As the total length the contractors had at their disposal for the launching platform was only about 60 metres, it was necessary to proceed in three steps. The first portions having been delivered in the middle of July, the first launching was made on August 20, the second on September 8, the last one on the 30th of the same month.

The centreings of the bridge were completed and ready to be used at the beginning of November.

The steel voussoirs were cast at five different steel works, each of which received orders for a certain number of arches to be delivered in succession :—

Chatillon & Commentry steel works . . .	Four arches.
St. Chamond steel works	„ „
Creusot steel works	Three „
St. Étienne steel works	Two „
Firminy steel works	„ „

Before being delivered each arch was mounted in the manufacturer's shop in halves. On a plain solid platform made of concrete or of timber the exact shape of a half-arch was drawn with the utmost precaution; one of the most experienced inspectors went through the five shops to examine these drawings, to compare them with the contemplated dimensions, and to note the conditions of their structure.

When it was found that the drawings were satisfactory in every respect, and identical with each other, the different voussoirs of each half-arch were placed upon them and connected.

In this way, when leave was given to deliver the voussoirs, the engineers were assured that no difficulty would arise in the course of the operations of erection. They were right in so thinking, because it only once happened that an operation was interrupted on account of a joint table not being truly planed.

The first operation made *in situ* was the exact measurement of the distance between the abutments, which was effected very easily by means of the rolling bridge itself considered as a gauge. The measurements made in this way *in situ* for every arch allowed every thrust stone to be properly cut beforehand with satisfactory exactness.

The travelling bridge had been fitted with four trucks running on two elevated systems of rails above the place where the arches were to be erected. Each truck was pulled by a chain from the extremity of the bridge above the abutment to its central part, and could stop at any intermediate point. The load hung from the truck by means of pulleys and cable, so that it could be kept up or down at any height. Cables and chains were moved by means of steam winches at each extremity of the travelling bridge according to the orders communicated.

In this way, when the orders were carefully given by the foreman to the engine-drivers, the workmen had scarcely any trouble; the handling required only a certain cleverness in the operation of keeping together the corresponding bolt-holes by means of crowbars, while each voussoir was slowly slipping along the next one that had just been erected.

The time necessary to hold a voussoir, to present, and to connect it to the next one, and also to secure it with oak wedges, was only about ten minutes. The successive operations were really a little longer because it was not possible, within ten minutes, to clean the surfaces of the table-joint from the coat of paint which kept them from rusting. Nevertheless, as every half-arch consisted only of sixteen voussoirs, two sets of six workmen with good foremen easily connected up two arches within two days.

During the work of connection the foreman noted with a gauge that the arches were at the proper distance, so that when it was completed the direction of each half-arch was almost correct. But as it was indispensable on account of the necessity both of assuring a good transmission of the enormous thrust and of mounting the flooring, which was manufactured in shops at a great distance from the steel foundries, to get a very high degree of exactness in the setting of the arches, the chief erector accurately provided for it. When by small removals, obtained by means of crowbars and wedges, he judged the arches to have been brought in their proper places, when the inspectors had stated that the springing articulations were at the proper level, that the two parts of each arch were exactly in the prolongation of each other, and that the sockets were satisfactorily in connection with the pins, then the thrust sockets were sealed in the thrust-stones with liquid cement forced into the joint.

Four days after they were filled, the cement joints were fast enough to support the thrust of the arches, so that it was possible to take away the centreings.

In spite of the precautions taken at the steel works, the engineers did not rely on the measurements made at a distance for the regulation of the arches; they had purposely arranged the length of the voussoirs to be in the total three centimetres (one inch) shorter than the arches, the difference being filled in by sheets of rolled steel placed at the joints of each of the two central socket voussoirs. A sufficient number of rolled steel sheets of various thicknesses having been cut beforehand, drilled and prepared, it was possible to fit at once, by a proper combination of them, joints of any required thickness.

The last operation to be described is the method of removing the centreings from the arches.

The processes commonly used for such operations did not seem satisfactory because the stresses developed in the supports as well as in the arches could not be well known, and it was equally inconvenient, even dangerous, both to develop extension stresses in the arches—for which the joints were not made—and to bring the loads in the central part of the rolling bridge to an excessive amount. Moreover, it was indispensable to secure the possibility of putting the arches again in connection with the centreings, in order to change, if necessary, the size of a regulating joint. It was decided on these accounts that the operation should be completed by means of screw cranes, and that the screw cranes should be dynamometric. The screws were fitted with Belleville washer springs constructed by Schneider & Co.

The time required for the successive operations should have been 160 days; it was really six months and a half, from the end of November to June 9. The increase in the time was only due to the delay in delivering metal for the upper part of the bridge, on account of which the operation of mounting the arches was interrupted in the month of January.

Some peculiarities of the metallic structure in connection with the use of cast steel, and the flatness and the width of the bridge, present a certain interest of novelty.

As the steel-makers deemed it important for the good and cheap casting of the voussoirs that the thickness of all parts of them should be as uniform as possible, the surfaces of the webs and of the top and bottom flanges have been designed to be plain without any hook or prominent block. Only a few bearings, obtained by planing at places an extra thickness of ten or twelve millimetres, were allowed besides the stays stiffening the webs and flanges.

As, moreover, the bridge is skew, there is no correspondence between the stays of the consecutive ribs, and, therefore, no possibility of using them for the necessary connections between the ribs.

For these reasons the voussoirs have been arranged to be held only by the top flange, and they have been stiffened in consequence by strong joint tables and two main stays. Near the springings, cast steel shoes fixed at the base of the upright pillars grasp the top flange of the voussoirs properly planed and drilled at these points ; bolts keep the shoes from slipping along the flanges. The upright pillars being connected together by means of horizontal and cross bars, the shoes are strongly maintained at the required distance.

In the central part, on account of the want of height, the top flanges of the voussoirs are held by the beams of the flooring. This arrangement, which the engineers could not help making use of, was somewhat troublesome. In consequence of it the structure of the flooring required the most careful designing ; the distance from the top of the arches to the top of the beams being extremely variable, and according with no simple law on account of the convexity of the flooring and of the obliquity of the beams to the direction of the axis of the river, the joints connecting the beams with the arches have been necessarily made in the most various ways, the number being no less than 173.

The last peculiarity I have to mention to you concerns the precautions taken on account of the transversal expansion, which is not to be neglected on a length of 40 metres (141 feet). It was found that the stresses developed in the arches near the springings in consequence of the expansion of the rigid beams in which the top flanges were inserted by the aforesaid cast steel shoes, could rise at a dangerous rate. Consequently, the three sets of beams near the springings have been supplied with expansion joints made of Belleville spring washers, so that the stresses transmitted by the horizontal bars of the beams are limited.

The test requirements for the steel do not present anything of special interest. The steel has been divided into four grades :

Steel for angles and plates ; grade I.
Steel for rivets ; grade II.
Steel castings for voussoirs ; grade III.
Hammered steel for pins ; grade IV.

All steel castings have been thoroughly annealed. The tests required for this part of the work concerned not only tensile strength, but also power to resist shocks.

The required conditions and the most interesting results are shown in the following tables :

Test Requirements for Tensile Strength.

—	I.	II.	III.	IV.
Minimum ultimate— kg. per sq. millimetre	45	38	48 *45* 42	60
lb. per sq. inch	64000	54047	68267 *64000* 59734	85332
Minimum elastic limit— kg. per sq. millimetre	24	24	24 *24* 22	40
lb. per sq. inch	34130	34130	*34130* 31284	56890
Minimum percentage elongation in 200 millimetres	22%	28%	—	—
Minimum percentage elongation in 100 millimetres (150 sq. millimetres specimens)	—	—	10 *12* 15 per cent.	18%

Results obtained for Grade III. *Average for each Steel Shop. (Each arch is shown by a letter from A to O.)*

—	Arches A,H,L,O,	Arches B,F,J,N,	Arches C,G,M,	Arches D,I,	Arches E.K.
Minimum ultimate— kg. per sq. millimetre	54·9	50·1	67·1	52·4	55·6
lb. per sq. inch	78080	71252	95427	74523	79074
Minimum elastic limit— kg. per sq. millimetre	28·5	27·4	36·7	28·6	34·1
lbs. per sq. inch	40528	38964	52198	40670	48501
Minimum percentage elongation in 200 millimetres	—	—	—	—	—
Minimum percentage elongation in 100 millimetres (150 sq. millimetres specimens)	16·4%	19·4%	15·8%	17·9%	17·0%

Test Requirements for Fragility. (Specimens shaped in square bars 900 *sq. mm. in section,* 200 *mm. in length.)*

	Distance between the edge cutters supporting specimens	160 millimetres.
	Weight of the hammer	18 kilogrammes.
Grade III.	Height of the fall	Increasing from 1 metre to the minimum height of 1·50 by distances of 0·05 at each blow.
	Minimum number of blows	10.
Grade IV.	Height of the fall	2·75 metres.
	Minimum number of blows	15.

The test experiments for Grade III., when compared with the similar tests commonly used for cast iron, are such that one could say the fragility of the steel is to the fragility of cast iron of good quality as 1 : 7.

The total weight of masonry used in the foundations is about 36,400 tons for each abutment.

The total weight of steel required for the erection of the bridge amounted to 5,400 tons. About 4,330 tons are included in the metallic frame of the bridge, 670 tons are incorporated in the foundations, and 400 tons was used for the temporary rolling bridge. (Exactly 5,481, 4,385, 730, 385 metric tons).

Decoration of the Bridge.—I have now completed the description of the engineering features of this bridge, but it is impossible to leave the subject of the erection of Alexander III. Bridge without saying some words about its decoration.

It was decided, at the outset, that the entrances of the bridge should be fitted with ornaments of an architectural style, harmonising with the adjacent Palaces of Fine Arts. The design and the erection of these monumental pillars, as well as the preparation of the designs for the ornamental details of the bridge, were the special task of the architects.

The work was entrusted to Messrs. Cassieu Bernard and Cousin, distinguished architects, who sent in remarkable designs for the Exhibition, and were consequently selected for co-operating in an important part of it.

The ornaments of the external ribs consist of a frieze fixed upon the curved webs of the ribs, and of a decorative portico which covers the rolled steel spandril uprights. This portico is fitted with garlands and masks, and it is crowned with a moulded cornice. The cornice itself is surmounted by a balustrade, which is the guard-rail of the bridge. Frieze, portico, garlands, masks, cornice, and balusters are made of cast iron.

Directly above the pillars of the portico bronze lamp-posts are inserted in the balustrade, the upper part of which is of bronze.

This ornamental system is completed by three great hammered copper cartouches hanging from the balustrade at the three articulation points. The central one is the most important, being supported by two female figures of about three times life-size.

All the ornaments have been carefully designed, the decorative elements being chiefly studies from aquatic animals or plants. The best French sculptors were asked to co-operate in the designs of the monumental pillars at the entrances, and nothing has been spared to secure an excellent artistic effect.

More than twenty engineers attended the preparatory meeting, at which the steel-makers undertook to try the use of cast steel as arranged by the authors of the design ; they afforded great help, the fruit of their wide experience, in fixing the most convenient shapes of the voussoirs.

Messrs. Pillé and Daydé, assisted by M. Gilliard, designed and constructed the caissons for Messrs. Letellier and Boutrinquieu, general contractors for the masonry works.

M. Lautracq, chief engineer to the firm Fives of Lille, one of the contractors for the steel-work, and his assistants designed the somewhat complicated framework of the bridge.

Messrs. Schmidt and Rochebois, engineers to Schneider & Co., the other contractor for the steel-work, specially designed the rolling bridge and carried out the operations for erecting the bridge with the help of their very clever chief erector, M. Camus.

To these names I need only add the name of the firm Durenne, to whom the ornamental part of the cast iron was entrusted.

I will finally mention our inspectors, Messrs. Boucher, Lavallez, Grimaud, and Retraint, distinguished members of the French 'Corps des Conducteurs des Ponts et Chaussées,' amongst whom engineers are sure to find, in all circumstances, the truest assistance and, what is more, friendly companionship.

Many obstacles have been mastered, but the trials are not yet over, and the battle is not yet won. I was very ill at ease as to the success of the bridge when I accepted the kind and gratifying invitation that I should prepare this paper; I am still rather anxious, but I hope soon to be free of this anxiety, and next year when you come to see the Exhibition I trust to have the pleasure of showing you the completed bridge in its bright artistic dress.

Dover Harbour Works. *By* J. C. Coode, *M.Inst.C.E.*, *and* W. Matthews, *M.Inst.C.E.*

[Ordered by the General Committee to be printed *in extenso.*]

[PLATE.]

Many interesting records, extending back more than 400 years, still exist of works proposed and executed for the formation and improvement of the harbour at Dover; necessarily these older records apply chiefly to works on the sites now occupied by the Tidal Harbour and the Wellington and Granville Docks.

The history of the port is dealt with in a special chapter of the Guide Book issued by this Association, and it is therefore now proposed to refer only to a few of the steps which, more directly, have led to the adoption of the important works at present under construction.

In the year 1840, a Royal Commission was appointed to survey the harbours of the south-east coast.

It is on this occasion unnecessary to quote the recommendations of the Commission with regard to other ports, but with reference to Dover they remarked:—

'This harbour, as the principal port of communication between Great Britain and the Continent, has been regarded at all times as a place of the greatest importance.'

It may be of interest to quote here a somewhat similar but more detailed opinion given by Sir Walter Raleigh in a memorial presented to Queen Elizabeth in the year 1580:—

'No promontory, town, or haven, in Christendom, is so placed by nature and situation, both to gratify friends, and annoy enemies, as this town of Dover; no place is so settled to receive and deliver intelligence for all matters and actions in Europe, from time to time; no town is by nature so settled, either to allure intercourse by sea, or to train inhabitants by land, to make it great, fair, rich, and populous; nor is there in the whole circuit of this famous island any port, either in respect of security or defence, or of traffic or intercourse, more convenient, needful, or rather of necessity to be regarded, than this of Dover, situated on a promontory next fronting a puissant foreign king, and in the very streight, passage, and intercourse of almost all the shipping in Christendom.'

Having completed their inspections, the Commissioners reported as follows:—

'The situation which appears to us of the greatest importance, and at the same time affords the most eligible position for a deep-water harbour, is Dover Bay. Independently of its proximity to the Continent, this bay possesses considerable advantages; the depth of water at 400 yards from the shore is two fathoms at low water of spring tides, and but six fathoms at 1,100 yards, which therefore affords sufficient width for the construction of a capacious deep-water harbour, without getting into such a depth for the site of the piers or breakwater as would greatly add to the expense of the works.'

The works recommended by the Commissioners were indicated on a large cartoon, which was exhibited to the Section, by black lines, and were described as follows:—

'The principal feature of the proposed plan is a breakwater at the average distance of 1,000 yards from the shore, with piers projected from the land towards its eastern and western ends.'

The area at low water enclosed within the works would have been 450 acres, of which 320 acres would have been seaward of the two-fathom line. It was pointed out that either one entrance, or two entrances, could be provided as desired. The advantages of two entrances were stated to be—

'That vessels might enter or leave the harbour with the wind from any quarter, and a ready access be afforded to the mouth of the present harbour from the western entrance, without passing through the centre of the new harbour.'

On the other hand the provision of only one entrance in the middle of the breakwater would have the advantage of rendering the interior of the harbour in some degree more quiet. The Commissioners were in favour of two entrances. The estimated cost of the works proposed was 2,000,000*l.*

Chiefly on account of the terms of a report on shipwrecks made by a Select Committee of the House of Commons in 1843, a further Royal Commission was appointed in 1844 to consider:—

1st. Whether it was desirable that a harbour of refuge should be constructed in the Channel.

2nd. What site would be the most eligible for such a harbour on account of its combining in the greatest degree the following grounds of preference:—

(*a*) That it should be of easy access at all times of tide to vessels requiring shelter from stress of weather.

(*b*) That it should be calculated for a station for armed vessels of war in the event of hostilities, both for purposes of offence and defence; and

(*c*) That it should possess facilities for insuring its defence in the event of an attack by the enemy.

In reporting, the Commissioners agreed with their predecessors of 1840 in pronouncing a favourable opinion of Dover as a site for a harbour of refuge, but gave special attention to the quality of the anchorage and the liability of the harbour to silt up. At the instance of the Commissioners, Captain Washington, in command of H.M.S. *Blazer*, made practical trials of the holding qualities of the anchorage, and reported in the following terms:—

'Thus the tough nature of the holding ground, so much better than, from common report, I had anticipated, having disabled one anchor and parted the cable from the other, and the fact of two large ships having also parted their cables in recent gales, appeared to be decisive as to the good quality of the anchorage, nor, after the trials I have witnessed, should I have any hesitation in riding out a gale of wind in Dover Bay in its present state; how much less so when enclosed by a breakwater!'

The probability of the deposit of silt in an enclosed harbour could not be so definitely determined; samples of water taken in various positions and depths showed that the quantity of matter in suspension varied from three to thirteen grains per cubic foot in calm weather, and from ten to fifty-four grains in a strong S.W. breeze. The Commissioners were of opinion that more extensive experiments were necessary, and that these should be continued for the space of a year, in all circumstances of weather.

They submitted the design shown by purple lines on the cartoon, and, pending further consideration of the general scheme, urged the immediate commencement of 'that portion which is to commence at Cheeseman's Head.' For the information of visitors, it may be well to say that the work thus described is that now generally known as the 'Admiralty Pier.'

In the next year, *i.e.* 1845, a further Commission was appointed to consider plans submitted by eight of the leading engineers of the day, and reported that the form of the harbour should be practically that recommended in the previous year.

Further observations on the quantity of silt held in suspension were made, and the report pointed out that if liability to silt were deemed an objection, it would be idle to attempt such works on any part of our coast. To minimise the difficulty it was considered better to admit only the quantity of water required to maintain the level in the harbour without sensible current, than to permit a free tidal current which would sweep through without causing a deposit.

As an instance supporting this contention, reference was made to Kingstown, in Dublin Bay, where the harbour, although in the neighbourhood of numerous sandbanks, and with a single entrance in the fair line of the tide, remained, after twenty years' experience, free from any permanent deposit.

The only other point considered by this Commission to which reference need now be made was the mode of construction. After receiving very contradictory evidence, the system of upright walls was recommended in preference to sloping stone breakwaters.

As a result of these inquiries and recommendations the contract for the first portion of the Admiralty Pier was let in October 1847, and, excepting only a small addition to its seaward end, it was completed in 1871. Its total length, including the turret, is about 2,000 feet, and the general character of its construction was indicated on a diagram. It will be universally admitted that, considered either as an engineering structure or as affording accommodation for an enormous passenger traffic, this pier bears favourable comparison with any work of a similar character, and reflects the greatest credit on its designers and builders.

On only one occasion since its completion has any serious accident occurred to the Admiralty Pier. This took place during an exceptionally heavy gale on January 1, 1877, and was confined almost entirely to the superstructure above quay-level. The damage was clearly due to the thickness of the parapet, as originally designed by Messrs. Walker and Burgess, having been very largely reduced with a view to give greater width for passenger platforms. At the time the pier was designed it was not contemplated that it would be used for train service.

Between the years 1869 and 1889 many designs were put forward for the improvement of the port; these need not be now considered, but it may be of interest to note that a Committee appointed in 1881 to consider certain questions relating to the employment of convicts in the United Kingdom reported in favour of a continuation of the system under which large public undertakings, such as the fortifications and breakwater at Portland, the great basins at Chatham, and other similar works, had been constructed. From all the schemes laid before them, the Committee selected, on account of their magnitude, their importance from a national point of view, and as well suited for the employment of prison labour :—

1. The construction of a pier and breakwater at Dover so as to form with the Admiralty Pier a large harbour similar to that at Portland ; and
2. The formation of a harbour of the same character at Filey in Yorkshire.

The large convict prison on the East Cliff was constructed with the intention of carrying out the recommendation of the Committee as regards Dover, but, for several years, no further steps were taken (see Plate).

On reference to the diagram, which was exhibited to the Section, it is seen that the Admiralty Pier must give fairly good accommodation for landing and embarking even during ordinary gales from the S.W. During exceptional storms, broken water is carried over the parapet, and access to and landing from steamers is attended with risk. For use during moderate winds from the E. and N.E., landing facilities have been provided by the construction of stages on the western face of the pier. It is, however, evident that with winds from the S.E., the pier is exposed on each face, and serious delay and inconvenience have been thereby caused. To improve the then existing conditions, the Dover Harbour Board in 1890 consulted the late Sir John Coode with a view to the construction of a sheltered deep-water harbour.

The work was sanctioned by Act of Parliament in 1891.

The design recommended and adopted is shown on the Plate. The scheme, for convenience of description and to distinguish it from the larger national works, is frequently designated 'the Commercial Harbour,' and will be so named whenever it is referred to in this paper.

The sheltering works proposed were: (1) An Eastern Pier, running about S.E. from the Clock Tower, and (2) An extension in an approximately eastern direction of the Admiralty Pier. The sheltered area which would have been enclosed was 56 acres, and within this it was proposed to reclaim an area of about 5 acres lying between the inner end of the Admiralty Pier and the entrance to the existing Inner Harbour. From the front of the reclamation two jetties, each 400 feet long and 100 feet wide, were to be constructed. They were to be furnished with commodious landing-stages, having platforms at various levels to accommodate steamers at all states of the tide, and were to be connected with the railway systems of the South-Eastern and London, Chatham, and Dover Companies. A depth of 15 feet at low water was to have been provided alongside and in the approach to the jetties.

The only part of this scheme commenced up to the present time is the

East Pier. The contract for its construction was let to Sir John Jackson in 1892, and the memorial stone was laid by his Royal Highness the Prince of Wales on July 20, 1893.

Towards the end of 1895 the Admiralty instructed the authors to prepare a design for an enclosed harbour suitable for the accommodation of Her Majesty's navy. For this purpose it was necessary that a detailed engineering survey should be made, including many thousand soundings extending about $1\frac{1}{4}$ miles from the shore, borings to ascertain the character of the foundation on the lines of the several proposed works, and observations on the direction and strength of the tidal currents at various periods.

The works, which, as the result of the survey, were recommended (see Plate), are:

(*a*) An extension of the Admiralty Pier in an E.S.E. direction for a length of 2,000 feet, practically doubling its present length.

(*b*) An east arm commencing against the chalk cliffs a few hundred feet east of the eastern boundary wall of the convict prison enclosure. The direction of this work will be approximately S. by W., and its length 3,320 feet.

(*c*) An isolated breakwater, 4,200 feet long, forming the southern protecting arm and running generally W. by S. and E. by N., but turning towards the north at its eastern end. The average depth, at low water, of ordinary spring tides on the line of this Southern Breakwater is 42 feet.

(*d*) The reclamation of 21 acres of the foreshore to the eastward of the Castle Jetty. This reclamation is now being formed by the construction of a substantial sea-wall, founded on the chalk, a little above the level of low water of ordinary spring tides. The length of the retaining wall from the Castle Jetty to its junction with the east arm will be 3,850 feet, of which length the foundations are now laid and the wall brought up to varying levels for 2,000 feet.

Between the seaward end of the East Arm and the eastern end of the South Breakwater there will be left an entrance 600 feet in width, with a navigable low-water depth of seven fathoms. A second entrance will be formed by the head of the Admiralty Pier extension and the western end of the Southern Breakwater. This will be 800 feet wide, and it will also have a depth of about seven fathoms.

It will be observed that the western head of this last-named entrance will be between 400 and 500 feet to the south of the eastern head. This arrangement was decided on in order to assist vessels entering the harbour at times when the east-going current is running at its greatest velocity of nearly four knots per hour. The overlap will also facilitate the entrance or exit of vessels during south-westerly gales.

The total length of sheltering works to be constructed is 9,520 feet, and the area enclosed, exclusive of the Commercial Harbour, will be 610 acres at low water, 322 acres being outside the five-fathoms line, and 171 acres outside the six-fathoms line.

Comparing these figures with the proposals of the Commission of 1844, and allowing for the existing Admiralty Pier, which was not commenced until 1847, it is found that by the addition of only 700 feet of sheltering works, the following gain of area will be obtained :—

At low water	30 acres.
At five fathoms	52 acres.
At six fathoms	59 acres.

This comparison appears to be perfectly fair, as the depth on the lines of the several works of the two designs are practically identical.

The contract for the Admiralty Harbour was let in 1897 to the well-known firm of Messrs. S. Pearson & Sons, of London.

Having generally described the works for the formation of the Admiralty Harbour and the original proposal for the Commercial Harbour, reference was made to the modified proposals for the latter (see Plate).

In the year 1890, when the Commercial Harbour was designed, there was no expectation that the Government would, in the near future, consider it desirable to proceed with the large national work, and the design was consequently drawn up so that it might be complete in itself. It will be apparent that, as soon as the 2,000 feet extension of the Admiralty Pier was decided on, the smaller extension of the same work became unnecessary. As the construction of the East Pier had, fortunately, not reached the point at which it would have commenced to curve to the south-west, the Harbour Board were advised that by continuing the work in the direction in which it had been commenced, and by a short addition to its length, a more capacious harbour would be obtained without in any way interfering with the Admiralty scheme.

The proposal being adopted by the Board, and sanctioned by the several Government Departments, the pier has been built on the line shown on the Plate, and is now rapidly approaching completion.

The construction of the short western arm has consequently been abandoned, and, as a substitute, a short 'spur' will eventually be run out from the extension of the Admiralty Pier.

The low-water area of the Commercial Harbour as laid down in 1890 was 56 acres; as now modified it will be 75 acres. This will be admitted to be a substantial increase, more particularly when it is noted that the addition is entirely outside the five-fathoms line, and that it will be obtained with little or no expense to the Harbour Board beyond that entailed by the original proposal.

Such are the objects for which the various piers for both the Admiralty and Commercial Harbours have been adopted.

Passing from the question of the design of the harbours to that of the method of construction of the several works by which they will be formed, it is proposed to describe in some detail the operations employed in the building of the East Pier. This particular pier is selected because the work is so far advanced that the results can be inspected, and also because the *principle* adopted for the solid portion forming the outer length is similar to that on which the several Admiralty works will be built.

The pier is formed first by 1,260 feet of open iron viaduct, and second by a solid masonry work, 1,650 feet long.

The open work was introduced chiefly to afford free circulation of the water in the Commercial Harbour, but had it been necessary to make it solid much additional expense would have been incurred, as the seas caused by heavy easterly and south-easterly winds would have been concentrated in the re-entering angle between the new work and those then existing on the sea front, and would probably have caused much damage to the latter. It is almost unnecessary to say that the adoption of open instead of solid work represented a substantial decrease in cost.

To carry the shore end of the viaduct and to form a retaining wall to the inclined approach leading from the promenade level, a masonry abutment, founded on concrete cylinders carried down to the chalk, was formed close to the Granville Clock Tower at the west end of the Esplanade.

The viaduct is built in spans of 40 feet, each pier consisting of three hollow wrought-iron piles strongly braced together. The width at deck level is 30 feet, and provides for a central roadway of 18 feet, and a footpath on each side of 6 feet. The level of the deck is 19 feet above high water of ordinary spring tides, and it is therefore not liable to damage even in the heaviest seas. At three points in the length of the work, the number of piles in a few bays is increased to five, giving a deck width of 56 feet, while the spans are reduced to 20 feet. Considerable additional stability, both laterally and longitudinally, is thus obtained. On the piers so constructed longitudinal lattice girders carry a platform or deck of corrugated iron plates.

The ordinary section of the viaduct, and the section at the centre stiffening bays were shown.

At first the piles were fitted with steel points, and were driven about 25 feet below ground level, inclusive of about 15 feet into the chalk which exists over the whole of Dover Bay. Contrary to expectation, the bearing power of these piles was not found sufficient, and cast-iron screws, 3 feet 6 inches in diameter, were substituted for the steel points.

The screws for a few piers proved satisfactory under the 100 tons dead weight test to which each centre pile was invariably subjected, but during the application of the test load at a pier about 200 feet from the shore, the pile, much to the surprise of all present, suddenly sank about 20 feet vertically. Borings taken at close intervals round the site of the pile showed that its position was exactly at the bottom of a cavity in the chalk, the surface of which sloped down to the pile in all directions.

The accident proved that the quality of the chalk was extremely variable, and a change in system became necessary. The method adopted for the remaining length of the viaduct is shown on the diagram. Under the centre of each pier a cast-iron cylinder 8 feet in diameter was sunk into the chalk and filled with concrete, the centre pile or column being erected on a granite block bedded therein. The two side piles, on which the loads are considerably less than on the centre, were, after the accident before described, fitted with cast-steel screws 4 feet in diameter, and no further trouble has been experienced.

It may be interesting to members to learn that when the excavations in the cylinder on the site of the pile which failed reached the depth to which the screw had originally penetrated, the blade was found broken into three pieces, having parted from the boss very close to the pile shank. The explanation of the accident appears to be that parts of the screw blade were bearing on hard chalk or flints, while other parts, as well as the point of the boss, were in soft material lying in the cavity indicated by the borings as already described.

The corrugated deck of the viaduct will be filled with concrete as soon as the outer or solid portion of the pier is completed. The surface, both of roadway and footpaths, will be formed of asphalte.

The solid masonry portion of the pier has a length, including the head, of 1,650 feet, with a width at quay level of 35 feet, and at foundation level of 48 feet. The general level of the surface is 10 feet above high water, but at the inner end this rises on a gradient of 1 in 40 to meet the higher level of the viaduct deck. When originally designed as a sheltering work, it was intended to provide on its eastern side a parapet somewhat similar to that on the Admiralty Pier. As shelter will in time be given by the works of the Admiralty Harbour, this parapet will now be omitted.

For the construction of the solid work, a substantial temporary stage carrying three powerful 'Goliath' cranes was erected. The outermost Goliath worked a heavy grab, by means of which the loose material overlying the chalk was excavated. From the centre Goliath was slung an exceptionally large diving-bell, from which the excavation and levelling of the chalk bed were effected. This part of the work was very heavy, as no block was allowed to be set at less than 3 feet below the surface of the solid chalk.

The inner Goliath was used for unloading the blocks brought on trucks, over a temporary connecting viaduct now removed, and for setting them in the pier.

The blocks throughout are of concrete, those above low water level being faced with granite. They vary in weight from 12 to 20 tons. Below low water they are set without mortar, but are well bonded and keyed together by 'joggles,' inserted into recesses cored out at the time the blocks are moulded.

Above low water the blocks are set in Portland cement mortar, and are also keyed by joggles.

Probably some members of this Association may wish to visit the works, and will then be able to see many details, a description of which time does not allow to be included in this paper. Among these details, the concrete mixing machinery, the character of the moulds used in the manufacture of the blocks, and the methods employed for lifting them, will probably be of most general interest.

The pier will be fitted with two fendered berths on each side and a landing-stage, for the accommodation of steamers, on the west side. Landing-steps, mooring-bollards, lamps, gas and water services are also to be provided.

The pier terminates in a circular head 52 feet in diameter, and on this a lighthouse of concrete masonry, faced with granite, will shortly be constructed.

It has already been indicated that the type of structure adopted for the East Pier is similar to that to be followed in building the works for the formation of the Admiralty Harbour, but on account of their exposed positions and the heavy wave stroke to which they will be subjected, the latter will necessarily be of considerably greater dimensions; comparison of the section of the East Pier with the section of the Admiralty Pier extension, as shown on diagrams, confirms this statement.

The cross section of the Admiralty Pier extension, shown on the diagram, is worth notice if only on account of the magnitude of the temporary works. The staging, of which a short length can now be seen projecting from the end of the turret, is probably more massive than any similar structure hitherto erected in the sea. The height from the ground level to the highest point of the Goliath is 150 feet, and the total width of the stage at rail level 115 feet.

Comparative sections of the South Breakwater, east arm and reclamation wall were shown.

The area to be reclaimed between the east arm and the Castle Jetty will be filled with chalk obtained by sloping or 'scarping' the cliffs immediately behind the wall. The ground so formed will, in the first instance, be utilised for the formation of the block building yards and the erection of the workshops, stores, and offices required for the construction of the east arm and South Breakwater.

A temporary yard for the service of the Admiralty Pier extension has been formed on the beach in front of the South-Eastern Railway Company's 'Town' Station.

The blocks for the reclamation wall are built at Sandwich, where a large quantity of ballast—*i.e.* sand and shingle—eminently suitable for the manufacture of concrete has been obtained by the contractors. The blocks, and a considerable quantity of ballast, are now brought from Sandwich by lighters, but a light railway at present under construction will, when completed, deliver material direct on to the reclaimed yard. Ballast is also obtained from Dungeness, but, being practically free from sand, requires to be mixed with the material from Sandwich before it is used for block-making.

Portland cement of the highest quality, manufactured under continuous inspection, analysis, and test, is alone used in any of the permanent works.

It is feared that the patience of the meeting must already have been severely tried by the length of this paper, and a subject so largely technical. Even at the risk of being tedious it is considered that this opportunity should not be lost for a reference to the inconvenience, discomfort and serious delay experienced during last winter from the interruptions to the passenger service from the port.

That the interruptions were largely due to the position of the works during a season unexampled for the number of heavy south-westerly gales cannot be questioned.

The exact cause of this will be easily understood by reference to the Plate on which the direction of S.W. winds is represented. The seas brought up Channel by gales from and near this quarter, and outside the shelter of the Admiralty Pier, travel on until they strike the western face of the East Pier and recoil therefrom on to the landing-stages on the eastern side of the Admiralty Pier, which stages in similar gales had previously been available.

That this action would occur and become stronger as the East Pier advanced seaward, without a corresponding advance of the Admiralty Pier, was evident before the inconvenience was actually experienced.

In order to minimise the delay two steps were taken by the Harbour Board. First, an entirely new landing-stage was constructed near the outer end of the Admiralty Pier, where the disturbance was much less felt than at the stages nearer the shore. This was frequently available when it was impossible to approach the older berths.

Secondly, negotiations were opened with a view if possible to delay further progress with the East Pier until the extension of the Admiralty Pier was sufficiently advanced to give the required shelter. It was, however, found that the cost of retarding the work would be so great that the financial position of the Board did not justify this course being adopted.

The advance of the masonry extension of the Admiralty Pier is not likely to be sufficient to give much additional shelter during the coming winter, but the large number of piles in the temporary stage will, as experience has shown to be the case in other places, no doubt assist in breaking up the seas; thus it may reasonably be expected that delay will be on a smaller scale than was experienced last year.

In Sir John Coode's original design, the whole of the East Pier during south-west winds would have been inside shelter of the Admiralty Pier as it then existed.

It is hoped it has been made clear that had it not been for the change of plan consequent on the decision of the Admiralty to carry out the splendid work lately started, no disturbance of the traffic would have been experienced.

Is it unwise to suggest that the inconvenience, serious as it has been, is only temporary, and that to obtain such a harbour—probably second to none—much greater sacrifices would willingly be made by almost every port in the kingdom?

In conclusion, at the request of the Mayor, Sir William Crundall, attention was drawn to the peculiarly favourable situation of Dover, with reference to several Continental ports. To illustrate this point, an enlarged chart of the English Channel was shown, and the distances in nautical miles from port to port were figured thereon.

The proverbial schoolboy knows that Dover is the nearest port to Calais. It is, however, believed that very few persons, whether schoolboys or of more mature age, are aware that Dover is also nearer to Boulogne than Folkestone; nearer to Flushing, and therefore to Antwerp, than either Queenborough or Harwich; that as regards Dieppe, Newhaven has the advantage by only 7 nautical miles, and Southampton, only a similar advantage with reference to Havre.

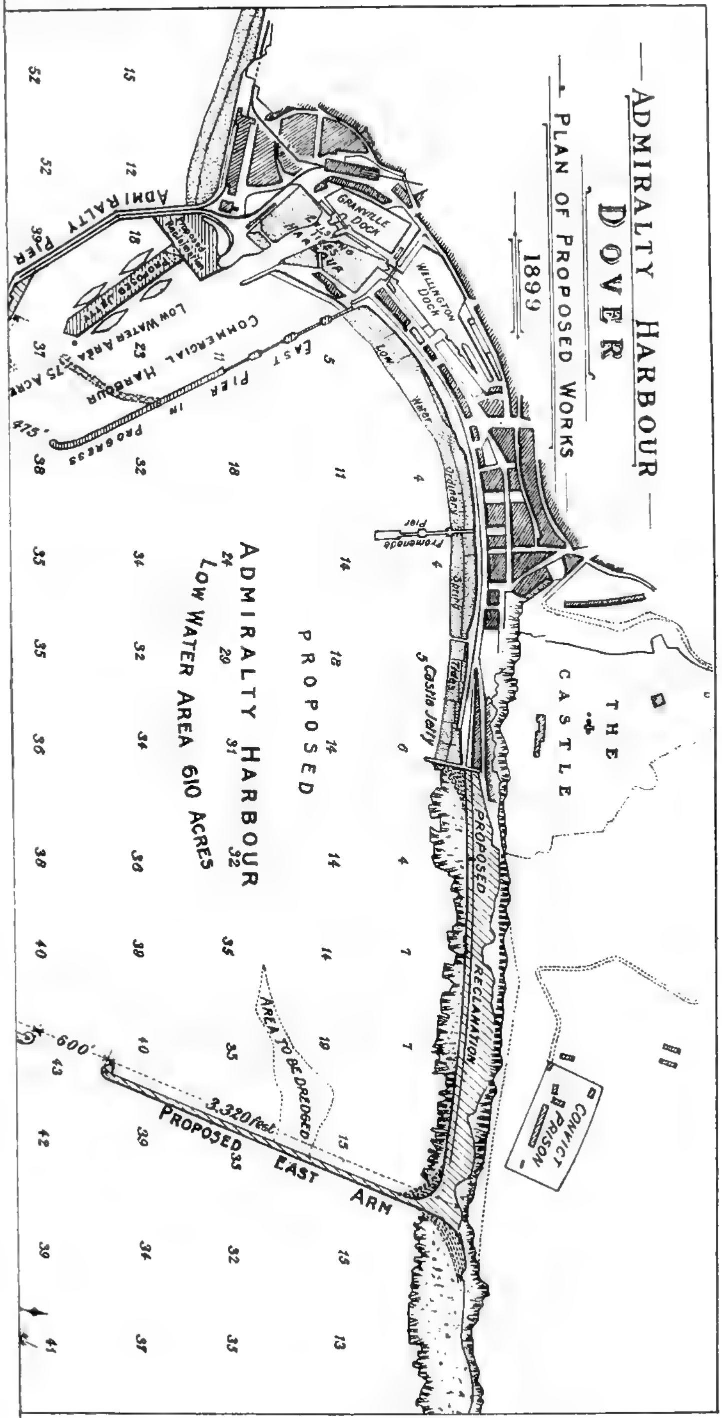
Again, compare Dover with Southampton as a 'port of call' for foreign liners from Antwerp, Rotterdam, Hamburg, and all ports to the North. The comparison will hold good whether these liners are bound for the United States, *via* the Lizard, or for South Africa, India, China, and Australia, &c., *via* Ushant.

The call at Dover would involve no complicated course such as that necessary for Southampton, *via* Dungeness, the *Royal Sovereign* lightship, the Owers, Spithead, and Southampton Water.

The course on leaving the 'port of call' is also in favour of Dover, as after passing Dungeness a straight course could be set for either the Lizard or Ushant, no variations corresponding to Southampton Water, the Solent, and the Needles being requisite.

Not only would there be a saving in distance, but the risks of fogs, so prevalent at the back of the Isle of Wight, would be much reduced.

Under these circumstances it is not surprising to learn that proposals have been made to utilise Dover in connection with several lines of ocean-going steamers, and that the Harbour Board have already received inquiries on the subject. Finally, it is hoped that with the schemes for the improvement of the port fully before them the members of the Association will cordially agree with the forcible language of Sir Walter Raleigh—'nor is there in the whole circuit of this famous island any port more convenient, needful, or rather of necessity to be regarded, than this of Dover.'



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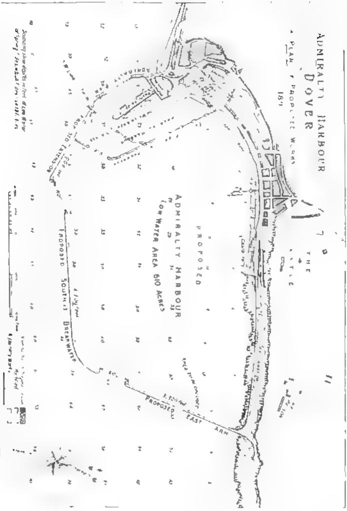

Illustrating Paper on the Dover Harbour Works.

Mental and Physical Deviations from the Normal among Children in Public Elementary and other Schools.—Report of the Committee, consisting of the late Sir DOUGLAS GALTON (*Chairman*), Dr. FRANCIS WARNER (*Secretary*), Mr. E. W. BRABROOK, Dr. J. G. GARSON, *and* Mr. E. WHITE WALLIS. (*Report drawn up by the Secretary.*)

IN presenting this our Seventh Annual Report, we must first express our deep regret at the loss sustained by the death of Sir Douglas Galton, at whose instigation the Committee was first appointed in 1892, who acted as Chairman, and took a deep interest in all its proceedings.

The Committee have continued to work in conjunction with the Childhood Society, to whom they are indebted for access to the records of children examined individually by members of this Committee and the Society.

Since our first Report in 1893 much attention has been directed to the care of children subnormal in mental or physical conditions, and a Bill is now before Parliament to make better provision for the elementary education of defective and epileptic children in England and Wales.

We here give a further account of the 1,120 exceptional children requiring special care and training, in continuation of our former Reports. They have previously been arranged in sub-classes, presenting the class or classes of defect named only; the cases being distributed first in age-groups, secondly under school standards.

Some of these children will require special modes of care and teaching, many are delicate in health, and a small proportion are imbecile.

This catalogue of cases was asked for in evidence by the Committee of the Education Department on Children Feeble-minded; it appears in our Report for 1897.

Following the catalogue of cases is a table, in which the children are arranged in primary groups, presenting only the class of defect indicated; they form about 1 per cent. of the children in public elementary schools. Table B 3 (Report 1897) deals with children collected by the Charity Organisation Society in various parts of London, and presented for report as to mental and physical status; they were examined and reported on by Dr. Francis Warner. It is there shown that of 149 boys and 89 girls collected by the C.O.S. Committee and teachers as being defective, only 88 boys and 68 girls were on examination found so far subnormal as to be reported 'exceptional children.' This indicates that much care and discretion will be needed in selecting these children and in organising special classes of schools.

In our Report (1898), the co-relation of classes of defects in these children is shown to be very high: they have a much greater tendency than average children to become delicate in an adverse environment, especially the girls; this, as might be expected, is most marked in those under seven years of age.

In our present Report the 1,120 exceptional children are arranged in a table as presenting only the class or classes of defect indicated in primary groups, showing their proportion to the compound groups, respectively as distributed under ages and sex.

The primary groups are those containing all cases presenting the defect or combination of defects indicated, only.

The compound groups are those containing all cases presenting the defect or combination of defects indicated, alone or in combination. Thus: there were 388 boys and 352 girls at all ages who presented developmental defects; of these, 4·380 per cent. of the boys and 2·557 per cent. of the girls presented abnormal nerve-signs only, *i.e.* without either low nutrition or mental dulness accompanying. Such cases may be found, for instance, among children crippled by congenital absence of a hand.

The main classes of defect are indicated at the left hand of the table by symbols:—A. Defect in development of body; B. Abnormal nerve-signs; C. Low nutrition; D. Mental dulness.

The facts shown in the table suggest the need of management and care in training stage by stage, with the object of improving each phase of mental ability and removing individual disabilities; children with any degree of congenital defect in development usually require medical care as to conditions of the ears, throat, and mouth, also as to eyesight and in general health culture.

The abnormal nerve-signs may often be removed one by one in the daily practice of physical exercises, and adapted training, thus rendering the brain more apt for mental instruction and teaching.

The investigation made and the facts thus far tabulated have proved of much value, as a basis of knowledge of childhood, especially in its subnormal conditions.

The Committee desire to be reappointed with an addition to their number, and a new Chairman elected to act in conjunction with the Childhood Society, for the scientific study of the mental and physical conditions of children, and ask a grant of 10*l.* in aid of their work.

TABLE *based on the observation of* 1,120 *children who appeared to require special care and training on physical or mental grounds—Boys* 597, *Girls* 523—*showing the proportion of the Primary Groups to the Compound Groups respectively. This Table is arranged in four columns, giving the percentages for children in age-groups and at all ages. The percentages are taken on the number in the Compound Group,* i.e. *all the cases with that class of defect. Thus: of all cases with developmental defect (Compound Group) at all ages* 1·030 *per cent. of the boys and* 1·990 *per cent. of the girls presented low nutrition only (Primary Group).*

No. of Cases and Primary Groups	7 years and under		Ages 8–10		Ages 11 and over		All ages		—
	B.	G.	B.	G.	B.	G.	B.	G.	
No. of cases—A .	*114*	*146*	*151*	*126*	*123*	*80*	*388*	*352*	*Of all cases with Developmental defect.*
A	1·755	4·110	3·311	1·588	4·878	1·282	3·350	2·557	Per cent. with no other class of defect.
A B . . .	4·386	1·370	3·311	1·588	5·691	3·842	4 380	2·557	„ „ Abnormal Nerve-signs only.
A C . . .	1·755	2·740	0·662	0·794	0·813	2·562	1·030	1·990	„ „ Low nutrition only.
A D . . .	4·386	2·055	3·311	3·960	8·130	6·410	5·154	3·695	„ „ Mental dulness only.
A B C . . .	1·755	1·370	1·324	0·000	0·813	0·000	1·288	0·569	„ „ Nerve-signs and Low nutrition only.

TABLE—*continued.*

No. of Cases and Primary Groups	7 years and under		Ages 8-10		Ages 11 and over		All ages		—
	B.	G.	B.	G.	B.	G.	B.	G.	
A B D . . .	12·284	8·903	20·531	15·875	32·520	24·361	21·910	14·780	Per cent. with Nerve-signs and Dulness only.
A C D . . .	0·877	2·055	0·662	3·175	2·435	3·842	1·288	2·841	„ „ Low nutrition and Dulness only.
A B C D . .	72·802	77·397	66·888	73·020	44·720	57·701	61·600	71·011	„ „ Low nutrition and Dulness, and Nerve-signs.
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	
No. of cases—**B** .	*142*	*153*	*186*	*148*	*141*	*115*	*469*	*418*	*Of all cases with Abnormal Nerve-signs.*
B	6·338	3·922	9·679	6·086	11·346	10·432	9·169	6·458	Per cent. with no other class of defect.
A B . . .	3·521	1·308	2·689	1·352	4·960	2·607	3·616	2·153	„ „ Developmental defect only.
B C . . .	—	—	0·000	0·676	0·709	1·739	0·213	0·717	„ „ Low nutrition only.
B D . . .	16·200	9·803	12·364	13·511	14·185	27·831	14·080	16·030	„ „ Mental dulness only.
A B C . . .	1·408	1·308	1·076	0·000	0·709	0·000	1·067	0·478	„ „ Developmental defect and Low nutrition only.
A B D . . .	9·856	8·497	16·663	13·511	28·370	16·524	18·120	12·440	„ „ Developmental defect and Dulness only.
B C D . . .	4·226	1·308	3·227	2·704	0·709	1·739	2·772	1·914	„ „ Low nutrition and Dulness only.
A B C D . .	58·451	73·854	54·302	62·160	39·012	39·128	50·963	59·810	„ „ Low nutrition and Dulness, and Developmental defect.
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	
No. of cases—**C** .	*96*	*126*	*115*	*105*	*63*	*57*	*274*	*288*	*Of all cases with Low nutrition.*
C	2·084	0·000	3·478	1·902	1·587	3·508	2·550	1·395	Per cent. with no other class of defect.
A C . . .	2·084	3·175	0·869	0·951	1·587	3·508	1·445	2·436	„ „ Developmental defect only.
B C . . .	0·000	0·000	0·000	0·951	1·587	3·508	0·350	1·053	„ „ Abnormal Nerve-signs only.
C D . . .	0·000	1·589	0·000	0·951	0·000	1·754	0·000	1·395	„ „ Mental dulness only.
A B C . . .	2·084	1·589	1·739	0·000	1·587	0·000	1·825	0·695	„ „ Developmental defect and Nerve-signs only.
A C D . . .	1·042	2·381	0·869	3·814	4·769	5·262	1·825	3·486	„ „ Developmental defect and Dulness only.
B C D . . .	6·252	1·589	5·218	3·814	1·587	3·508	4·735	2·790	„ „ Nerve-signs and Dulness only.
A B C D . .	86·454	89·677	87·827	87·617	87·296	78·952	87·270	86·750	„ „ Nerve-signs and Dulness, and Developmental defect.
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	
No. of cases—**D** .	*146*	*157*	*177*	*159*	*144*	*115*	*467*	*431*	*Of all cases Dull Children.*
D	9·586	3·822	5·650	8·175	10·416	6·956	8·352	6·265	Per cent. with no other class of defect.
A D . . .	3·421	1·911	2·822	3·141	6·947	4·345	4·283	3·016	„ „ Developmental defect only.
B D . . .	15·751	9·555	12·992	12·586	13·894	27·831	14·140	15·540	„ „ Abnormal Nerve-signs only.
C D . . .	0·000	1·274	0·000	0·626	0·000	0·869	0·000	0·928	„ „ Low nutrition only.
A B D . . .	9·586	8·277	17·512	12·586	27·768	16·525	18·200	12·071	„ „ Developmental defect and Nerve-signs only.
A C D . . .	0·684	1·911	0·562	2·515	2·083	2·607	1·071	2·311	„ „ Developmental defect and Low nutrition only.
B C D . . .	4·110	1·274	3·390	2·515	0·694	1·739	2·784	1·857	„ „ Nerve-signs and Low nutrition only.
A B C D . .	56·862	71·976	57·072	57·856	38·198	39·128	51·170	58·012	„ „ Nerve-signs and Low nutrition, and Developmental defect.
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	

TABLE—*continued.*

No. of Cases and Primary Groups	7 years and under		Ages 8-10		Ages 11 and over		All ages		—
	B.	G.	B.	G.	B.	G.	B.	G.	
No. of cases—**A B** .	*104*	*130*	*139*	*114*	*103*	*67*	*346*	*313*	*Of all children with Developmental defect and Nerve-signs.*
A B .	4·808	1·538	3·598	1·755	6·797	4·475	4·914	2·869	Per cent. with no other class of defect.
A B C . . .	1·922	1·538	1·439	0·000	0·971	0·000	1·446	0·638	„ „ Low nutrition only.
A B D . . .	13·462	10·000	22·301	17·550	38·840	28·361	24·560	16·621	„ „ Dulness only.
A B C D . .	79·808	86·924	72·662	80·695	53·392	67·164	69·080	79·872	„ „ Dulness and Low nutrition.
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	
No. of cases—**A C** .	*88*	*122*	*105*	*97*	*60*	*50*	*253*	*269*	*Of all children with Developmental defect and Low nutrition.*
A C . . .	2·271	3·279	0·951	1·031	1·667	3·999	1·582	2·602	Per cent. with no other class of defect.
A B C . . .	2·271	1·639	1·902	0·000	1·667	0·000	1·976	0·751	„ „ Nerve-signs only.
A C D . . .	1·136	2·459	0·951	4·124	5·001	6·003	1·976	3·716	„ „ Dulness only.
A B C D . .	94·322	92·623	96·196	94·845	91·665	89·998	94·466	92·931	„ „ Dulness and Nerve-signs.
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	
No. of cases—**A D** .	*103*	*132*	*138*	*121*	*108*	*72*	*349*	*325*	*Of all children with Developmental defect and Dulness.*
A D . . .	4·841	2·273	3·624	4·132	9·260	6·944	5·722	4·000	Per cent. with no other class of defect.
A B D . . .	13·591	9·850	22·461	16·526	37·040	26·384	24·353	16·011	„ „ Nerve-signs only.
A C D . . .	0·971	2·273	0·724	3·305	2·774	4·161	1·433	3·076	„ „ Low nutrition only.
A B C D . .	80·597	85·604	73·191	76·037	50·926	62·511	68·492	76·913	„ „ Low nutrition and Nerve-signs.
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	
No. of cases—**B C** .	*91*	*117*	*109*	*97*	*58*	*49*	*258*	*263*	*Of all children with Nerve-signs and Low nutrition.*
B C . . .	0·000	0·000	0·000	1·031	1·727	4·081	0·383	1·141	Per cent. with no other class of defect.
A B C . . .	2·194	1·704	1·835	0·000	1·727	0·000	1·938	0·764	„ „ Developmental defect only.
B C D . . .	6·594	1·704	5·505	4·124	1·727	4·081	5·030	3·042	„ „ Dulness only.
A B C D . .	91·212	96·592	92·660	94·845	94·819	91·838	92·649	95·053	„ „ Dulness and Developmental defect.
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	
No. of cases—**B D** .	*126*	*143*	*161*	*136*	*116*	*98*	*403*	*377*	*Of all children with Nerve-signs and Dulness.*
B D . . .	18·251	10·495	14·282	14·705	17·241	32·648	16·373	17·756	Per cent. with no other class of defect.
A B D . .	11·111	9·094	19·261	14·705	34·482	19·387	21·094	13·790	„ „ Developmental defect only.
B C D . . .	4·761	1·398	3·722	2·943	0·861	2·041	3·225	2·122	„ „ Low nutrition only.
A B C D . .	65·875	79·013	62·735	67·647	47·416	45·924	59·308	66·332	„ „ Low nutrition and Developmental defect.
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	
No. of cases—**C D** .	*90*	*120*	*108*	*101*	*59*	*51*	*257*	*272*	*Of all children with Low nutrition and Dulness.*
C D . . .	0·000	1·661	0·000	0·990	0·000	1·962	0·000	1·471	Per cent. with no other class of defect.
A C D . . .	1·112	2·501	0·926	3·961	5·085	5·886	1·943	3·676	„ „ Developmental defect only.
B C D . . .	6·672	1·661	5·556	3·961	1·695	3·924	5·054	2·941	„ „ Nerve-signs only.
A B C D . .	92·216	94·177	93·518	91·088	93·220	88·228	93·003	91·912	„ „ Nerve-signs and Developmental defect.
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	

TABLE—*continued.*

No. of Cases and Primary Groups	7 years and under		Ages 8–10		Ages 11 and over		All ages		—
	B.	G.	B.	G.	B.	G.	B.	G.	
No. of cases—A B C	*85*	*115*	*103*	*92*	*56*	*45*	*244*	*252*	*Of all children with Developmental defect, Nerve-signs, and Low nutrition.*
A B C . . .	2·351	1·732	1·942	0·000	1·786	0·000	2·034	0·794	Per cent. with no other class of defect.
A B C D . .	97·649	98·268	98·058	100·000	98·214	100·000	97·966	99·206	„ „ Dulness.
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	
No. of cases—A B D	*97*	*126*	*132*	*112*	*95*	*64*	*324*	*302*	*Of all children with Developmental defect, Nerve-signs, and Dulness.*
A B D . . .	14·431	10·313	23·481	17·858	42·115	29·686	26·231	17·224	Per cent. with no other class of defect.
A B C D . .	85·569	89·687	76·519	72·142	57·885	70·314	73·769	82·776	„ „ Low nutrition.
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	
No. of cases—A C D	*84*	*116*	*102*	*96*	*58*	*48*	*244*	*260*	*Of all children with Developmental defect, Low nutrition, and Dulness.*
A C D . .	1·192	2·585	0·985	4·167	5·181	6·251	2·047	3·855	Per cent. with no other class of defect.
A B C D . .	98·808	96·415	99·015	95·833	94·619	93·749	97·953	96·145	„ „ Nerve-signs.
	100·000	100·000	100·000	100 000	100·000	100·000	100·000	100·000	
No. of cases—B C D	*89*	*115*	*107*	*96*	*56*	*47*	*252*	*258*	*Of all children with Nerve-signs, Low nutrition, and Dulness.*
B C D . .	6·744	1·732	5·608	4·167	1·786	4·255	5·164	3·121	Per cent. with no other class of defect.
A B C D . .	93·256	98·268	94·398	95·833	98·214	95·745	94·836	96 879	„ „ Developmental defect.
	100·000	100·0 00	100·000	100·000	100·000	100·000	100·000	100·000	

Ethnographical Survey of the United Kingdom.—Seventh and Final Report of the Committee, consisting of Mr. E. W. BRABROOK (*Chairman*), Mr. E. SIDNEY HARTLAND (*Secretary*), Mr. FRANCIS GALTON, Dr. J. G. GARSON, Professor A. C. HADDON, Dr. JOSEPH ANDERSON, Mr. J. ROMILLY ALLEN, Dr. J. BEDDOE, Mr. W. CROOKE, Professor D. J. CUNNINGHAM, Professor W. BOYD DAWKINS, Mr. ARTHUR J. EVANS, Dr. H. O. FORBES, Mr. F. G. HILTON PRICE, Sir H. HOWORTH, Professor R. MELDOLA, General PITT-RIVERS, Mr. E. G. RAVENSTEIN, Mr. GEORGE PAYNE, Mr. EDWARD CLODD, Mr. G. LAURENCE GOMME, Mr. JOSEPH JACOBS, Sir C. M. KENNEDY, K.C.M.G., Mr. EDWARD LAWS, the Ven. Archdeacon THOMAS, Mr. S. W. WILLIAMS, Professor JOHN RHYS, *and* Dr. C. R. BROWNE.

THE Committee present this as their final report, not indeed as suggesting that the work of organising an Ethnographical Survey of the United Kingdom, which was first entrusted to them at the Edinburgh Meeting in 1892, has been completed, but because in their opinion the preparation for that work has been carried as far as the means at their disposal have enabled them to carry it, and because they have arrived at the conviction that the work itself may now properly be left to be completed by other hands possessing the necessary organisation and more adequate means.

They are as fully convinced as ever of the importance of the work itself and of the soundness of the principles laid down for the conduct of it. There is ample evidence that the mixed population of this kingdom retains in many parts of the country traces of the constituents of which it is formed. Those traces are to be found in physical characters, in the expression of the features, in modes of thought, in tradition (using that word in its wider sense), and in language; and the conclusions drawn from them are capable of being verified by the testimony of local history and of archæology.

The method adopted by the Committee for setting on foot a comprehensive and scientific investigation into the existence and character of these traces of the past was:

1. To inquire what places were suitable for the survey, as containing a population in which there had been comparatively little admixture of race.
2. To draw up a brief and comprehensive code of instructions for observers, with explanatory comments and directions as to the use of instruments for measuring, &c.
3. To enlist the voluntary assistance of local societies and local observers in making measurements, collecting items of folklore, and otherwise.

Under the first head, the Committee collected in their first and second reports, from the information supplied to them by persons of authority resident in the various districts, a list of between 300 and 400 villages and places which complied with the definition laid down by the Committee as containing a number of persons whose ancestors had belonged to the locality for as far back as could be traced.

Under the second head, the Committee prepared and published, in their second and third reports, a code of instructions for observers in the several branches of the investigation. The directions as to physical measurements were drafted by Dr. Garson and Professor Haddon; those as to photographs by Mr. Francis Galton; those as to folklore by Mr. Edward Clodd; those as to dialect by Professor Skeat.

The Committee have also published in subsequent reports a paper drawn up by Mr. Hartland, containing many useful hints to observers; and a paper by Mr. Gomme, on the scientific method to be pursued in localising folklore observations, so as to enable trustworthy conclusions to be drawn from the presence or absence in any locality of one or more features incidental to a particular practice or superstition.

In other reports, the Committee have published at length specimen collections of physical observations and folklore observations, the principal of which collections were made by the lamented Dr. Walter Gregor. These are intended to serve as models for other observers, as it was not the intention of the Committee to print at length in their reports the records of observations contributed to them by the several collectors, but only a digest of the results.

Under the third head, the policy of the Committee has been :—

1. To establish Sub-committees in various parts, and secure the co-operation of local societies in forming such Committees and otherwise.
2. To obtain the services of volunteer individual observers.

The Committee feel that their best thanks are due to the societies and persons by whom they have been favoured with information ; but they are also of opinion that for the future conduct of the survey, it will not be sufficient to rely upon such assistance, however generously bestowed. To ensure absolute uniformity in the methods of collecting information, upon which the usefulness of the information for the purposes of comparison almost entirely depends, it is essential that one or more persons should be wholly engaged upon the work.

There are two methods by which this can be done :—

1. The entrusting to the Committee of the necessary means.
2. The transfer of the work to another body possessing the necessary means.

Should the first course approve itself to the Section and to the Association, it would be practicable, by a comparatively small expenditure, for the Association itself (through the present or some other Committee) to proceed with a work of great interest and value, on the lines which have been exemplified by Dr. Gregor's model collections, and by the excellent publications of Dr. Browne and Professor Haddon relating to certain communities in Ireland, as it would not be difficult to find competent persons if sufficient remuneration were assured to them to justify giving their whole time to the work.

The circumstance which induces the Committee to lean rather to the second course is that the Ethnographic Bureau, which has been so long an object of desire to anthropologists, has now been established under the auspices of the British Museum ; and the Committee cannot but think that that Bureau might well include the British Islands within the scope of its functions.

In the meantime they suggest that the reports and observations now in their hands might, where not returned to the writers, be distributed among the representatives on their body of the several societies interested, who will be able to proceed with the work of digesting them, and to publish such of them as contain matters suitable for publication in full. The five sets of measuring instruments in their possession will be returned to the Association.

Silchester Excavation.—Report of the Committee, consisting of Mr. A. J. EVANS (*Chairman*), Mr. JOHN L. MYRES (*Secretary*), *and* Mr. E. W. BRABROOK, *appointed to co-operate with the Silchester Excavation Fund Committee in their Excavations.*

THE excavations at Silchester in 1898 were begun on May 2 and continued, with the usual interval during the harvest, until November 26.

Operations were confined to an area of about eight acres in the south-west corner of the city.

This area is bounded on the north by *insulæ* XV. and XVI. ; on the east by *insulæ* XVII. and XVIII., excavated in 1897 ; and on the other sides by the city wall. It contained two *insulæ* (XIX. and XX.), together with a large triangular area to the south, forming apparently part of *insula* XVIII. See the plan in last year's report.

Insula XIX. presents the peculiarity of being inclosed by a wall, and contains, in addition to three minor buildings, a well-planned house of early date and of the largest size, with fine hypocausts. To it is attached the workshop of some industry, with a large inclosure dependent on it, containing two settling-tanks, perhaps belonging to a tannery. The court-yard of this house is partly underlaid by the remains of a much earlier one, of half-timbered construction, containing in one of its chambers a mosaic pavement of remarkable design, and perhaps the earliest in date yet found in this country. A small house in this *insula* is somewhat exceptional in plan and also, perhaps, of early date.

Insula XX. contains a number of buildings scattered over its area, but none of these appears to be of any importance. Two of them are of interest as furnishing plans of houses of the smallest class. This *insula* also contains one of the curious detached hypocausts which were noticed in the excavations of 1897. A large inclosure with attached chambers, near the lesser west gate, may be conjectured to have contained stabling for the accommodation of travellers entering the city.

Several wells were found in both *insulæ*, lined either with the usual wooden framing or disused barrels. A pit in *insula* XX. contained a double row of pointed wooden stakes driven into the bottom, and may have been for the capture of wild animals at some period anterior to the existence of the Roman town, or subsequent to its extinction. No architectural remains were found, but the rubbish-pits yielded the usual crop of earthen vessels.

The finds in bronze and bone do not call for any special notice, but an enamelled brooch of gilt-bronze, with a curious paste intaglio and several settings of rings, may be mentioned.

Among the iron objects are a well-preserved set of hooks, perhaps for hoisting barrels, and a curious pair of handcuffs or fetterlock.

From a pit in *insula* XIX. was recovered an upper quern stone, still retaining its original wooden handle.

Although a considerable area in the southern part produced no pits or traces of buildings, the *insulæ* excavated are quite up to the average in point of interest, and their addition to the plan completes a very large section of the city.

A detailed account of all the discoveries was laid before the Society of Antiquaries on May 4, 1899, and will be published by the Society in ‘Archæologia.’

The Committee ask to be reappointed with a further grant.

Ethnological Survey of Canada.—Report of the Committee, consisting of Professor D. P. PENHALLOW (*Chairman*), Dr. G. M. DAWSON (*Secretary*), Mr. E. W. BRABROOK, Professor A. C. HADDON, Mr. E. S. HARTLAND, Sir JOHN G. BOURINOT, Abbé CUOQ, Mr. B. SULTE, Abbé TANGUAY, Mr. C. HILL-TOUT, Mr. DAVID BOYLE, Rev. Dr. SCADDING, Rev. Dr. J. MACLEAN, Dr. MERÉE BEAUCHEMIN, Mr. C. N. BELL, Hon. G. ROSS, Professor J. MAVOR, *and* Mr. A. F. HUNTER.

DURING the past year the work of this Committee has been extended in important directions, although the great number and diversity of interests to be considered, the difficulty of securing interested and competent observers, and the great reluctance of many people to be made the subject of such investigations, however simple, serve to make our work one of slow progress. We nevertheless experience a sense of gratification in view of the increasing interest in our investigations manifested during the last year, and we feel confident that as the nature of our work becomes better and more widely known this interest will gain in strength.

A large number of schedules giving detailed directions to observers have been distributed; but it was found necessary to issue supplementary instructions respecting facial types and directions for certain measurements. Through the courtesy of Professor F. W. Putnam and Dr. F. Boas, we have been enabled to make use of the excellent series of facial types employed by the Bureau of Ethnology of the World's Columbian Exposition at Chicago.

Several requests for anthropometric instruments have been received, but, owing to delay in obtaining the instruments ordered, this work has not progressed as rapidly as we had hoped, and the expected data will not be available until another year. Several observers have already forwarded extensive records of measurements, but it would be premature at the present time to undertake any analysis of these, as the investigations to which they relate are still in progress.

Much of the work in progress is of such a nature that returns cannot be looked for under a year or more, but with the present organisation it may be expected that each year will witness an increasing amount of material from the various observers. Steps have been taken for the special study of groups in different provinces, and it is hoped that these efforts may result profitably in the near future.

The introduction into the North-West of large bodies of Europeans who are to become permanently incorporated in our population has suggested the importance of securing, at as early a date as possible, such facts relating to their general ethnology as may seem to establish a suitable basis for the study of these people under the influence of their new environment. Satisfactory arrangements have been made with respect to the Doukhobors, and it is probable that similar arrangements may be completed during the coming year with respect to other large bodies of immigrants.

The exceptional circumstances surrounding the Indians of British Columbia; the fact that it is becoming more difficult each year to obtain reliable accounts of these people; the rapid disappearance of old customs, dress, and mode of living; and also the present availability of the services of an expert and enthusiastic observer, have seemed sufficient reasons for devoting to their study a much larger share of the resources of the Committee than might otherwise appear justifiable.

The work now in progress includes:—

1. Customs and Traditions of the Huron Indians of Lorette, P.Q. Mr. Leon Gerin, Ottawa.

2. Anthropometric Studies. Dr. C. A. Hibbert, Montreal; Mr. A. F. Hunter, Barrie, Ont.; Dr. F. A. Patrick, Yorkton, N.W.T.; Dr. F. Tracey, Toronto.

3. Photographic Studies of the North-West Coast Indians. Dr. C. F. Newcombe, Victoria, B.C.

4. Studies of the Early Settlers of Canada. Mr. B. Sulte, Ottawa.

5. Ethnological Studies of the Indians of British Columbia. Mr. C. Hill-Tout.

Apart from the records of measurements previously alluded to, the completed work of the past year is represented by the two papers appended hereto.

1. The Origin of Early Canadian Settlers. Mr. B. Sulte, Ottawa.

2. Studies of the Indians of British Columbia. Mr. C. Hill-Tout, Vancouver, B.C.

The important studies of Mr. Hill-Tout have been prosecuted under considerable difficulties, but with the most painstaking care. They represent, for the most part, material which is altogether new, while those which cover ground previously worked over embody results in such a way as to preserve their value as contributions to our knowledge of these people.

One of the principal difficulties met with by Mr. Hill-Tout has been the reluctance of the Indians to submit themselves to the process of measurement, or even, under satisfactory conditions, to the camera.

Prints, in duplicate, of a certain number of photographs already obtained by Mr. Hill-Tout accompany this report, and it is hoped that a more important contribution of this kind may be forthcoming next year.

Also accompanying this report is a series of fifteen prints, in duplicate, of photographs of the villages and totem-poles of the Haida Indians of the Queen Charlotte Islands, taken by Dr. G. M. Dawson, Director of the Geological Survey of Canada, while engaged in a survey of these islands in the year 1878. These are the first photographs taken of the villages in question, and they possess some interest as a matter of record in consequence of the fact that the objects and conditions represented by them have now almost wholly disappeared. Some of these views have been reproduced in the Report of Progress of the Geological Survey for 1878–79, to which reference may be made.

APPENDIX I.

Early French Settlers in Canada. *By* B. SULTE.

Leaving aside the men engaged in the fur trade, and who did not adopt the colony as their home, we find that only 122 actual settlers or heads of families arrived in Canada during the period of 1608–1645.

Nine-tenths of these men have numerous descendants still amongst us. In this respect Canada is far ahead of any colony. The New England States can hardly name twenty families coming from their first stock, that is before 1645, although their immigration was five times at least larger than ours.

There was no special organisation for recruiting in France.

Nearly every one of these 122 men married just before leaving for Canada or soon after their arrival in the colony. They all belonged to that class of people devoted altogether to agriculture, such as grains, hay, oats, vegetables, hemp, flax. They understood thoroughly well the work of felling trees and clearing land, because the provinces they came from were of good soil, but not adapted for fruits and vine, nor fit for pasturage on a large scale.

Eighty-four men arrived from 1634 to 1641, nineteen only from 1642 to 1645, probably on account of the raids by the Iroquois.

From 1608 to 1645 Normandy sent 38, Perche 27, Paris 5, Beauce 4, Picardy 3, Maine 3, Brie 3, or a total of 83 from the north of the river Loire to the English Channel.

The married women numbered 119, out of which 68 were from the north of the Loire; Perche 24, Normandy 23, Paris 10, Picardy 7, Anjou 2, Beauce 2.

Women whose provinces are not known number thirty, but it would seem they were also from the north, and had followed their parents and relatives. Therefore the eighty-two [1] married men enumerated in the list as coming from the north were equalled by the same number of married women from the same region, whether the wedding took place in France or in Canada.

Five women born in Canada married in the colony before 1645: three of them became widows and remarried. Three women born in France, and who had arrived with their husbands, became widows, and remarried during that period. Girls thirteen or fourteen years old married young men newly settled.

The women from Champagne, Auvergne, Saintonge, Rochelle, and Poitou are nine in all, with eleven men from these same parts. Besides this Brittany furnished 2 men, Lorraine 1, Nivernais 1, Forez 1. They undoubtedly came by themselves, like those of the north.

The proportion is about the same of men and women whose places of origin are not indicated, a sixth of the total immigration.

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[1] Including one widower and two bachelors.

APPENDIX II.

Notes on the N'tlaka'pamuQ of British Columbia, a Branch of the great Salish Stock of North America. By C. Hill-Tout.

The following notes on the N'tlaka'pamuQ are a summary of the writer's studies of this division of the Salish of British Columbia. They treat to some extent of the ethnography, archæology, language, social customs, folklore, &c., of this tribe, recording much, it is believed, not hitherto gathered or published. For my folklore, ethnography, and social customs notes I am chiefly indebted to Chief Mischelle, of Lytton, than whom there is probably no better informed man in the whole tribe.

Ethnography.

The N'tlaka'pamuQ is one of the most interesting of the five groups into which the interior Salish of British Columbia are divided. They dwell along the banks of the Fraser between Spuzzum and Lillooet, and on the Thompson from its mouth to the boundaries of the SEQuapmuQ, and have also some half-score villagers in the Nicola valley. They possess altogether some sixty-two villages throughout this area: eleven on the Thompson, nine in the Nicola valley, eleven on the Fraser above Lytton (Tlk·umtcī'n)—their headquarters from time immemorial—and thirty-one below. These are respectively:—

Thompson River.

1. Tlk·umtcī'n, present Lytton, meaning unknown.
2. N'kau'men, meaning unknown.
3. N'hai'ikEn, " "
4. N'kum'tcīn, Spence's Bridge, meaning unknown.
5. N'koakoaē'tkō, yellow water.
6. Pīmâi'nūs, grassy hills.
7. 'P'kâi'st, white rock (contracted from St'pEk = white).
8. Cpa'ptsEn, from Spa'tzin = *Asclepias*, or great milkweed, from which natives make their thread, string, nets, &c. Place where 'Spa'tzin' grows.
9. C'npâ', barren or bare place.
10. Sk·lalc, place where the Indians secured a certain mineral earth with which they covered the face to prevent it from chapping.
11. N'tāi'kum, muddy water.

Nicola Valley.

1. Klūklū'uk, a slide.
2. CQokunQ, a stony place.
3. N'hothotkō'as, place of many holes.
4. Koaskunā'.
5. Cūlū'c, open face (*cf.* radical for face).
6. N'cīckt, little cañon.
7. ZōQkt.
8. Kōiltca'na.
9. S'tcukōsh, red place (?).

On Fraser above Lytton.

1. N'homi'n.
2. Stain, Stain Creek.
3. N'ōkoiē'kEn.
4. YEō't.
5. S'tcaēkEn.
6. N'k·lpan, deep.
7. N'tā'-kō, bad water.
8. N'cēk'p't, destroyed (refers to the incidents of a story).
9. TcEūē'q.
10. TsuzEl, palisaded enclosure containing houses.
11. Skāikai'Eten.

On Fraser below Lytton.

1. Spapī'um, level grassy land (river bench opposite Lytton).
2. N'kai'ā.
3. Sk·āpa, sandy land.

4. K·okōīap′, place of strawberries.
5. Si′ska, uncle.
6. Ahulqa.
7. N'zatzahatkō, clear water.
8. Sluktla′ktEn, crossing place (Indians crossed the river in canoe here).
9. Statcīa′nī, beyond the mountain (Jackass Mountain).
10. N'kō′īam′, eddy.
11. N'ka′tzam, log bridge across stream.
12. K·apaslōq, sand roof (a great settlement in former times).
13. Cūk′, little hollow or valley.
14. Sk′mūc, edge of the flat.
15. C'nta′k'tl, bottom of the hill.
16. Spē′im, pleasant, grassy, flowery spot.
17. Tzau′āmuk, noise of rolling stones in bed of stream.
18. N'pEk′tEm, place where the Indians obtained the white clay they burnt and used for cleaning wool, &c. (*cf.* pEk = white).
19. Ti′metl, place where red ochre was obtained.
20. Klapatcī′tcin, North Bend = sandy landing.
21. Klēau′kt, rocky bar.
22. Tk·kōēau′m.
23. Sku′zis, jumping. Place where the people were formerly much given to jumping.
24. Ckūō′kEm, little hills.
25. Tca′tūā.
26. Skuōūa′k·k, skinny (people).
27. Tīk′ūilūc.
28. C'kūēt.
29. Cūimp, strong (head village of the Lower N'tlaka′pamuQ, just above Yale).
30. Cpu′zum or Spu′zum. Name has reference to a custom prevalent here in the old days. The people of one place would go and sweep the houses of the people in another, and they would return the compliment next morning at daybreak. This was a constant practice.
31. N'ka′kim, despised. Name has reference to the poor social condition of the inhabitants of this village in former days. They were much looked down upon by the Spu′zum people. Hence the name.

Social Organisation.

The primitive customs of the N'tlaka′pamuQ, like those of their neighbours, have for the most part given way to new ones borrowed from the whites. Some few are retained in a more or less modified form, and are still practised by the older people. The social system of the N'tlaka′pamuQ seems to have been a very simple one. I could hear of nothing in the way of secret societies, totemic systems, or the like. The whole group was comprised under one tribal name, and spoke the same tongue with slight dialectal differences. They were, however, divided into numerous village communities, each ruled over by an hereditary chief. Of these latter there were three of more importance than the rest, viz. the chief of the lower division of the tribe, whose headquarters was Spu′zum ; the chief of the Nicola division, which was called by the lower division Tcūā′qamuq ; and the chief of the central division, whose headquarters was Tlk·umtcīn (Lytton).[1] Of these three the most important was the chief of the central division. He was lord paramount. The conduct of affairs in each community was in the hands of the local chief, who was

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[1] Dr. Boas divides the tribe into five divisions. It is true there are five groups, but not, in the strict sense of the word, five divisions. There were the central Tlk·umtcī′nmuQ at the confluence of the Fraser and Thompson (who, together with the neighbouring communities, constituted the N'tlaka′pamuQoē, *i.e.* the N'tlaka′pamuQ proper), and the villages on the Fraser above Tlk·umtcī′n, which formed the central division; the villages on the upper part of the Thompson, and those of the Nicola valley, which formed the upper division; and the villages below the N'tlakapamuQoē, which formed the lower division. Dr. Boas has named this division *Uta′mpt*, as if it were the divisional name of these lower communities. This is a misconception. The term means, rather, 'below river' people or 'down river' people, and is applied by these very people themselves to the Yale tribe below them, and by the Yale people again to the other Kau′itcin tribes farther down the river. I know of no proper 'group' name peculiar to the lower division other than the general term N'tlaka′pamuQ.

assisted by a council of elders. In all the relations of life the elders of the bands played an important part, and in all family consultations their advice was sought and listened to with the greatest deference and respect. In addition to the hereditary chiefs, martial chiefs or leaders were temporarily elected during times of warfare from among the warriors. It was a rare thing for the district or communal chief to lead or head a war party. The only part it seems they played was in sanctioning fights and in bidding them cease. My informant told me that the N’tlaka′pamuQoē chiefs were, as a rule, peace-loving men, always more anxious to prevent wars than to bring them about; and that the grandfather of the present Lytton chief would go out after a battle and purchase the prisoners taken captive in the fight, who were held as slaves by their captors, and set them free and send them back to their own people again. How far this was general I cannot say. That war, however, with the neighbouring tribes was not an unusual occurrence is clear from the fact that it was found necessary to fortify their villages or some particular portions of them by palisades, inside of which the people would retire when hard pressed by the enemy. The name of one of the upper villages close to the boundary of the StlatlumH bears testimony to this fact, as it signifies in English ‘a palisaded enclosure with houses inside,’ and the old men of Lytton can recall the old fort of their village. These protective measures would seem to bear out my informant’s statements that the N’tlaka′pamuQ were not a warring people, and all the notes that I could gather of past encounters with other tribes show the N’tlaka′pamuQ to be the defenders and not the attackers.

Weapons of Warfare.

The warrior’s weapons were the bow and arrow, stone swords, and clubs, &c. Of these latter there were several kinds. One of these was a sling-club formed by inclosing a round stone in a long strip of elk-hide. The stone was placed in the centre of the strip and securely sewn there, the ends of the hide being left to swing the weapon by. This was a deadly weapon in the hands of a skilful person, but awkward to handle by those not accustomed to its use; for if not properly wielded it was just as likely to damage the holder as the person he struck at. A wooden club fashioned from the wood of the wild crab-apple tree was another effective weapon much used by the warriors. This would sometimes be studded with spikes of stone or horn. It was fastened to the wrist by a thong when fighting (see fig. 1). Besides these there were also stone-tipped spears or javelins, and elk-horn or stone tomahawks. Poisoned arrows were used in warfare, and these were always put in a special quiver of dogskin. The stone tips of these arrows were always larger than those used for game. The poison was obtained either from the rattlesnake or from certain roots. For protection the fighting men wore a short sleeveless shirt of doubled or trebled elk-hide, which hung from the shoulders, and was fastened at the sides by thongs. This shirt was called N’tsk·En in the Thompson tongue. It was usually covered with painted figures and symbols of war (see fig. 2) in black, white, and red paint. The two latter colours were mineral products. Red ochre is found in considerable quantities within their boundaries. The white paint was obtained by burning a certain kind of mineral clay which, when burnt, produced a fine white powder easily converted into paint by mixing with oil or fat. This powder was also employed by the women in the weaving of their goat-hair blankets. A trivial matter or misunderstanding would sometimes bring about a fight. It is recorded that a party of Indians from the interior paid the Thompsons a visit once upon a time. The visitors wore soles of pitch upon their feet to protect them. This novel style of foot-gear excited the mirth of the Thompsons so much that their visitors became deeply offended, and a big fight was the result.

FIG. 1.—Ancient war club made from wood of the wild crab-apple tree, after drawing by Chief Mischelle, of Lytton, B.C.

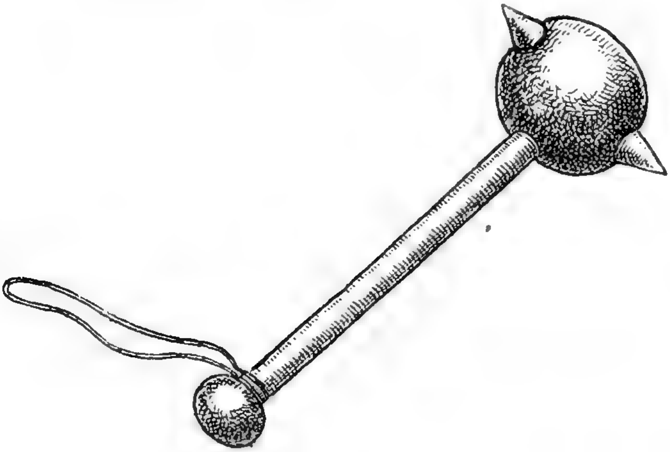
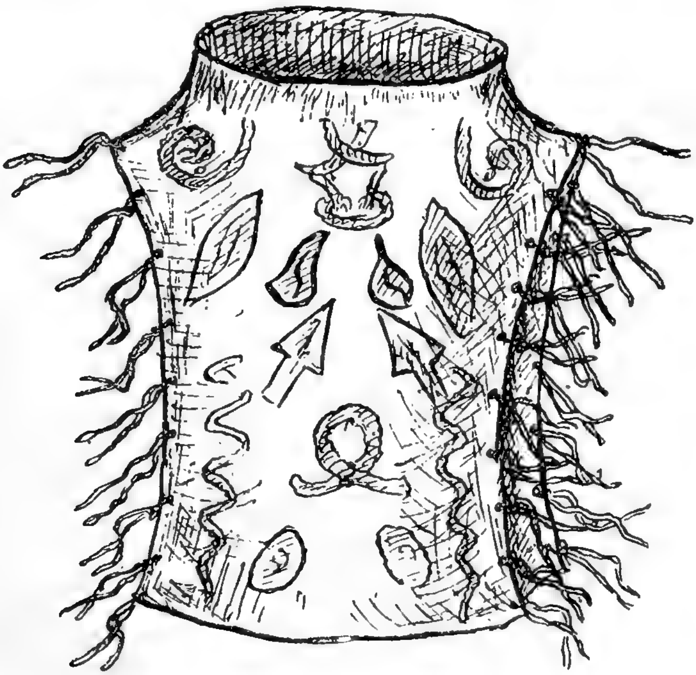


FIG. 2.—N'tlakápa'muQ warrior's shirt of the old days, after drawing by Chief Mischelle, of Lytton.



As far as I could learn, the hunting, fishing, and berry grounds of the

N'tlaka'pamuQ were common property. But no one under penalty of a severe punishment could take a fish, pick a berry, or dig a root until after the Feasts of First Fruits had been held. These feasts were conducted as follows :—When the salmon, for instance, begin to run, word is brought to the divisional chiefs that the fish are coming up river. Messengers are then sent to the neighbouring villages, calling a meeting of the people on a certain day, at which all must attend at the appointed place. When the day has arrived and the people have assembled, the head chief, attended by the other lesser ones and the elders, opens the ceremony at daybreak by a long prayer. While the prayer is being said everybody must stand with eyes reverently closed. To ensure this being done, as it was regarded as an essential part of the ceremony, certain of the elders were assigned the duty of watching that no one opened his eyes while the prayer was being said. Exactly to whom these prayers were addressed my informant could not tell me. All I could gather was that the 'old Indians' believed in some great and beneficent power who dwelt behind the clouds, and who gave them the salmon, fruits, roots, &c. ; who, if they showed themselves ungrateful or unthankful, could, and might, withdraw his gifts from them. He could not give me any of the words of these prayers.[1] After the prayer is over every one present is given a bit of salmon which has been cooked for the purpose. As soon as all have partaken of the salmon a feast is prepared at which each is free to eat as much as he desires. When the meal is concluded, a dance takes place. Each person lets down his or her hair and a space is cleared for the dancers. Singing always accompanies the dancing, and a certain individual leads the dance song in a loud voice, and the dancers keep time with the singer. They dance on this occasion in a circle, with the hands extended, palm upwards, before them, swaying them with a rhythmic motion from side to side as they sing and dance. Towards the conclusion of the dance the time quickens and the movements are more rapid and vigorous. As the dance is about to end the master of the ceremonies calls to the people to stretch their palms towards the sky and look upwards. They continue in this attitude for a little while, and the chief presently brings his hands together, closing them as he does so, as if he held something in them, and lowers them gently to the level of his breast and then places them, one fist over the other, against his breast. This action signifies the reception of the gifts asked for in the prayer and song. The whole ceremony is conducted throughout with the greatest decorum and reverence. This dance is repeated again at noon and at sunset. The Feast of Berries and Roots is conducted in a similar manner. Besides these periodic prayings, daily prayers were said by one of the elders in each 'keekwilee-house' every morning at daybreak, all the worshippers closing their eyes reverently the whole time and repeating in an earnest tone the closing formula *Aksai'as*, which signified to them very much what our *Amen* does to us.

Other dances were indulged in at times besides these at the Feasts of First Fruits, at which all the actors sat and swung their extended hands, palm upwards, from side to side, keeping time to a song called K·ōia'tct.

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[1] In an account of the training of the young men of the tribe given below, the young man addresses his prayer to a being called *Kōana'kōa*, who is the giver of the gifts he desires. From the strong resemblance this word bears to those having reference to the sun, and to heat, day, &c., I am disposed to think this being to whom the N'tlaka'pamuQ addressed their prayers was the Sun God of the Coast tribes (see below)

The N'tlaka'pamuQ apparently never used masks of any kind at their dances, such paraphernalia being quite unknown to them.

Puberty customs seem to have been much simpler among the N'tlaka'-pamuQ than among other tribes. All I could gather concerning them was that when a girl arrived at puberty she must withdraw herself from her family for a time and live apart by herself. I could not gather that any particular course of life was prescribed for the occasion, or that she was forbidden to eat certain kinds of food. It would appear that their whole lives were much simpler and more natural than those of their congeners elsewhere. We see this in their marriage customs, for instance, which are simple compared with those of other tribes, or even with those of the 'Stalo' or River Indians below them.

Marriage Customs.

When a youth arrived at marriageable age he generally had a maiden in his eye whom he wished for wife. He would first put himself in her way and they would stroll out together. He would next send her little presents from time to time. If she was not averse to his suit she would accept these; if otherwise she would refuse them. If his gifts were accepted he would then declare his liking for her, and tell her he would give her a year to make up her mind in the matter. If things went smoothly during this period, at the end of the time he would then send a present by a friendly elder of his family to the girl's parents. If they accept the present they call together the relatives and friends of the family, who discuss the subject; and if the young man is acceptable to the majority of them, the girl's father takes an elk-hide, cuts it into strips of useful lengths, and gives each one present a piece. This witnesses to their agreement. After this has been done one of the old men of the girl's family goes to the young man and informs him that his suit is acceptable to the family, and that he may have the girl for wife. Supposing that a majority of the family be against him his present is returned and he is notified as before that he cannot have the girl, and must look elsewhere for a wife. When he has been accepted the bridegroom goes the day following to the girl's home, accompanied by all his friends and relations, who carry food and other gifts with them. A feast is prepared from this food, the gifts are distributed, and a general good time is indulged in. After the meal is over the old people declare themselves satisfied with the arrangements in a loud voice. The young man and his bride are now man and wife, and share the same blanket that night. Next day the girl returns with her husband to his home, and some days later her parents and relatives come and pay them a return visit, bringing with them also food and gifts. A second feast is then prepared, the gifts are distributed, and all partake of the food as before. This concludes the marriage ceremony, the pair after this being regarded as man and wife by the whole community. A man was free to marry whom he might outside of his own family.

Shamanism.

Shamanism was prevalent among the N'tlaka'pamuQ. This we can gather readily enough from their stories, and certain spots and localities are pointed out by the older Indians as the places where certain celebrated Shamans underwent their fasts and training to gain their powers. There are several such spots on the banks of Stain Creek, a mountain stream that runs into the Fraser about five miles above Lytton. Worn and hollowed places are pointed out here and there, and these are said to have been made by the feet of the aspirants after Shamanistic powers in the performance of their exercises. We find several groups of rock paintings along this creek, which are believed by the present Indians to have been made in the past by noted Shamans. It is interesting to note that these paintings are invariably found high up on the cliff surfaces above the reach of the tallest man—in some cases as high as twenty or thirty feet from the ground. It is clear, therefore, that they must have used some kind of ladder or platform to reach these heights. This, to the Indian mind, always adds to their mystery. The modern Indians seem to have no knowledge of the signification of these paintings, and say that the pigments used by themselves will not stand the weather or endure like those of the ancients.

Names.

The ceremony of name-giving was observed by the N'tlaka'pamuQ nobility. It would appear that when a child was born it might be called by any name. Later, when he had grown up, his parents gave a great feast, to which all the friends of the family were invited, and a name was then chosen from among the names of his dead ancestors and bestowed upon him by which he was thereafter known. Among the common people the men kept the names given at birth, or had nicknames applied to them.

Mortuary Customs.

Very little could be learned directly of their ancient mortuary customs. They have been so long under missionary influences that their old practices have for the most part died out and been forgotten. A few of these, however, they still keep up, such as cutting the hair short and special washings or cleansings in the river. The widow must not lie in her bed, but on branches spread on the floor, and every morning she must undergo a purification by washing her body with fir-tips. This is kept up for a longer or shorter time, as the widow's feelings dictate or prompt.

I could not learn that slaves were ever killed at the burial of their masters; and there is certainly nothing in the disposal of the bodies of the ancient dead, as far as is now discoverable, to warrant a belief in such practices. In modern burials horses and colts are frequently killed, but not, my informant was at pains to tell me, for sacrificial or religious purposes, but that their flesh might supply food for the burial feast. The skins of these slain animals were afterwards hung upon the branches of some neighbouring tree. I have seen several of these skins myself on trees near the burial-grounds.

Birth Customs.

The birth customs, like the death customs, have also been much modified by missionary influence. In the days before the whites, when a child was born, it was wrapped in a bundle of the soft inner bark of the cedar prepared for the purpose. Later it was wrapped in soft skins and placed in its cradle, which was (and still is) made, in the case of the poorer class of natives, from birch-bark, and in the case of the better class from neatly woven basket-work. It would seem that no cradle was ever used twice over for different children, but after the child had grown out of it, and needed it no longer, it was taken to the burial-ground and placed in or under a tree with all the paraphernalia belonging to it wrapped up inside; or was suspended to the branches or placed in a fork of a tree in the forest. I have myself found many such thus placed or hidden away. In the modern cradle one invariably finds the bottom lined with a piece of tin cut from the side of a kerosene can. This in former days was, of course, impossible. They are also sometimes highly decorated with the brass cases of rifle cartridges fastened through the cap-hole by thongs to the edge of the cradle. They doubtless had a practical as well as an æsthetic value. The jingle of them would attract the infant's attention and amuse it. Infants were, and still are, always nursed and dandled in the cradle, which the mother always carries about with her. On Sundays nothing is commoner where there is a church than to see the mothers bringing their cradles to the service with them. When the child is fretful they rock the cradle on their knees or set it upright so that the child may look about it and see what is going on. Generally the head of the cradle is covered with a movable hood, which can be pushed back or drawn forward at will.

Tattooing and Painting.

Tattooing was, and to some extent still is, practised by the women. The commonest marks are three parallel lines. On old women these are seen on the side of the face, and sometimes on the chin, but on the younger ones more commonly on the wrist or arm. I made many inquiries, but was unable to discover what signification these marks had other than that they were decorative. I am disposed to think, however, that in earlier days they had some special significance, this particular marking of three simple lines being so common and so universal among the women. The women also formerly pierced the septum of the nose, in which the dentalium shell was worn. Facial and body paintings were quite common among the men of the N'tlaka'pamuQ. To express joy they painted the face white and red, as we learn from their stories. The warrior always painted his face before going into battle, and the youths in their morning sports and exercises covered their bodies with all kinds of fanciful designs.

Games.

They were fond of games, like their neighbours, and utilised the level grassy river benches for various games of ball. One of these games, called by them *suk'-kul-lila'-ka,* was not unlike our own game of football. The players were divided, as with us, into two groups, and at each end of the field was a goal formed by two poles planted several feet asunder. The play commenced from the middle of the field, and the object of the players was to get the ball through the goal of their adversaries. The ball was made from some kind of tree fungus, cut round and covered with elk-hide. I could not learn anything of the rules of the game; nor was my informant certain whether the feet or hands, or both, were used in propelling the ball. Mention is made of this game in one of the stories here recorded. Gambling was also a favourite pastime here as elsewhere. The game known by the term *L'tpīq* was that commonly practised. Much betting went on among the players, and all bets were made and 'booked' before the game commenced. The method of 'booking' was primitive. The objects staked were simply tied or fastened together and set on one side till the game was over, the winner then taking his own and his opponent's property. The game seems to have consisted in declaring in which hand the player held the marked one of two otherwise similar short bone rods, which could easily be held in the closed palm. My informant possessed a pair of these, which he was good enough to give me. Besides these two rods there were also twelve short pieces of wood used as well. These seemed to have played the part of counters, but of this I am not certain, this part of the game not being clear to me.

Clothing.

The old-time clothing has entirely gone out of use, with the exception of the moccasin, which is still almost exclusively worn by the old people of both sexes. A man's clothing in former days consisted of a shirt which reached to his middle, made from the skin of the elk, deer, coon, or ground-hog. Below this he wore leggings of deer-skin or other suitable material which reached to the top of the thigh. In addition to this he would sometimes wear a breech-clout of skin. For his feet he had neatly made moccasins; and for his head, when he so desired it, a cap of the skin of the porcupine or of a loon with the feathers on. Commonly they wore no head covering, living as they did mostly within the dry belt of the province. The dress of the women of the nobler class consisted of a long doe-skin shroud or smock, reaching from the neck to the feet, and tied in at the waist with a band fastened on either side (see fig. 3). They were usually fringed at the side seams and at the upper and lower seams of the arms. They were also, in the case of chiefs' wives and daughters, at times profusely decorated with beads, shells, and other ornamentation. The native name for this garment was *tlatlū'k*. Below these they sometimes wore leggings called *matta's*, and on their feet finely wrought moccasins. The commoner women and female slaves wore only a short skirt, and went bare-legged and bare-footed.

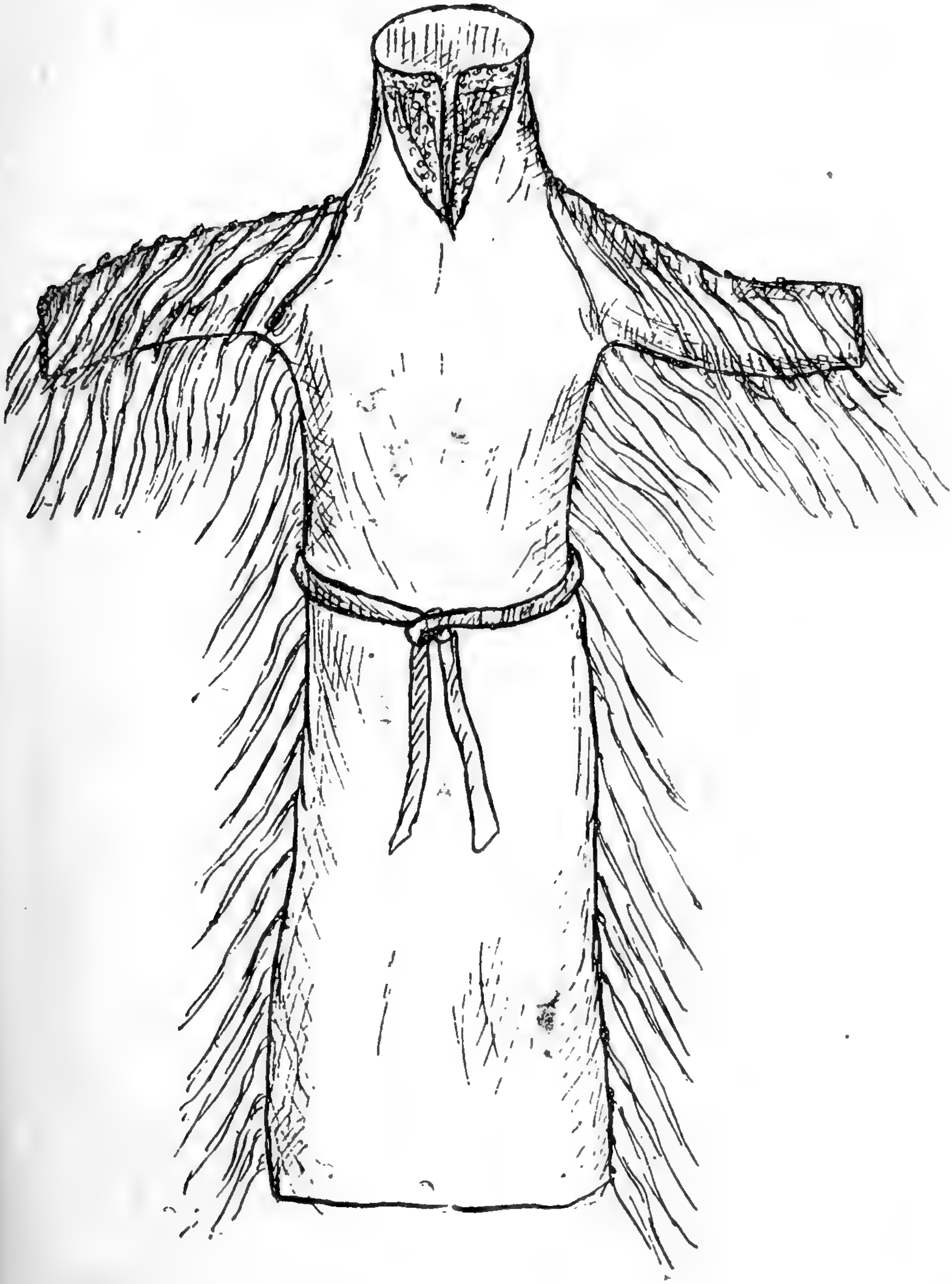
Sweat-houses.

The sweat-house was and still is a great institution among the N'tlaka'pamuQ. My informant, who on my last visit to Lytton was suffering from paralysis of his lower limbs, was looking forward to the time when he would be so far recovered as to be able to take a sweat-bath. The method of taking the bath appears to be the same here as elsewhere, and as a description of these houses has been given before by Dr. G. M. Dawson, it will be unnecessary for me to give it here.

Food.

The food of the N'tlaka'pamuQ depended somewhat upon the location of the various divisions of the tribe. The chief food of the Thompsons was venison, and the men of this district were usually skilful hunters and trappers. They sometimes followed the game with the bow and arrow, accompanied by dogs trained to pull down the quarry; but most of their game was taken by means of traps and snares of various kinds. Of these the noose, pit, and drop-snares were the commonest. Mention is made of the noose snare for catching deer in one of the stories given below. On the Fraser below Lytton the Indians were mostly fishers and poor hunters. Their method of taking the salmon between Lytton and Yale was by means of the dip-net. When the salmon are running, the Indians may be seen in great numbers thus fishing on the banks of the river.

FIG. 3.—Pattern of ancient dress of a chief's wife or daughter, after drawing by Chief Mischelle, of Lytton, B.C. Material, soft doe-skin.



This net scarcely needs description: its name implies its use and form. Briefly it is a meshed bag, from three to four feet deep, attached to a hoop-like frame, to which a long slim pole is fastened. The fisher holds this pole in his two hands, and dips in the net on the up-stream side of him, with its mouth towards the current, and draws it slowly and regularly against the stream, as far as the pole allows, and then returns it in the air and repeats the action again. He continues thus till he has secured a fish. The women stand by to receive the fish, which they kill by a blow on the head. They then quickly and deftly cut it open, wrench off the head by inserting a stick through one of the gills and out through the mouth, and, giving it a dexterous turn of the wrist, cut out the backbone, spread the two halves open, and hang it up to dry in an open shed constructed of poles for the purpose near by on the bank. Scores of these may still be seen along the line of the railway as one passes from Yale to Lytton. The knives which the women use for this are fashioned after the pattern of their own old implement, and are quite commonly made from a piece of an old hand-saw about five or six inches long, on the back of which is secured a grooved piece of rounded wood about one and a half inches thick, which runs the whole length of the steel, and serves as a handle. The opposite or blade edge is ground down, and the ends are rounded, having, when completed, very much the appearance of a meat or suet chopper. I was told by some Indian women whom I watched at work that they prefer this style of knife to any other; and to judge by the dexterous manner in which they ran the edge from the vent upwards along the belly of the fish, opened it out, cut out the backbone, and had it ready for drying, it certainly is an effective instrument for the purpose in their hands.

Above Lytton on the Thompson, where the water is too clear for catching fish in nets, they spear them by torchlight. The fish show white at night under the glare of the torches, and the men go out in canoes and spear them readily. The spearman occupies the centre of the canoe, and when the salmon, attracted by the glare of the torches, comes near, he throws his spear at it and rarely misses his mark. The fish is now quickly seized by one of the others, knocked on the head, the spear withdrawn, and the fish thrown to the bottom of the canoe.

Salmon Oil and Butter.

The N'tlaka'pamuq had another way of treating the salmon besides drying them. They extracted oil from them in considerable quantities. To do this they would place some forty or fifty fish, according to their size, in a large trough which they hollowed out from the trunk of a tree, as they did their canoes, with fire and adze. When the salmon were ripe, that is in a rotten state, water was poured in upon the mass in sufficient quantities to just cover the whole. Heated stones were then put in and the whole mass stirred till it was reduced to a hot pulp. The stones were then taken out and a pailful of cold water was poured on, which caused the oil to rise to the top. The oil was at this stage of a reddish tinge, and had, so say the Indians, no offensive smell. It was now skimmed off into birch-bark buckets with a spoon, made sometimes from the horn of the mountain sheep and sometimes of wood. It was allowed to stand overnight and boiled afresh next day and skimmed till quite clear. The oil was then stored away in bottles very ingeniously made from whole skins of medium-sized salmon. The skin for this purpose was drawn from the salmon much as one draws off a tight-fitting glove that will not come off without being turned inside out. It was then carefully cleaned by rubbing with dry punk-wood, after which it was rubbed with deer or mountain-sheep suet. The skin was then ready, and was turned right side out; the oil was poured in and the mouth securely fastened. In the meantime the flesh of the salmon had not been neglected. After the oil had been skimmed off, the water was strained away and the remains worked up and kneaded into balls and put in the sun to dry. While drying it was occasionally smelt to see that it was sweet and devoid of flavour. After a time it was squeezed and washed and kneaded again and put to dry once more. When quite dry and free from all smell it was broken up and rubbed fine between the hands till it took on the appearance of flour. Some of this was then placed in the bottom of a birch-bark basket, and on this were laid the bottles of oil; and when the basket was full more of the salmon flour was spread over the top and down the sides until the bottles were encased and buried in it. The whole was then stowed away for winter consumption. In addition to this way of preserving the oil, they had another way of treating it. A kind of butter was manufactured from it by mixing it with equal quantities of the best kidney suet, taken from the deer or, preferably, from the mountain sheep. The oil and suet were boiled up together, thoroughly mixed, and then set to cool. When cool the compound had the consistency of butter, and was esteemed a great delicacy among the natives. It was eaten, among other things, with the compressed cakes which they made from the service (*amalanchier*) and other berries, of which great quantities grow in their region. Only the wealthier class could afford food of this kind. Besides venison and fish, wild fruit of all such kinds as grew in their neighbourhood and was edible, and roots and many kinds of herbs, were eaten. As Dr. G. M. Dawson has given a list of these, with their botanical names, and has also described with some detail their method of preparing them in his 'Notes on the Shuswap People of British Columbia,' it will be unnecessary for me to enumerate them here.

Utensils.

For boiling their food the N'tlaka'pamuQ always used basket kettles made like their other basketry from the split roots of the cedar.[1] These roots are sometimes dyed red and black, and very beautiful patterns are made from the three different colours. According to my informant, the red dye was obtained from the bark of the alder-tree, and the dark stain was obtained by soaking the roots in black slime or mud.[2] So skilfully

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[1] Dr. G. M. Dawson, in his 'Notes on the Shuswap People of British Columbia,' tells us that these baskets were made from roots of the spruce, and Dr. Boas, in his Report on the Shuswaps, informs us that the basketry of the Shuswaps and N'tlaka'pamuQ was made from the roots of the white pine. I cannot say what material the Shuswaps constructed their baskets from, but if my informant is correct, the N'tlaka'pamuQ always used the root of the cedar; and I know no better authority among the Thompson Indians than Chief Mischelle, of Lytton, from whom to obtain information of this kind. [As the N'tlaka'pamuQ were pre-eminent in basket-making, it is possible that the information gained by Mr. Hill-Tout may be accepted as correct, although the cedar (*Thuya*) is not abundant in the Thompson River country.—G. M. D.]

[2] According to Dr. Boas the black dye was obtained from the fern root. It is possible it was got in both ways.

did the women make these baskets that they would hold liquids without trouble. In preparing any food two kettles were customarily used—one containing water for washing off any dirt that might adhere to the heated stones, and the other for holding the food. In boiling salmon for eating the fish were tied up in birch bark to prevent breaking and falling to pieces.

The house furniture and utensils were few and simple. Tables and chairs, or such like conveniences, were quite unknown. Wooden dishes, hollowed out from the solid block by means of stone, bone, or beaver-teeth chisels, and wooden or horn spoons were sometimes used by the wealthier class; but usually the food was served up and eaten off reed mats, which served also as seats, carpets, and beds. These latter were commonly laid directly on the ground, which was strewed with the bushy ends of fir branches. The beds of the common people were simply a few reed mats, but in the houses of the chiefs and headmen these were supplemented with skins and blankets woven from the hair of the mountain sheep or goat. The people always disrobed when going to bed, and as there were no division or apartments in the 'keekwilee-houses,' but for the dusk there could not have been much privacy about the matter. Yet it is clear from their folk-tales that the maidens of the upper ranks, at least, were modest and diffident, and when out bathing always chose the most secluded spots, and were as embarrassed and shamed at being seen naked as any white maiden might be. I have been struck again and again in my work among the Indians with this keen sense of modesty in the girls of the interior, particularly those who have come under the influence of the Sisters.

The houses of the N'tlaka'pamuQ resembled those of the other interior tribes. For the greater part of the year they lived in semi-subterranean dwellings known in the trade jargon as 'keekwilee-houses.' These houses, of which there is no perfect specimen left in the province, were of varying dimensions. Those of Lytton were from 30 to 50 feet in diameter. Nothing of them now remains but the saucer-like depressions which mark the spots where they formerly stood. As a description of these dwellings has been given both by Dr. Boas in his Reports, and by Dr. G. M. Dawson in his 'Notes,' &c., it will be unnecessary for me to give another here. I will only say that the dimensions of these dwellings as given by the above writers fall considerably below the dimensions of those commonly found among the central and lower divisions of the N'tlaka'pamuQ. Of the upper I cannot speak from personal knowledge. Dr. G. M. Dawson speaks of those he saw as having a diameter of from 10 to 30 feet; and Dr. Boas describes his as having a diameter of from 12 to 15 feet.[1] The shortest diameter to be found on the old camp site at Lytton was 34 feet, and they rise from this to 54 feet; and the old men of the neighbourhood, whom I questioned on this matter, and most of whose lives had been spent in them, informed me that 60 and even 70 feet were not uncommon diameters. There is one now, which I measured in company with Mr. Harlan Smith, of the New York Museum of Natural History, on the left bank of Stain Creek, not far

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[1] The dimensions given by me were not from actual measurement, and I am ready to accept Mr. Hill-Tout's figures. Dr. Boas's illustration of the construction of these houses, in one of the Reports of the B. A. A. S. Committee on the N. W. tribes, is incorrect, as afterwards stated by him. The actual method of construction is shown in a diagram in my paper, here several times referred to by Mr. Hill-Tout.—G. M. D.

from where it joins the Fraser, that measures 59 feet from the posthole on one side to the corresponding hole on the other. These dwellings were usually inhabited by several families, more or less closely related to one another ; and in the very large ones sixty or seventy souls would often pass the winter together. Commonly there was but one fire in the centre, but if the weather was very cold smaller fires would be kindled near the four great supporting poles. Fires were also at times lighted here for culinary purposes, when many families inhabited the same house. The floors of these houses were kept covered with small fir branches, which were renewed about every three or four days. The entrance to these houses was through the smoke-hole in the roof, a notched tree which projected some way beyond the hole being used as a means of ascent and descent. The central space between the four supporting poles was common ground in the centre of which was the fire. Behind this, under the sloping roofs, each family or group had its own quarters.

The summer dwellings were extremely simple, consisting merely of a framework of light poles covered with mats or wattled, and all cooking was done in the open air. The food supplies of the central N'tlaka'pamuQ were invariably stored in caches, *i.e.* holes in the ground, which were roofed with poles or boards, and then again covered with earth or sand. The food was commonly protected from the soil or sand by bark. Remains of these caches or cellars, with rolls of birch and other bark in them, may be seen at any of the old camp sites. Many such, now filled with sand to the level of the surrounding ground, are found at Tlk·umtcī'n. In the lower division and elsewhere small sheds were erected on poles standing from 5 to 10 feet above the ground, to be out of the reach of dogs and other animals. As a rule these structures are found only where the ground is rocky, or of such a nature as makes excavations difficult or impossible, as along the Fraser Cañon above Yale.

Hospitality.

Hospitality was recognised as a virtue, and practised as a duty, among the N'tlaka'pamuQ, and every one was constrained to offer the stranger or visitor the best he possessed.[1]

Customs.

The N'tlaka'pamuQ had many singular and superstitious customs and practices, some of which we may gather from their folk-tales. Some of these they still practise. For instance, when roots are to be baked, women only must do it. I could learn no satisfactory reason for this. The old-time training for young men has many interesting and unique features about it. Of these I learnt the following, none of which are any longer practised. In the days before the advent of the whites, when a youth wanted to fit himself to become a hardy hunter, he would go down to the river's edge at the close of the salmon run, when the carcasses of dead and maggot-filled salmon would be found lying along the banks in great numbers, and thrust his hands up to the wrists in the rotting, maggoty mass, and keep them there for hours together. This was said to harden them, so that they became impervious to the cold when out hunting in cold weather. They would do this many times in their late boyhood. Another method of attaining the same end was to lie down at

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[1] See the story of Snikiā'p, &c., p. 551.

the edge of the river all night with the hands and wrists soaking in the cold water. They would also repeat this many times before the desired callousness to cold was attained. The old people affirm that the young men of their day and earlier were hardier and stronger than the young men of to-day. They say the present youths would succumb to the training and hardening endured by their grandfathers. In the old days a youth was generally ambitious of becoming a great hunter, or warrior, or runner, or athlete generally. To acquire a superiority over his fellows he was ready for the greatest acts of self-denial and self-discipline. This spirit of emulation was encouraged and enjoined by the elders, and they were taught to pray to the great spirit known as Kōana′kōa, and seek gifts from him in the following manner. When a young man desired any special blessing or gift, he would rise early in the morning, some time before daybreak, and go alone and unseen to the top of some hill or eminence, or to the river's side, and pray. This act in itself required, on his part, no small courage and self-conquest, the forest and mountains at night being peopled in the lively imagination of the Indian with spirits and shades of all kinds. If he sought for some physical athletic gift he would practise himself therein as well as pray for it in words like the following: 'O Kōana′kōa,[1] make my arm strong, my chest strong, my legs untiring. Make all my body strong; make my heart good. Make me a great hunter, a great man, a great warrior, a great runner or jumper,' as the case might be.

In order that the prayers and exercises might be efficacious, it was necessary that the suppliant should arise before any one was awake or stirring; and his prayers and exercises must be finished and he on his way home before the sun appeared above the horizon. He does this three mornings successively, and if he has been careful to observe the rules and conditions twice out of the three times at least, his prayers will be granted, and he will receive the gifts asked for. If, on the contrary, he has been lazy and careless, and did not rise early enough, and was seen leaving the camp, or did not perform his exercises or say his prayers before sunrise, instead of his requests being granted some evil gift will be given him instead.

Besides these special trainings and exercises undertaken at their own desire, there were the daily morning exercises. The young men of the village were accustomed to turn out early in the morning and go to the river to swim, after which they would return to the camp and indulge in various athletic exercises. There are two big boulders standing

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[1] It is interesting to note here that the name of the power to whom the youths' prayers are addressed contains the same radical as is found in the Nootka and Kwakiutl terms for *morning*, viz., Koa′-koai′la and Kō′atl, which both signify that light or day is coming. The same root is found in the Coast Salish terms for *day* identical in form or slightly modified, as Koā-(yil) and Skūa-(yil), and which in these dialects signifies sky also. It is also seen in the terms of both stocks for *red* and *blue*, and for the terms expressive of *heat* and *warmth*. There can be little doubt, I think, that this being was associated in the minds of the suppliants with the sun, or sky, or light, all of which are intimately connected. I have pointed out in another paper (see *Proceedings of the Royal Society of Canada* for 1898–99) that the Salish and Nootka-Kwakiutl were originally an undivided people, or had a common origin, the two languages being full of common terms of all kinds employed in identically the same way, and that between the extreme members of the stocks, rather than those contiguous to each other, between whom we know no intercourse or communication has taken place from time immemorial.

in the midst of the village site of the old Lytton people. They are of irregular shape, 10 and 4½ feet high respectively and about 20 feet apart. Their perimeters are 31 and 27 feet respectively. After the Tlkumtcī′nmuQ youths had been in the river it was the custom for them to exercise themselves near these rocks. They would run in succession up the side on to the top of the lower one, pause there a moment, and then run down the side facing the other rocks, reach it in three strides, and leap upon the top. They would then shake their clubs and spears as if defying an enemy, leap down again, and run at the boulders with uplifted weapon, as if they were enemies. Those practices have long since been given up, and the youths of the present day are very different from those of the past.

Canoes.

The N'tlaka′pamuQoē used three different kinds of canoes, the birch-bark, cedar, and skin canoe. The commonest and that most preferred for ordinary use was the birch-bark canoe. Sometimes the place of this would be taken by one constructed from cedar hollowed from the log in the usual way by means of fire and adzes. The skin canoe, made by stretching the skin of an elk or caribou over a framework of wood, was essentially the hunter's canoe, and was mainly employed by him in ferrying himself and his belongings over bodies of water that lay in his path when out hunting. The paddles for both the skin and bark canoes were double-bladed. For the cedar canoe a single-bladed paddle was employed.

Archæological.

Under this heading, and as announced in the last report of this Committee, I had prepared a somewhat lengthy paper, before the American Museum of Natural History had published Mr. Harlan Smith's Report on the Archæology of Lytton and Neighbourhood. But, as this publication covers the same ground as my own, it will be unnecessary at this time to publish a second report of this area. I shall therefore simply add a few further remarks upon the method of stone-cutting employed by the old-time dwellers in this region, as evidenced by the partially cut stones themselves, recovered from the ancient camp sites of this locality. In his report Mr. Smith inclines to the opinion that the cutting was done by sandstone slips or flakes. That many of the cuts were effected in this way there can be no doubt, as I pointed out some two years ago ; the bevelled sandstone grinders found in great numbers on the old camp-sites fitting these grooves to a nicety. And that these can make grooves of this kind in the greenstone boulders I have demonstrated by grinding them out myself. Indeed it surprised me to find how readily the hard serpentine or harder nephrite (jade) could be grooved in this way But all the boulders were not so cut. Dr. G. M. Dawson was informed by some of the old men at Lytton that the old people' used to cut out their jade, adzes, and chisels from the block by means of quartz crystals. Chief Mischelle also made the same statement to me, and explained further how they effected it. Having selected a suitable boulder, the stone-cutter would fasten two strips of wood together at a distance of about half an inch apart, something after the principle of parallel ruler only the parallels are rigid in this case. This he laid upon the surface of his block for holding his crystal in place and keeping his line straight the cutting utensil working to and fro between the parallel bars or strips

When the groove is sufficiently deep to hold the cutter in place, this apparatus is thrown aside and the cutting is continued without its aid. Water is used throughout the process to keep the cut clean and open. Rock crystals of various kinds were employed for the purpose, agate being a favourite. I have attempted cutting the jade block with an agate crystal myself; and, although the progress is not so rapid as with the sandstone grinder, the crystal soon cuts into the stone, and there can be no doubt that the boulders can be cut in this manner. And that they were so cut sometimes in the old days is perfectly clear from the evidence of the grooves themselves, which in such cases are entirely different from the curvilinear grooves made by the bevelled sandstone. They are distinctly angular, and the bottom of the cut narrows to a point, the outline of the cut having the appearance of a triangle standing on its apex. Mr. Smith must either have secured no specimens of this kind of grooving or have overlooked the difference between this and the rounded grooves given in his illustrations.

The advantage of cutting with a crystal over the sandstone grinder would appear to be a saving of material, less of the block being cut away in the process; and although there is no scarcity of greenstone blocks, they are not all of jade or of the first quality, and this fact may have weighed with the cutter at times. In any case, whatever the reason may have been, the fact remains that the ancient stone cutters employed both crystal and sandstone to cut out their adzes and chisels from the rough block. The polish afterwards put upon these and others of their polished tools and utensils was effected by first rubbing with rushes and afterwards with the naked hand. The old Indians would sit for hours together by the camp fire rubbing a stone in this manner; and I was informed that the polish found on some of the highly finished stone pestles or hammers would take more than one person's lifetime to effect. I secured some good examples of the crystal-cut boulders in my last visit to Lytton. Some of these are now in the Provincial Museum at Victoria, and a particularly interesting specimen I recently forwarded to the Dominion Geological Survey Museum at Ottawa. This last is doubly interesting from the fact that it exhibits in itself the two different modes of cutting, some of the grooves being curvilinear in section and some angular. The workman who owned this block, however, favoured the grindstone method, for on one of its surfaces we find three shallow, rounded grooves, parallel to each other, as if the cutter had been marking the block off into sections to see how many pieces he could cut out of it. It is quite possible that the cutter found it easier to *start* his cuts by grinding, and when the groove was deep enough to hold his crystal, he *finished* the cut by this means. This particular block favours this idea. At any rate it is perfectly clear that there were two methods of cutting employed, and not one as indicated by Mr. Smith.

I concur with Mr. Smith in his conclusion that there is no evidence for supposing the old-time dwellers on these prehistoric camp sites to be of a different race from the present tribes. No evidence as yet has been gathered which takes us back more than a few centuries at most. Mr. Smith secured many skulls from this locality, and it would have been interesting if the indices of these had been compared with the indices of the heads of the present N'tlaka'pamuQ. I think they will be found interesting. In speaking of the arrow-heads of this district Mr. Smith remarked that the prehistoric points were invariably larger than the more modern ones. This appears to me to be a misconception on his part. His collection of arrow-heads is not as large as mine, nor is he, perhaps, as familiar with the several varieties as I am; and from my own observation, as well as from the reports of others who have worked on these grounds, I should say the reverse was the case if there is any difference at all, or if this difference can be determined, which I much doubt. It has always been considered one of the peculiarities of this district that so many very small arrow-heads have been found there. I have myself seen scores less than half an inch in length. Indeed, some of them seemed too small for practical purposes, but the old Indians say they were undoubtedly used for game, while the bigger ones were used in warfare.

Another point of interest on which a few further remarks will not be out of place is the number of knives and 'flakes' found in these old burial-grounds. These are at Tlk·umtcī′n commonly formed from a kind of obsidian, called by Dr. G. M. Dawson augite-porphyrite. At least 75 per cent. of these are chipped on one or more of their edges. On the other side of the river large quantities of agate, chalcedony, and jasper of various colours have been found in the old burying-grounds. These latter resemble closely the flint knives, flakes, and scrapers found in the old mounds in England. Except for the difference in material it would be impossible to distinguish between the two. On inquiry from the old Indians as to what purpose the ancients put these small knives and flakes to, I was informed they employed them to cut or scarify their bodies, particularly their legs. 'It lets out the bad blood,' said one old man, 'and makes a man good and strong.' One of the peculiarities of these flakes or knives is that a considerable number of them are more or less curved in form. Whether these forms are accidental or otherwise I am unable to determine.

Physical Characteristics.

Owing to the absence of most of the men from Lytton and the neighbouring villages during my last visit to them, and the extreme reluctance on the part of such of the women as remained at home to be measured or photographed, I am unable to add any new matter of importance to our knowledge of the physical characteristics of N'tlaka′pamuq. Dr. Boas has already shown that the men of this tribe are a finer and taller race than their congeners on the coast. This fact is so patent that it requires no comparative measurements to demonstrate it. This is probably due to two distinct causes—environmental conditions and intermixture with non-Salishan tribes. With regard to the first, while the lower Fraser and coast tribes spent a large portion of their lives squatting in canoes on the water, the N'tlaka′pamuq spent the larger portion of theirs in hunting and land exercise; and with regard to the second, the presence of two distinct types among the people clearly reveals itself in their countenances. The photographs I secured at Lytton will make this quite clear. The difference in colour, too, is also here more remarkable than in any other group I am familiar with, and this incidentally supports the evidence I have set forth elsewhere of an oceanic origin for the ancestors of the Salish stock. Some of the natives are fairer than the darker races of Europe, while others recall strongly the dark hue of the Tongan Islanders. They are more than swarthy; and the other characteristics of their features are negroid of the Oceanic type.

Intermediate types between these two extremes are of course common, but if a large number of people were brought together the observer would have no difficulty in classifying them under one or other of the two predominant types. The same holds good equally, or more so, of the cast of countenance. In the one we see the high prominent cheek bones, the squat concave nose, and thick coarse lips; in the other the cheek bones are inconspicuous, the nose straight or slightly aquiline and pointed, and the lips of average thickness. In this latter type the ear is small and very finely developed, and sits close to the head.

LINGUISTICS.

In the following linguistic notes on the Lower N'tlaka'pamuQ, I have spared no pains to make them as accurate and reliable as possible. I did not content myself with obtaining information from one or two persons, but checked my notes again and again with different individuals whenever an opportunity offered. As far as my notes go I think they may be relied upon as trustworthy and accurate. I am largely indebted to an educated young woman named Ma'li, who was for many years at the mission school at Yale, for my knowledge of the grammar and structure of N'tlaka'pamuQ. She is a member of the Lower N'tlaka'pamuQ.

PHONETICS.

VOWELS.

ă	as in	English	h*a*t	*ī*	as in	English	p*i*que
ā	,,	,,	f*a*ther	*o*	,,	,,	p*o*nd
â	,,	,,	*a*ll	*ō*	,,	,,	t*o*ne
e	,,	,,	p*e*n	*u*	,,	,,	b*u*d
ē	,,	,,	th*ey*	*ū*	,,	,,	b*oo*t
E	,,	,,	flow*er*	ai	,,	,,	*ai*sle
i	,,	,,	p*i*n	au	,,	,,	c*ow*
				oi	,,	,,	b*oi*l

The vowel sounds in the N'tlaka'pamuQ tongue, as in others of this region, are frequently very indefinite. The short vowels are practically interchangeable. In the mouths of many Indians *ō* and *ū* run into one another. The same may be said of *ā*, *â*, *ai*, and *ē*, and of i and ī.

CONSONANTS.

t, as in English. This does not appear to interchange with our *d*, which as far as my experience goes is an unknown sound in Lower N'tlaka'pamuQ.

g, k, as in English.

g·, k·, somewhat as in the English word *kick*, but more forcibly and gutturally.

q, as in the German *ch* in *Bach*.

Q, approximately like our *wh* in the word *who*, but rather more forcibly than we commonly utter it.

H, as in German *ch* in *ich*.

h, as in the English word *h*ouse or *h*ow.

y, as in English; b, p, w, m, n, l, s, as in English; c = sh in English; tc = ch in church; ts, tz, as uttered in English; dj = English j; tl, an explosive l. This latter sound as often resembles kl as tl. I have, however, followed Dr. Boas's usage and written it invariably as tl. The dl (dorso-apical) of some of the other dialects I could not detect in the Lower N'tlaka'pamuQ.

INTERCHANGES.

The commonest interchange of consonant is *s* with *c*. Where the Upper and Middle N'tlaka'pamuQ commonly use *s*, the Lower invariably employ *c*; but throughout the whole area the interchange is quite common. Other common consonantal equivalents are q = Q = H = h; k· = k; k· = g·, k = g; ts = tz = tc; b = p = m.

It is distinctly noticeable that the rough breathings are very indeterminate in character, making it at times difficult to detect the differences. The mild aspirate *h* appears and vanishes in a word in quite a bewildering fashion. If a native is asked to repeat a word two or three times, in many instances, if it be a characteristic Indian term, the inquirer will be in doubt how to write it on account of the appearance and disappearance of the rough breathings. A word uttered slowly and apart from its context has often a different sound from the same word uttered quickly in ordinary speech. The same words in the mouths of women and children are often quite different from what they are in the mouths of the men. The consonants are much softer and the aspirates are less guttural, or even wholly wanting, in the former.

NUMBER.

The noun, I think, has no true plural; its place is supplied by a distributive formed by amplification of the stem, commonly by reduplication of the first syllable of the word, as skai′uq, man; skai′akaiu′q, men; tūō′t, boy; tūtūō′t, boys; slānats, girl; slaslā′nats, girls; which, in such sentences as the following, approaches the character of a real plural: cīcai′a tik skai′akaiu′q ’n tlEn tskau′tl, there are two men in the boat; quītl tl skai′akaiu′q ’n tlEn mita′tluQ, there are several men in the church; mucmucēō′kstā, bring four pieces (of wood) at a time.

The plural of the adjective is formed in the same way: as tait, (he is) hungry; tī′tait, (they are) hungry, when standing as the complement of the *verbum substantivum.* Sometimes the distributive is formed by epenthesis or diæresis, but this is comparatively rare, reduplication being a strong feature in the N’tlaka′pamuQ.

INSTRUMENTAL NOUNS.

There is a large class of nouns which take a suffix -tEn, and which may be termed instrumental nouns; as,

N’pō′e*tEn*, bed, *i.e.* thing to sleep on.

N’tl’kō′ap*tEn*, chair, *i.e.* thing to sit on.

N’tzaukūi′cqa*tEn*, lamp, *i.e.* instrument of light.

N’kōano′c*tEn*, window, *i.e.* instrument for letting sunlight through.

Nukoatlūc*tEn*, eye, *i.e.* the part of the face that lets light through.

N’cūi′p*tEn*, ashes.
N’tuktcī′n*tEn*, door.
N’keltcī′ntEn, key.
Tzaula′tEn, shovel.
N’kūēncū′tEn, language.
N’tsak·ō′ētctEn, pipe.
N’kūī′atEn, shot pouch.

This initial *n*’, which appears as a regular prefix in most of these terms, is probably a preposition. There is a prepositional form of this kind; as, n’ tla kūa′koa, in the box; n’ tla tcī′tūQ, in the house; n’ tlen pō′etEn, in bed.

AGENT NOUNS.

There is another large class of nouns which takes a suffix in -*utl*, and which carries with it the idea of agency or action; as,

pekhpekhEmu′tl, a hunter,	from	pe′khEm, to hunt
tzauEmtzauEmu′tl, a fisher,	,,	tzau′Em, to fish, *cf.* tzautzau, a fishing ground
tcū′tcūEmu′tl, a worker,	,,	tcu′Em, to work
uk·ai′Emutl, a shooter,	,,	k·ai′Em, to shoot
tlaha′ndju′tl, an eater,	,,	tlaha′ndj, food
âwī′Emu′tl, a laugher,	,,	âwī′Em, to laugh
wī wī u′tl, a crier or caller,	,,	wawī′, a cry or call
ī′tlītlEmu′tl, a singer,	,,	ī′tlEm, to sing
tlEzuzu′tl, a lazy person,	,,	tlEzu′z, lazy
kumakumu′tl, a digger (of roots)	,,	ku′mEn, to dig for roots
yu′k yukEmu′tl, a planter,	,,	yu′kEm, to plant or bury in the earth
pca′kEmu′tl, a wood gatherer,	,,	pca′kEm, to gather wood
k·ūē′auEmu′tl, a berry picker,	,,	k·ūēau′Em, to pick berries; from skūē′it, [berries

Of the above terms those that end in -*Em* are verbs in their simplest, uninflected form. This form may be called the substantive form of the verb. This is not peculiar to the N’tlaka′pamuQ, but is characteristic of most, if not all, of the Salish dialects. It will be observed that whenever the action is continuous or repeated, the stem of the word is reduplicated. This reduplication serves several purposes. It not only expresses the plural and continuous repeated action as above, but enters also into the ideas of diminution in several ways.

DIMINUTIVES.

Kau'iQūi'sk·En, a little axe, from kaui'sk·En, axe; spEzu'zō, a little bird, from spu'zō, bird; pīpī'ēōkQ 'just a few trees,' from pīē'ōka, one tree; cikata'na, I strike it strongly; cikci'katā'na, I strike it a little; kūēnta'ta, talk to me; kūēkūēnta'ta, talk to me a little; pī'latci'na, I speak; pilpī'pElatci'na, I speak very little. Sometimes a different word is employed for the same purpose; as, tzEzoi'tsta, chop it in big pieces; tcīmīma'tstā, chop it in little pieces.

The diminutive is also expressed by compounds as stō'matl, ox; stō'matl-tītī't, a little ox; sk·a'qa, dog; sk·aqa'-tza, a puppy; or by a different word; as, tū'ōt, boy; cīna, a little boy; slā'nats, a girl; ma'qa, a little girl.

COMPOUND NOUNS.

Compound nouns are a common feature of the language. Examples of one class of these are formed by simple juxtaposition with or without modification: ō'iyiptsk·au'tl, fire-canoe, *i.e.* steamer; q'k·"ōpa, beaver, from qtluk·t=broad and cū'pa=tail; n'kEltza-sk·a'qa, horse. Another and commoner class are the 'instrumental' and 'agent' nouns given above.

GENDER.

There is no evidence of grammatical gender in N'tlaka'pamuQ. When a speaker wishes to distinguish between male and female he does so either by the use of separate words; as,

skaī'uq, man; s'mū'tlatc, woman;
tū'ōt, boy; slā'nats, girl;
cī'na, baby boy; ma'qa, baby girl;
ck·'ca, nephew; sklumkē'Et, niece;

or, by adding to the class-word in a more or less modified form the terms for man or woman; as,

dog, sk·a'-kai'uq; bitch, smū-mE'tlatc.

When there is no possibility of ambiguity the class-word is not used, but just one or other of these two terms, as the case may be.

A few words are used of male and female alike, without distinction, when there is no possibility of ambiguity or need to mark the sex; but all these general terms can, and sometimes do, add the words for man and woman when there is need to be explicit.

Doctor, mE'laQmē'it; skū'kEmīt, child
widow,
widower, } slEūē'amEt;
orphan, cua'ka, boy or girl.

Many class nouns are omitted in common speech when qualified by an adjective, as in English; as, ku'tlamīn, old man or woman. The full form of these would be: ku'tlamīn tik skai'uq; ku'tlamīn tik smū'tlatc. A great many of the adjectives may thus be used substantively.

CASE.

Ordinarily the noun undergoes no inflexion for case, but in expressions denoting possession or ownership there is a modification of the stem which might at first sight be taken for a genuine inflexion; as, tcītūQ, house; tcī'tūQ*c* ha 'n ska'tza, the house of my father, or 'n-ska'tza tcītūQ*c*, my father's house.

But this is not a true inflexion; it is merely one of the affixes of the possessive pronoun. These affixes are seen also in the intransitive verbs, and are likewise suffixed to adjectives when they stand as the complement of verbs of incomplete predication, or of the *verbum substantivum*. Schematically they are as follows:—

ha-'*n*-tcī'tūQ, my house; ha-tcī'tūQ, thy house;
ha-tcītūQ*c*, his or her house; ha-tci'tūQ*k't*, our house
ha-tcī'tūQ*āp*, your house; ha-tcī'tūQ*ī'gs*, their house.

It is interesting to notice that in the first and second persons singular the pronominal elements are prefixed, while in all the others they are suffixed. The common prefix *ha-* is a demonstrative particle, and signifies the presence of the thing possessed. It may be replaced by *tla*, which signifies the absence of the thing possessed (see under Pronouns). These particles are abbreviated forms of the demonstrative pronouns 'this' and 'that.' They have also the function of a definite article in N'tlaka'pamuQ in certain constructions.

The object-noun presents some interesting features. Generally speaking, the object of a transitive verb follows the verb in an unmodified form, and is distinct from it; as,

pūī'cena tlum *smītc*, I killed a deer;
kūēta'ta *smītc*, cook the meat;
ō'ita'ta *tcī'tūQ*, burn down the house;
nīka'ta *cūīpum*, cut the wood;
n'saua'ta *tzatl*, wash the dish.

But sometimes the noun is verbalised, taking on regularly the inflexions of the transitive verb; as,

pāmata, make a fire; from spām, a fire;
n'tuktci'nta, shut the door; from n'tuktcī'ntEn, a door.

In other instances the object noun is incorporated into the verbal synthesis in a contracted modified form between the stem and the personal inflexion; as,

tcū-*kai'n*-na, I struck him on the head, from tcūta'na, I strike, and k·u'mk·an, head; tcū-ū'cena, I struck his face, from tcūta'na and sk'tlū'c, face; qo'nī-akst-kin, I have hurt my hand, from qo'nī·kin, I am hurt, and lākst, hand or finger; pau'-c-kin, my face is swollen, from pau'it, swollen, and sk'tlu'c, face, more literally, I am swollen as to my face; nīk-qE'n-kin, I cut my foot, from nīkkin, I am cut, and lā'kaqEn, foot or toe.

It would appear that when the object affected by the verbal action is a person, or any part of a person's body, such object is almost invariably incorporated with the verb, as in the examples given above. There seems, however, to be one striking exception to this rule. When the object happens to be the third person singular, no incorporation or modification of the object takes place, but the pronoun follows the verb as in English; as,

Pō'īsta'na tcinī'tl, I killed him or her;
Tcūtā'na tcinī'tl, I struck him or her;
CEu'ksta'na tlEna, I know that person.

In all other instances it would appear that the pronominal object is invariably incorporated into the verbal synthesis, and placed between the stem of the verb and the terminal inflexions; as,

Huz-*tcī'*-n, I love thee;
Huz-*tē'i*-c, he loves us;
Huz-*tī'gs*-na, I love them.

(For other examples see under Verbs.)

The same principle holds good for the incorporated reflexive pronoun tcūt; as,

Ōī-tcū't-kin, I burn myself;
Quz-tcū't-kin, I love myself.

It will be seen in the above incorporative nouns that their synthetic forms differ from their independent forms. This difference consists in the main in a cutting down of the independent form of the word, which is not infrequently a compound term. At times a different radical is used, but in such cases, I think, it will always be found to be a synonymous term, which has by chance taken the place of the common term. Much of the differentiation in the Salish dialects has been brought about in this way, a good example of which may be seen in the terms for beaver. In the N'tlaka'pamuQ we find the common word for this animal is *s'nūya.* But the primary signification of this term is not beaver but 'wealth,' 'treasure,' 'riches.' Beaver-skins in the old fur-trading days were a standard of value; hence beaver-skins are 'wealth' or 'riches,' and hence the application of the term to the animal itself. But there is also another term quite commonly employed to designate the beaver by, viz., *qk'ōpa*, which is derived by severe syncopation from *qtlukt*, broad, and *cū'pa*, tail. Either of these terms may stand for the word beaver, yet neither of them is the primitive term commonly employed before the division of the Salish stock took place. The word common to the greatest number of tribes is *ske'lō,* or some modification of it. It is the ordinary term for beaver in the dialects of contiguous tribes, both above and below. It is also used by the Coast and Vancouver Island Salish, and even by one division of the Kwakiutl. It must, therefore, have been thrust aside in the dialect of the N'tlaka'pamuQ and forgotten, and the other synonymous terms taken its place, for I could not find it upon inquiry.

The following expressions will serve as examples to show the difference between the compounded and the independent forms:—

English	Compound Forms	Independent Forms	Examples of Synthesis
face	—ūc and —c	sk'tlū'c	pau-c-kin, I am swollen in the face. tcū-ūc-ena, I struck him on the face.
head	—k·an and —k·ain	k·u'mk·an	ska'p-k·an, hair. tcū-kai'n-na, I struck him on the head.
hand	—akst	kē'uq	qo'nē-akst-kin, I have hurt my hand; more correctly, I am hurt as to my hand.
finger	—kainkst	lâkst	skī'a-kainkst, thumb, *i.e.* the 'first finger;' koa'-kainkst, finger-nail.
mouth	—cin and —tcin	tcū'tcin or splu'tcin	stlī'pcin, jaw or chin. n'tcū'tcin.
people	—muQ	citkinmuQ	K·umtcin'-muQ, people of K·umtcī'n.
nose	—ak·s	sp'sa'k·s	tzā'ak·s, long-nose, from tzâqt, long, and sp'sa'k·s, nose.
breast	—kumau-	sk â'am	tlil-kumau'-tcih, chest.
fire	pām	c'pām	pam-a'ta, make a fire.
hair	skap	skapk·an	skapka'tEm, to be struck on the head. The difference between this term and the one above in the compound for 'head' is interesting. When the blow has been given by somebody '*kain*' must be used; when the blow is from above on that part of the head where the hair grows, inflicted by an inanimate object by striking the head against it, '*skap*' is always used.
house	—ūQ and tlūQ	tcī'tūQ	Swa'tlūQ, white man's house. mita'tlūQ, church, *i.e.* house of prayer.
light	mā— and mE—	māmā	ma'-qEtEn, moon, lit. light-above instrument; mEā', daybreak; mā'auīEnu'Q, dawn, lit. light is spreading.

PRONOUNS.

The independent personal pronouns are:

'ntcau'a, I, me.	nEmē'mEtl, we, us.
â'wI, thou, thee.	pīya'pst, you, you.
tcinī'tl, he, she, it; him, her.	tcinkō'st, they, them.

The function of these pronouns in N'tlaka'pamuQ is practically the same as that of the corresponding forms in English. They are used in answer to such questions as, 'Who did it?' They are never used with the verb, which has its own inflected forms. They are sometimes, however, added to the verbal forms to emphasise them, both as subjects and as objects; as, *'ntcau'a* pōīsta'a tcinī'tl, *I* killed him; *'ntcau'a* Quztcī'n, *I* love thee; *tcinī'tl* Quztēis *nEmēmEtl*, *he* loves *us*; Quztīgsna *tcinkōst*, I love *them*; Quztōī'men *pīya'pst* ta'kamōp, I love *you* all.

The synthetic personal pronouns form two distinct classes, one for transitive and another for intransitive verbs. This latter class also undertakes the function of the *verbum substantivum*. It may be suffixed to almost any part of speech, verb, noun. adjective, adverb, pronoun, &c. For example, in the last sentence in the preceding paragraph the terminal *p* in *ta'kamōp* is the characteristic terminal of this pronoun in the second person plural, ta'kamōp being otherwise written as ta'kamōs = all, the whole. Other examples will be found in other parts of the paper.

The two classes schematically given are as follows:—

TRANSITIVE.

Singular	—tena (often abbreviated to —*na* or even —*a*), I.			
	—tauq	„	„ „	q, thou.
	—tas	„	„ „	s or c, he, she, it.
Plural	—tam, we.			
	—tap, you.			
	—tīgs, they.			

INTRANSITIVE.

Singular	—kin, I.	Plural	—k·'t, we.
	—q, thou.		—k·'p, you.
	—		—

POSSESSIVE PRONOUNS.

Of these there are also two classes, or, more strictly speaking, the pronominal elements are modified by two distinct particles which have the function of marking the presence of the object possessed in the one case and its absence in the other; as,

	Object			Absent
Singular	tl—En	my	as:	*tlEn*—tcī'tuQ, my house.
	tl—a	thy	as:	*tla*—tcī'tuQ, thy house.
	tl . . . s	his, her	as:	*tl*—tcī'tuQ *s*, his or her house.
Plural	tl . . . k·'t	our	as:	*tl*—tcī'tuQ *k·'t*, our house.
	tl . . . ap	your	as:	*tl*—tcī'tuQ *ap*, your house.
	tl . . . īgs	their	as:	*tl*—tcītūī'gs, their house.

	Object			Present
Singular	ha—'n	my	as:	ha—'n—skâ'tza, my father.
	ha—a	thy	as:	ha—a—skâ'tza, thy father.
	ha . . . s	his, her	as:	ha—skā'tzas, his or her father.
Plural	ha . . . k·'t	our	as:	ha—skâ'tzak't, our father.
	ha . . . ap	your	as:	ha—skâ'tza ap, your father.
	ha . . . igs	their	as:	ha—skā'tzaī'gs, their father.

These particles that mark the absence and presence of the thing possessed are abbreviated forms of the demonstrative pronouns qaha' 'this,' and tlaha' 'that,' and consequently signify 'here' and 'there.' The position of the object noun varies. One may say ha'n ska'tza tcī'tuQ-s, my father's house; or tcī'tuQs ha'n ska'tza, the house of my father. The latter, however, is the more usual construction.

In the contiguous Shushwap Dr. Boas has recorded 'inclusive' and 'exclusive' forms for the first person plural and the possessive pronouns. I have not been able to discover these differentiations in the Lower N'tlaka'pamuQ dialect.

SUBSTANTIVE POSSESSIVE PRONOUNS.

These forms are used in answer to the question, 'Whose is this?'

Singular { 'ntca'ntl, mine, or it is mine.
hāwi'ntl, thine, or it is thine, sometimes wintl.
tcini'ntlc, his or hers, or it is his or hers.

Plural { nEmē'mEtlk't, ours, or it is ours.
pīa'pstalEp, yours, or it is yours.
tcinku'ctatlī'gs, theirs, or it is theirs.

There is another form compounded from a word meaning 'belongings,' 'possessions,' &c., and the possessive pronoun, and which is the equivalent of our phrase 'this is mine.'

Singular { 'n—cū'tEn, mine, or this is mine.
ā—cū'tEn, thine, „ „ „ thine.
cū'tEn—s, his, „ „ „ his or hers.

Plural { cū'tEnk't, our, „ „ „ ours.
cū'tEnāp, yours, „ „ „ yours.
cū'tEnīgs, theirs, „ „ „ theirs.

This term cū'tEn is also verbalised; as, cū'tEnsta'na, I own it; cū'tEnmī'na, I hold possession of it.

INTERROGATIVE PRONOUNS.

sqūat or cūat? who? ex., cūat Qā? who is that?
cūat q? who are you?
ha'ntla? which? ha'ntla wintl? which is thine?
ha'ntla ha sk·a'qa? which horse is yours?

But in the question 'which of them?' Aqa'n? is the correct form; stā? what? what do you want? stākas hoakst? Aska'num? what? what are you eating? sta'aōpinōq? what colour? aska'num mīta? nik stā? In what? In the phrase 'which horse is yours?' the term for horse is abbreviated to sk·a'qa, which commonly means dog. This abbreviation is quite common in conversation. The full term in Lower N'tlaka'pamuQ is *n'g·E'ltza-sk·a'qa*; in the Tlk·umtcī·'nmuQ dialect it is *intsa-sk·a'qa.*

RELATIVE PRONOUN.

The N'tlaka'pamuQ rarely, if ever, use relative pronouns as we do; indeed, I doubt if a true relative exists. But in translating an English sentence with a relative pronoun in it they sometimes use the particle *tas* to represent our 'who' or 'which;' as, tlaha' kō'kpī *tas* tcūtcams. 'The heavenly chief who made me,' but more often they express themselves thus: Quzte'na tlE'n kīq tla tzōk·, I loved my sister who is dead,' which, literally taken, is rather, 'I love my sister (absent), that one dead.'

EMPHATIC REFLEXIVE PRONOUNS.

n'tcau'amatl, I myself.	nEmē'mEtlmatl, we ourselves.
âwī'matl, thou thyself.	pīya'pstamatl, „
tcinī'tlmatl, he himself.	tcinkō'stamatl, „

There is another reflexive form used with verbs, viz., tcūt, as ōī*tcū't*kin, I burn myself; kestan*tcūt*, becoming bad in oneself. I have not found this form apart from the verb.

DEMONSTRATIVES.

qaha', this.	tlaha', that.
qa qa ha', these.	tla tla ha'. those.
ha, tla, the.	

NUMERALS.

Of these there are several classes formed by amplification of the stem of the regular cardinals. The common cardinal numbers are:—

1. pai'a.
2. cai'a.
3. ka'tlec.
4. mūs.
5. tcīkst.
6. tlakama'kst.
7. tcū'tlka.
8. pī'ōpc.
9. te'mutl pai'a.
10. ō'penakst.
11. ō'penakst atl pai'a
12. ō'penakst atl cai'a
13. ō'penakst atl ka'tlec
14. ,, ,, mus
15. ,, ,, tcīkst
16. ō'penakst atl tlakama'kst
17. ,, ,, tcū'tlka
18. ,, ,, pī'ōpc
19. ,, ,, te'mutl pai'a
20. cītl ō'penakst
21. ,, ,, atl pai'a
30. katl ō'penakst.
31. ,, ,, atl pai'a.
40. mūtl ,,
50. tcitl ,,
60. tla'kamtl ō'penakst
70. tcu'tlk'tl ō'penakst
80. pī'ō'tl ,,
90. te'mutl pai'atl ō'penakst
100. hutct pᴇka'qᴇnakst.

In 5, 6, 11, and all the decades of the above the suffix -akst appears. This is an abbreviated form of *lākst*, hand. To this suffix in 100 is added the synthetic form for foot, *qᴇn*. The analysis of the remaining part of the compound is not clear to me, but the meaning is obviously so many 'hands' and 'feet.' Nine has the signification of 'one less than,' 'one wanting.' Five means the 'whole hand' or 'fist.' Six means another added to the whole fist.

The following forms are used in counting persons :—

1, papai'a
2, cīcai'a
3, kᴇka'tlac
4, mō'cmas
5, tcītcī'kst
6, tlaktla'kama'kst
7, tciltcū'tlka
8, pīō'pst (?)
9, tᴇmutl papai'a
10, ōpᴇ'penakst
11, opᴇ'penakst atl papai'a
12, opᴇ'penakst atl cīcai'a

The following are used when counting animals :—

1, pīē'a, or pᴇpīē'a
2, caicī'a
3, kᴇk'tlᴇc
4, mōmc
5, tcitcī'ikst
6, tlaktlumkst
7, tcū'tctlika
8, (?)
9, tᴇ'mutl pᴇpīē'a
10, ō'pᴇnᴇkst

The following are used when counting trees, &c. :—

1, pīē'ōkꞯ
2, cīē'ōkꞯ
3, kᴇtlē'ōkꞯ
4, musē'ōkꞯ
5, tcikcē'ōkꞯ
6, tla'kamᴇkcē'ōkꞯ
7, tcū'lkacē'ōkꞯ
8, pī'ōpcē'ōkꞯ
9, te'mutlpīē'ōkꞯ
10, ō'penakcēōkꞯ

There is a secondary form for trees, wood, &c., the distinction between which and the above my informant was not able to make clear to me. Examples of this form may be seen in the following: mucmuccēōk·sta = 'bring four pieces of wood at a time;' pīpī'cōkꞯ = 'just a few trees,' said by a native when the trees or bushes are scattered. The reduplication here seen is a good example of the opposite uses to which it is put in N'tlaka'pamuꞯ. In the one instance it expresses augmentation; in the other, diminution or scantiness.

The following forms are used when counting houses :—

1, pīa'tlūꞯ.
2, cīa'tlūꞯ.
3, kᴇka'tlūꞯ.
4, moca'tlūꞯ.
5, tcīksta'tlūꞯ.
6, tla'kamaksa'tlūꞯ.
7, tcūtlka'tlūꞯ.
8, pī'ōpstca'tlūꞯ.
9, te'mutl pai'atla'tlūꞯ.
10, ō'penakca'tlūꞯ.

The distributive is apparently formed by suffixing the particle *tlōq* to the cardinals. This particle has an independent existence, and carries with it the signification of 'only;' as,

pai'atlōq, cai'atlōq, &c., one only, two only, &c.

ORDINALS.

first, kē'a.
second, ascai'astc.
third, aska'tlastc.
fourth, asmū'stc.
fifth, astcī'kstc.
sixth, astlakama'kstc
seventh, astcū'lkastc.
eighth, aspīhō'pstc.
ninth, astE'mElpai'astc.
tenth, asō'penakstc.

ADVERBIAL NUMERALS.

These are regularly formed by suffixing the particle *atl*; as, pai'atl, once; cai'atl, twice, &c. With regard to this suffix it is interesting to note that the same form is seen in the Kootanie in one of its three kinds of numeral adverbs; as, gōkwē'n*ātl*, once; gāskā'tlētl, twice, &c.

ADJECTIVES.

The position of the adjective varies with the construction of the sentence. Commonly it precedes the word it qualifies, and is attached to it by a kind of article thus: ī'ā *tik* tū'ōt, a good boy. The place of this article is always between the substantive and its qualifier. It seems sometimes to perform also the function of a partitive article; as, kwonam'ata *tik* kō, bring me some water; Qoa'kskin *tik* snū'ya, I want some money. It must likewise always stand between a numeral and a substantive; as, pai'a *tik* tcī'tūQ, one house; cīcai'a *tik* skai'akaiu'q, two men. It is probably the same particle as is seen in the Bilqula dialect under the form *ti*, though the functions of the two are not quite the same.

In such a sentence as 'This house is good,' the adjective commonly follows its noun; as, qah'a tik tcī'tūQ ī'a.

Comparison of the adjective is effected in the following manner:—

Positive	Comparative	Superlative
tlikt, sweet	tūwā tlikt, sweeter	kī'atik tlikt, sweetest
Qō'zEm, great	Qō'zEm tūwā, greater	kī'atik Qō'zEm, greatest

The superlative form is simply the numeral adjective 'first' joined to the positive by tik. This is the ordinary method of comparison, but the following phrases show that the comparative and superlative may sometimes be otherwise rendered: ōhitcā'hasī'as = 'better;' where ō'hitcā means 'more,' ha(s) 'this,' and ī'a(s) 'good,' and the whole compound is equivalent to our 'this one is more good;' kwumkwumet tik ia, 'best,' 'very good.'

ADVERBS.

The position of the adverb varies with its sense and the construction of the sentence in which it occurs, but the temporal adverb is invariably placed at the beginning of the sentence; as, *tlakamī'q* tlo hazQuztca'moq, *always*, you have loved me; *tlenaqEnōs* awīkta'na tlanā', *long ago* I saw him. Speaking generally, the adverbial modifier will be found as a rule *before* the word it modifies, but there are many exceptions to this rule.

VERBS.

The N'tlaka'pamuQ possess a verb of being. It enters largely into the composition of the other verbs in certain of their tenses. It is conjugated by means of suffixes and prefixes. It cannot be used independently, but must always take a complementary noun or adjective before or after it. Severed from its complement it is conjugated as follows:—

PRESENT TENSE.

Singular	ūā'kin, I am.	Plural	ūā'k't, we are.
	ūau'q, thou art.		ūā'k'p, you are.
	ūā'q, he or she is.		ūā'tzaq, they are.

PAST INDEFINITE TENSE.

This is formed by suffixing the particle *tlum* to the present tense forms; as, ūākintlum, I was, &c.

PERFECT TENSE.

Singular	tlōā'qūon, I have been.	Plural	tlōā'quōt, we have been.
	tlōā'qōq, thou hast been.		tlōā'qōp, you have been.
	tlōā'qōqc, he has been.		tlōā'tzaqōqc, they have been.

FUTURE TENSE.

hō'īkinūā'q, I shall be.	hō'īk'tūā'q, we shall be.

The other persons follow regularly.

POTENTIAL MOOD.

haua'quontlō, I may be.	haua'qōttlō, we may be.
haua'qōqtlō, thou mayst be.	haua'qōptlō, you may be.
haua'qōctlō, he may be.	haua'tzaqō'ctlō, they may be.

IMPERATIVE MOOD.

ūā'qawa, be thou.	ūā'qōsa, be you.

INFINITIVE MOOD.

ūāq, to be.	tlōaq, to have been.

kīaūEn'ska = if I were good.   k·e'stūenska = if I were bad.

In such sentences as these the complement precedes the main part of the verb, but in a simple direct sentence it follows; as, ū'ākin ī'ā, I am good.

In composition this verb is not regularly employed as the *verbum substantivum* in English is. In the present tenses the personal inflexions only appear in such sentences as we form with an adjective and the *verbum substantivum*. Thus:

PRESENT TENSE.

Singular	tai't-kin, I am hungry.	Plural	tait-k't, we are hungry.
	tai't-q, thou art hungry.		tait-k'p, you are hungry.
	tait, he or she is hungry.		tī-tait, they are hungry.

PAST INDEFINITE TENSE.

Singular	tait-ki'n-ūa, I was hungry.	Plural	tait-k'tūa, we were hungry.
	tait-qūa, thou wast hungry.		tait-k'pūa, you were hungry.
	tait-ūa, he or she was hungry.		tī-taitūa, they were hungry.

PERFECT TENSE.

tlōā'qūontait, I have been hungry.	tlōā'quotait, we have been hungry.
tlōa'qōqtait, thou hast been hungry.	tlōaqōptait, you have been hungry.
tlōa'qōctait, he or she has been hungry.	tlōatza'qōctait, they have been hungry.

FUTURE TENSE.

Singular	hō'īkin-tait, I shall or I am going to be hungry.
	hōīq-tait, thou wilt or thou art going to be hungry.
	hōī-tait, he will or he is going to be hungry.
Plural	hōīk'ttait, we shall or are going to be hungry.
	hōik'ptait, you will or are going to be hungry.
	hōitī-tait, they will or are going to be hungry.

DUBITATIVE TENSE.

tl'ma'taitkin, I may be hungry.

The other forms follow regularly, the particle tl'ma' = 'perhaps,' being prefixed to the present tense forms, as in the first person.

By suffixing the particle *ōq* or *nōq* to the above, as tai'tkin-ōq, we can get an intensive or emphatic form of the same expression, I am *very* hungry. Also kweno'qkin-ōq, I am *very* sick; tcE'lcEau'qkin-ōq, I am *very* glad.

A very constant feature of the verbal system of the N'tlaka'pamuQ is that the verbal stem is always *preceded* by the tense sign in the future. The meaning of the future is nearer our 'I am going to be' than 'I shall be.' There is another form of the future less positive than this, viz., hō'īkin-nōk-kwenō'q, 'I am afraid I am going to be sick.'

The negative forms are thus rendered:—

tata kin*s*kwenō'q, I am not sick.
tata qa*s*kwenō'q, thou art not sick.

The negatives strengthen each other as in Greek, the *s* here strengthening the independent negative tata.

Noun sentences are formed in the same way as the adjective sentences; as,

N'tlaka'pamuQ-kin, I am a N'tlaka'pamuQ.
,, -q, thou art a N'tlaka'pamuQ.
,, — he or she is a N'tlaka'pamuQ.
,, -k't we are N'tlaka'pamuQ.
,, -k'p you are N'tlaka'pamuQ.

The disjunctive personal pronouns may be added to these if emphasis is needed; as,

'ntcau'a N'tlakapamuQ-kin, *I* am a N'tlaka'pamuQ, &c.

The distinction between transitive and intransitive verbs is very clearly marked by the use of entirely different pronominal suffixes. The intransitive take the same pronouns as the adjective as given above, but usually form their past tense by suffixing the particle *tlum*; as,

PRESENT TENSE.

Singular	Plural
Nackin, I go.	nack't, we go.
Nacq, thou goest.	nack'p, you go.
Nac, he or she goes.	näic, they go.

PAST TENSE.

Singular	Plural
kītckin tlum, I went.	kītck't tlum, we went.
kītcq tlum, thou wentest.	kītck'p tlum, you went.
kītc tlum, he went.	kī'etc tlum, they went.

FUTURE TENSE.

hō'īkinnac, I shall go. hō'īk'tnac, we shall go.

The other persons follow regularly.

IMPERATIVE MOOD.

nacūāma'ltlō, go thou. nacūāza'tlō, go ye.

The two following forms are also used imperatively:—

na'cūā, nacūā'tlō } go thou. na'cōza, nacozatlō } go ye.

DUBITATIVE MOOD.

tl'mā'na'ckin, perhaps I may go. tl'mā'na'ck't, perhaps we may go.

The other persons follow regularly.

hacu'kōc tlEmā' na'ckin is another form of this mood; it expresses indecision on the part of the speaker; as, 'maybe I'll go.'

POTENTIAL MOOD.

qaqa'tak·kEnsnac, I can or may go.
qaqa'tak·cEnē'yEt, we ,, ,,
qaqa'tak·kEsnac, thou canst or mayest go.
,, -cEncap, ye can or may go.
,, -cnactc, he ,, ,,
,, -cEnē'yestc, they can or may go.

OPTATIVE FORMS.

enslēkasnac = I want you to go. tata kinsnac ma'mon, I don't want to go.

INFINITIVE MOOD.

nac, to go. nactlō, to have gone

PARTICIPLES.

nactl, going. nactlum, gone.
hō'ı-k't-amal-tlo-nac, let us all go. naict, we are going.

TRANSITIVE VERB.

TO LOVE.

PRESENT TENSE.

Singular	Plural
Quzta'na, I love.	Quztā'm, we love.
Quztau'q, thou lovest.	Quzta'p, you love.
Quzta's, he, she, loves.	Quztī'gs, they love.

In the past tenses of the transitive verb the particle *tlum* appears to play but a small part, its place being supplied by the verb 'to be.' This particle *tlum*, besides forming the past tense and perfect participle of the intransitive verbs, is otherwise employed to indicate absence from the speaker; as, tcinī'tl tlum, he (absent), tcinkōst-tlum, they (absent).

PAST OF INCOMPLETE ACTION.

Singular	Plural
Quzta'na tlō, I have loved.	Quztā'm tlō, we have loved.
Quztau'q tlō, thou hast loved.	Quzta'p tlō, ye have loved.
Quzta's tlō, he has loved.	Quztīgs, they have loved.

PAST OF COMPLETE ACTION.

Singular	Plural
Quzta'naūa, I have loved.	Quztā'm, we have loved.
Quztau'qūa, thou hast loved.	Quzta'p, you have loved.
Quzta'sūa, he has loved.	Quztīgs, they have loved.

The distinction between *ūa* and *tlō* is very nice. The former is used when the action or feeling no longer exists at the time of speaking; as, tlakamīq-ūa hazQuz-tcamōq, always thou hast loved me (up to this time); the latter when the feeling or action is continuing; as, tlakamīq-tlōhazQuztcamōq, always thou hast loved me and still dost. It will be noticed in these two sentences that the adverb takes the past signs and not the verb. They sometimes precede the verb; as, tlōQuzta'na, I have loved. The amplification of the verbal stem here observed marks the continuity of the action and strengthens the adverb.

The indefinite past is frequently expressed by the present without any modifying particles, the context or sense of the passage making the time of the action clear; as, Quzta'na tlᴇ 'nkīq tlᴇ tzōk, I loved my sister who is dead: more literally, 'I love that my sister that one dead.' The past action of the verb is here implied by the absence or death of the object. Other examples are tcū-uc-ᴇna, I struck him on the face; tcū-kain-na, I struck him on the head.

In these examples of incorporated object the subject pronoun sometimes suffers contraction as well as the object, as seen in these two instances. Occasionally the indefinite past takes *tlum*; as, pūī'cena tlum smitc, I killed a deer.

FUTURE TENSE.

hō'ɪQuzta'na, I shall love. The other persons follow regularly.

POTENTIAL MOOD.

hāQuzta'naŭac, I may love. The other persons follow regularly.

IMPERATIVE MOOD.

Quztā'tā, love thou; Quztatō'zā, love you;
Quztca'ma, love thou me.
Quztcamō'za, love you me.

POTENTIAL PASSIVE.

Singular.
- haQuztcē'maūac, I may be loved.
- haQuztcī'tōc, thou mayest be loved.
- haQuzsta'mōc, he may be loved.

Plural.
- haQuzstē'tōc, we may be loved.
- haQuzstō'īmatō'c, ye may be loved.
- haQuztī'gsatamō'c, they may be loved.

In verbs formed from nouns or adjectives the imperative inflection is *-sta*; as, tcimī'matsta, 'cut it in little pieces,' more literally, 'little it;' tzōzō'itsta, cut it in big pieces; mucmucēō'ksta, 'bring four pieces of wood at a time.' In each of these expressions the only verbal element is the sign of the imperative -sta.

The following are examples of the incorporated pronoun object, with the exception in the third person singular, as mentioned above:—

Quztcī'n, I love thee.
Quztō'īmEn, I love you.
Quztcī't, we love thee.
Quztī'gstcatc, they love thee.
Quztī'gsna, I love them.
Quztī'gsnūq, thou lovest them.
Quzta'c tcincō'st, he loves them.
Quztca'mq, thou lovest me.
Quztca'ms, he loves me.
Quztē'c, he loves us.
Quztana tcinī'tl, I love him.
Quztau'q tcinī'tl, thou lovest him.
Quzta's tcinī'tl, he loves him.
Quztcī'c, he loves thee.
Quztō'īmEc, he loves you.
Quztō'īmat, we love you.
(?) they love you.
Quztī'gscū'tEm, we love them.
Quztī'gscenu'q you love them.
Quztī'gs tcincō'st, they love them.
Quztcē'ip, you love me.
Quztī'gscatcams, they love me.
tlatla' huztē'ic, they love us.
Quzta'm tcinī'tl, we love him.
Quzta'p tcinī'tl, you love him.
Quztī'gs tcinī'tl, they love him.

PREPOSITIONS AND PREPOSITIONAL PHRASES.

The prepositional elements of the N'tlaka'pamuQ tongue vary with the construction of the sentence. Some of these are: tla'kut, across; tutl, beyond; n'kpa'nik na, under.

na, on.
'n, in.
mitca'k·a na tEmu'q, sit on the ground.
'n tla tcī'tūQ, in the house.
'n tla k·oa'koa, in the box.
'n tlEn pō'ItEn, in the bed.
na kō, on the water.
pa'kwata tsk·au'tl na kō, launch the boat on the water.
tla'kut kō, across the river.
na sqEnq, on a stone.
n'kpa'nik na sqEnq, under a stone.
tlatlat na kō, near the water.

MISCELLANEOUS PHRASES, &c.

What are you eating? stā'aōpinōq?
Who will do this? cūatka ōItcū'tamōs?
The sun is shining, nūEllrIc a skōa'koac.
It is raining, ūa'tEktl.
Launch the canoe on the water, pa'kwata tsk·au'tl na kō.
And one of them accordingly went, atl tlo-asna'c ha papai'a.
I alone will possess the treasure, au! kwonaQEnā aitl snū'ya.
Alas! what a world is this! au! kanum neka hā na' hai'ā!
Long ago I saw him, tlena'QEnōs awiktana tlEna'.

Immediately the cock crew, tlo nā ā' ās haimno ha sp'zō.
I cut my foot, nīkqᴇ'nkin.
I hurt my foot, qo'nīqᴇ'nkin.
My face is swollen, pau'ckin.
Where is the axe? ʜan kani'sk·ᴇn?
It is there, anī tla hā'.
The moon is bright, mama' tla ma'qᴇtᴇn.
Make a fire, pāma'ta.
A hungry person came here, tāit tik tluskai'uq tlakūā'yå'.
I know that person, cᴇu'kstᴇna tlᴇna'.
I nail it, tlāuktana. I have driven it home, akstlaukᴇnaꞯᴇna.
I know, yeꞯumstana. I know it thoroughly, yeꞯumᴡɪ'gstana.
I have four houses, muca'tlūq ha'n tcᴇtcītūꞯ.
A good house, ɪa' tik tcī'tūꞯ.
That house is good, tla-ha tik tcītūꞯ ɪa'.
Sit down, mītcaka.
I am still sick, ūa'kin tlo kwenō'q.
I was sick yesterday, I am better to-day, kweno'qkinūa spīqau'tl tcahai'tl īå' wīa'qkin.
Bring it in, ūlksta. That will do, hōmå'tl.
Here is some bread, hak ha pi'skᴡɪ.
Are you tired? pāpī'iktkuon?
Come to-morrow, ha tlaha'q tuk tlspīqau'tl.
Give me the saw, anakstcima tana'tlōs.
Are you awake? ā-ketlaꞯon?

and, atl; but, kamatl; kūk! hark! anā'! alas! tlō, then; tcatl, now; takumō'ɪ every; tatlō'ta, none; ta'kum or ta'kᴇnōs, all; tsītsīā, such as, like; sēmī'q, thē whole.

VOCABULARY OF LOWER N'TLAKA'PAMU*Q* TERMS.

Terms of Relationship.

father	skâ'tza.*
mother	sk·ī'ʜōza.*

* These terms are not commonly used by children when addressing their parents, the secondary forms are those generally employed. Old women are commonly addressed as k·īʜōza.

father	man or mama.
mother	kīk or kī'ka.
grandfather	capazā.
grandmother	k·zā'.
grandchild	ē'mitc.
uncle (father's brother)	cī'ckāʜ.
uncle (mother's brother)	„
aunt (mother's sister)	skōz'.
aunt (father's sister)	„
nephew	ck·'ca.
niece	sklumkē'ᴇt.
brother (elder)	kātck·'.
sister „	kiq'.
sister (younger)	tcᴇ'tca.
brother „	cincī'.
brother-in-law (said by girl)	cia'ctᴇm.
sister-in-law (said by girl)	cia'ctᴇm.
boy	tūō't.
youth	tūī'ōt.
girl	slā'nats.

orphan, cna'ka (this term is common to both sexes).

man	skai'ūq.
woman	s'mū'tlatc.
old man	ku'tlamīn.*
old woman	„

* Abbreviated from kū'tlamīn tik skai'ūq and ku'tlamīn tik s'mū'tlatc.

people	cai'tkinmaq.
person	tluskai'uq.
husband	ꞯai'ōᴡɪ (used by wife when addressing her husband).
husband	squai'ōᴡɪ (general term).
wife	cᴇm'a'm.
wives	cᴇmᴇ'mam
infant	sk·ūkumᴇ'met.
„	sk·ū'kᴇmīt (general term).
child (speaker's)	skō'za.

children	tcimamē't (general term).
,,	tcimē't, offspring, family; also employed when speaking of children of a certain family.
chief	kō'kpī, skiau'tl.

Parts of the Body.

head or cranium	k·umk·an.
head (entire)	skutlu'c.
crown of head	n'k·umau'isk·an.
forehead	n'k·umu'cūs,cīnez.
hair	ska'pk·an.
face	sk'tluc
cheek	kūza'pē.
jaw, chin	stli'pcin.
saliva	n'tcū'tcin.
eye	nukoatlūctEn.
eyebrow	k'tl'pai'st.
ear	tl'a'nī.
nose	sp'sak·s.
mouth	tcū'tcin.
tongue	tā'tla.
tooth	qī'auq, qai'ōq.
breast (of woman)	sk·aam.
chest	tlikumau'tcik.
back	ciqitskin
stomach	oiye'n.
arm	kē'uq, kēikq.
hand	kēiks (his hand).
finger	lākst.
fingers	lālā'kst.
little finger	cu'tum kakanakst (cu'tum = youngest).
thumb	skīa-kainkst (first finger).
finger-nail	kōa'kainkst.
knee	sk·'maswasqEn.
foot	sk·oat, sk·oaqt.
feet	sk·oa'quat.
toe	lā'kqEn.
toes	lākalā'kqEn.
toenail	kōa'kainkst.
bone	ōqk·ō'otl, kōk·ōol, kūōkūōltc.
bone (of fish)	tsam.
blood	peti'la.
heart	cua'kōk.
skin	cEpa'ts.

General Terms.

fog	cpūtlEt.
tide	cmc'katko'mā.
wave	cnakq.
eddy	czi'oko'mā'.
current	cqu'ako'mā.
hail	ctlā'ūs.
snow	cōkt.
rain	stEktl.
ice	n'pau'.
water	kô.
sea, river	kōqoē.
wind	naut, snaut.
sky	stlek·'t.
moon	mā'qEtEn.
sun	sk·ōa'koatc.
star	n'kōkū'tcEn.
day	ci'tl'k·'t.
night	ci'tict.
morning	nūwa'nūan.
dawn	māauī'Emuq.
daybreak	mEā'.
evening	tsōō'z.
sunset	rap or āap (there is no true *r* in N'ntlaka'pamuQ)
dark	k·lEpE'p (as in an eclipse).
dark	k·lE'pitk·lE'pit (as in the night).
light	māmā'.
earth, land	tEmū'q.
lake	palū'ckō.
mountain	sk·'m, sk·oEm.
hill	sk·oak·'m.
tree	cūā'p, cī'Ep.
trees	cī'EpEwa'p or cū'Epera'p.
leaf	p'tcictl.
bark	pai'am.
rock, stone	cEnq, sqEnq.
fence (picket)	skEq.
house	tcītūQ or tcī'tQ.
house of white man	swatlū'Q.
houses	tcītcī'tū'Q.
canoe	tsk·au'tl.
canoes	tsk·tsk·au'tl.
knife	cE'lis
axe (iron)	kaui'sk·En.
axe (stone)	cū'lkist.
door	n'tuktcī'tEn.
garden	nīu'kamin.
nail (iron)	klo'komin.
window	n'kōanō'ctEn.
mirror	kūEmō'sEn.
meat	smitc.
flesh	slEk.
spruce-tree	sklpa'ka.
moccasin	ciltzaū'ī.
leggings	skEl, mata's.
firewood	cū'īpEm.
fire	c'pām, ōi'yip.
steamer	o'iyip-tik-tsk·au'tl.
ashes	n'cūi'ptEn.
embers, sparks	dūkti'kq.
smoke	catc or sqatc.
dog	sk·a'qa.
horse	n'g·E'ltza-sk·a'qa, or simply sk·a'qa.
bear (black)	spatc.
deer	smītc.
grizzly	cūqcū.
rat	qaut.
beaver	s'nū'ya, qk·'ōpa

coyote	snikīā'p.
magpie	Qai'non.
diver	tzala's.
puppy	sk·a'qatza.
fly (common house)	mu'za.
mosquito	kō'k·oaskē.
wolverine	kōi'lEkin.
badger (?)	n'Qoeni'ken.
marten	Qua'kqōc.
weazel	tcītcq.
maggot-fly	haha'nūks.
bird (generic)	sp'zō.
beast ,,	,,
fish ,,	cwatl.
slave	cau'ūt, caicu'ltk.
slaves	cau'cEcūt.
fight, battle	k·oatoaq.
noise	halu'kū.
sounds (made by nature)	emi'nim.
sound of human voices	cauō'.
spirit or soul or life	cūmaqk.
ghost	clūska'lū.
spring (of water)	petōk.
cold weather	tsetltcin.
cold	tsetl.
summer-time	spandj'k· (lit. fruit season).
now	tucai'tl.
to-day	tcahai'tl.
to-morrow	tuk spīhau't.
yesterday	tl spīhaut.
midday	nEpī'kEn.
midnight	tetoa'hauc.
sunrise	bop tlum skōakoac.
moonrise	bop tlum mā'qEtEn.
pond	cpac.
waterfall	tcoktcē'oq.
bridge	nEhu'līoc.
lamp	n'tzaukūi'sqatEn.
half-moon	ckethau'ca.
full-moon	cai'ī.
glimmer	ōau'letc.
twinkle (of the stars)	tlipci'am.
bed	n'pō'itEn.
chair	n'tl'ko'aptEn.
horn	skwai'yakun.
name	skōast.
feathers (big)	cō'kbōst.
down	cqins.
forest	tzhau'elt.
mat (common)	cēp.
post (in keekwilee-house)	sku'tzamin.
box	qoa'kōa.
hat	kamō't.
joy, pleasure	k·u'lkutl.
'keekwilee-house'	sai'istikin.
arrow	skūī'.
bow	skī'nak.
book	tsuktsuk.
letters	tsuktens.
figures	paiapai'aus,
bright, brightly	māmā'.

hot	s'lōq.
warm	kumkumEt, qōatc.
(The difference between these two terms is that the former means 'warm from *fire*-heat, the latter from *sun*-heat.)	
sweet	tlekt.
hard	tlot.
high	wīst.
heavy	Homa'nk.
bad	kest, k·ect.
good	ī'ā.
broad	tlu'kEt.
narrow	tqīqEt.
white	stEpE'k.
black	stEpta'kt.
blue	st'k·ō.
large, great, big	QōzE'm.
small, little	q'mē'ma.
strong	zōzo'pt.
cold	tsā'atlt.
all	ta'kEm, ta'kEmōs.
this	qaha'.
that	tlaha'.
these	qaqaha'.
those	tla tla ha'.
none	tatlōlā.
no, not	tata.
yes	ăī, eh.
hungry	tait.
sick	kwenō'q.
ill	n'kīō'q.
well	wīE'q.
swollen	pau'it.
sharp	QuzQuz.
many, much	quāt.
to chew	k·hEm.
I sit down	mītcakin.
'to be'	ūā'q.
to go	nac.
I say	tcu'na.
I pass by	tlaha'qkin.
I find	punu'mna.
to increase	wīg.
I kill	pūī'cena.
I obtain	kuonawe'na.
I steal	nauq.
to hunt	pēa'kEm.
I send	kītamu'tcin.
to shoot	k·aiEm.
to work	tcu'Em.
to fish	tzau'Em.
to hunt	pekhEm.
to laugh	âwī'Em.
to call	wāwī'Em.
to sing	ī'tlEm.
to dig	ku'mEm.
to plant	yu'kEm.
to gather wood	pca'kEm.
to pick berries	k·ūēau'Em.
I strike	cikata'na,

I speak	pī'latci'na.	to paint	qi'kas.
I cut	nīkata'na.	to see	mīki'q.
I know	cEuksta'na.	to trap	ko'qEm.
to help	ki'ntEm.	to watch	tzomī'ntEm.
to lend	kwaku'mstEm.		

FOLKLORE.

In recording the following folk-tales of the N'tlaka'pamuQ, I have sought throughout to keep them as true to the spirit of the Indian mind as possible. I was the better able to do this as my informant possessed a more than common knowledge of English for an elderly Indian. Having acted as interpreter for many years to the missionaries, and also in the law courts, he had a fair command of words. Much, therefore, of the wording of the stories is his own. I have not sought to curtail or shorten in any way the details of the longer stories, believing these to be of the highest value in comparative studies. Mischelle is a born *raconteur*, and has always taken the deepest interest in the stories and old customs of his people. My method of recording was in the shorter tales to write the story almost verbatim as he related it. In the case of the longer detailed ones I wrote down the chief incidents of the story at the time of recital, filled in the rest from memory immediately afterwards, and then read the whole over to Mischelle next day to see that I had got it correctly. By this means, although I am responsible for the English, the spirit of the stories is Mischelle's.

Story of the Elk-maiden.

In the remote days of long ago, when the animals spoke and behaved like human beings, there lived in the far north an elk-man and his wife. They possessed an only daughter, and the one grief of their lives was that no husband could be found for her. The daughter, who had no wish to remain single all her days, grew dissatisfied with her lot, and determined to leave home and seek an old aunt, a sister of her father's, who lived somewhere in the far south. She accordingly set out and travelled by herself for many weeks and moons. She had not, however, gone far before her aunt, who was a very wise woman, learnt in a dream that her niece was on her way to seek her.

Now, in the old elk-aunt's village, of which she was chieftainess, and which consisted of many keekwilee-houses, or semi-subterranean winter dwellings, there were no women or females of any kind. The whole community, except herself, was composed of males. Being a wise old woman, she foresaw that as soon as her niece should arrive she would be pestered to death by suitors for the maiden's hand, and that trouble and discord would arise upon her appearance among them. She therefore set her wits to work to devise some plan by which she might keep her niece to herself and prevent discord and jealousies from disturbing the peace and harmony of the village. And this is the way she did it. She straightway sent for young Night-hawk, because he had a strong voice, and bade him make known to all his companions that if they desired to win a beautiful young elk-maiden for wife they should come to her on a certain day. Night-hawk soon made the news known to his companions. His tidings caused much commotion in the village, and not a youth was missing on the appointed day. When all were assembled the old aunt told them briefly that her niece was about to pay her a visit, and as she was unmarried would probably desire to have a husband and settle down with her. 'Among so many desirable youths,' said she, 'I find it difficult to select one whose claims are greater than the rest. In order, therefore, that each one of you may have a chance to obtain the maiden I have decided to let you race for her. You shall all be placed at one end of the village, and she at the other. At the word "Go," you shall start after her, and whoever first catches her shall have her for wife.' This plan was not equally pleasing to all. Young Deer and the other fleet-footed youths thought the idea an excellent one, each believing that he could easily snatch the prize from his fellows ; but Tortoise thought it was hardly fair to him and his friends, who were not gifted with long and nimble legs. His objection, however, was overruled, and he and his friends pacified by a promise of a good start in advance of the rest. All unconscious of the excitement the news of her expected arrival had caused in her aunt's village, the maiden had gradually neared her destination, and was now but a few miles distant. The old aunt had followed her course day by day in her dreams, and knew exactly where she was and when she would appear. So when she was but a little way off she went forth to meet and bring her in. She said nothing to the others as she went, hoping that she might pass out and in unobserved. But they had seen her stealing off, and when she returned a little while later with her niece every youth in the place was on the look-out for them. The maiden was wholly unprepared to pass the gauntlet of eyes that now met her, and was much embarrassed by the presence of so many males, and by the ardent glances they cast upon her. After one hurried look round, she bent her eyes to the ground, and did not raise them till she was within her aunt's keekwilee-house. The excitement in the village now became intense, and the old chieftainess saw that if she wished to prevent trouble and discord she must have the contest for her niece's hand settled without unnecessary delay. She accordingly fixed a near day, and bade all be in readiness. On the day appointed every youth in the village presented himself at the aunt's dwelling. The old chieftainess then arranged them for the contest, placing all the slow-footed competitors in the foremost rank, with Tortoise in front of all, and Deer and his comrades in the rear. She then led forth her niece, clad in a beautiful doeskin dress, embroidered from top to bottom with many-coloured beads and shells, and painted with numerous mystic symbols. A buzz of admiration greeted her as her aunt led her to the far end of the camp and instructed her to make straight for the house again as soon as the word was given to start. The aunt then went back to the others, and, bidding them be ready, gave the word to start. Such a rushing and striving as then followed was never seen in the village before, as each youth strove to outdo the others. At the command to go all had seen the maiden disappear behind the farthest keekwilee-house, and each endeavoured to be at the turn first. But no sooner had the old woman given the word to start than she exercised her magic powers and caused the sky to become quickly overcast with thick dark clouds, which effectually shut out the light of day and enveloped the runners in its bewildering folds, so that none could discern his fellow or see whither he went. One ran into another and eagerly clasped him, thinking he had secured the prize ; but, finding his mistake, let go his hold and started afresh, only to find himself repeating the same mistake again and again. 'I have her !' 'I have her !' cried a dozen voices at once. 'No, she's mine !' 'She's mine !' shouted young Raven, as he grasped the bark of a cedar tree which was hanging loose and fluttering in the wind, and tore it off in his excitement, thinking he had caught the maiden by her dress, which had given way in his hand. 'She is mine! I have her!' he repeated again, as he grasped the tree in his arms. But before he could realise his mistake he was dragged back from the tree by a dozen hands, and had to take up the hunt again. And thus they strove in vain to find the maiden, until they had torn the clothes from each other's backs, and the light of day had returned once more. 'Who's got her?' 'Where is she?' was now the cry all round; and, to the astonishment of all, no one seemed to have secured the prize. She had escaped them all, and, moreover, was now nowhere to be seen. While all these frantic struggles in the dark had been going on, the old aunt had run round the other way and led back her niece into the house again, and, taking off her beautiful dress, had straightway hidden her in a large basket fashioned like a cradle, which she had prepared for the purpose. This she placed on a shelf just under the roof, where no one would be likely to investigate and discover its contents. Every one now wondered what could have become of the maiden, but none save crafty keen-eyed Lynx suspected that a trick had been played upon them by their chieftainess. It was commonly supposed that the sun, observing the beautiful maiden as she ran, had become enamoured of her, and had left his abode in the heavens and come down and seized and carried her off. 'How else,' argued they, 'could you account for the sudden darkness of midnight at noonday?' But Lynx thought otherwise, though he said nothing. He, like the others, had entered the race, but, finding himself outstripped at the commencement, gave up the contest, and kept his keen eyes upon the chieftainess. He thought he had seen her run round the other side of the house and return again with her niece, but was not quite sure, as the darkness had baffled even his keen sight. Nevertheless he inclined to the belief that the maiden had returned to her aunt's dwelling, and even now lay concealed there, and he determined to satisfy himself on this point before long. For several days and nights, therefore, he hung round the old woman's keekwilee-house, making all sorts of excuses to pay her sudden and unexpected visits. At one time he would take her a fine salmon, at another some rare roots, and at another a haunch of venison; but enter as often and as suddenly as he would, no trace of the maiden could he see. Having failed in this plan, he had resort to another.

On each occasion that he had visited the old aunt's house since the girl's disappearance he had noticed the large cradle-basket on the shelf. He could not remember to have seen it before, and from its appearance it was plain that it was not an old cradle; so he could not help connecting its presence with the disappearance of the maiden. He vowed he would learn by some means the contents of that basket before long; but as there was no chance of doing this openly he must find some other way. So accordingly one night, when the whole village was asleep, he stole to the roof of the old woman's house and began sniffing over the spot where he knew the cradle lay, and having a keen nose soon assured himself that the maiden lay there asleep. Having satisfied himself on this score, he now carefully and quietly removed a little of the bark covering from the roof, thus making a small hole therein large enough to peep through and see the maiden sleeping soundly beneath him. Enlarging the hole a little, he thrust in his paw, and gently removing the blanket from her breast spat three times upon her abdomen. He then replaced the blanket, restored the hole as before, and slunk home to his own quarters. For three successive nights he repeated this action, after which he returned no more, but went about his business as usual and awaited results. In the meantime life had not gone very merrily with the maiden. Pent up in her narrow quarters she grew wearier each day as the weeks went by, and begged her aunt again and again to allow her to come out of her basket. But this the old chieftainess would not do. But as time went on the maiden presently discovered herself to be in a peculiar and distressing condition. It seemed as if she would shortly become a mother. When the first consciousness of her condition dawned upon her she would not believe it, but as the days went by she could no longer entertain any doubt of it. She hid the matter from her relative until it was no longer possible to do so, and then the aunt was angry indeed, and bitterly reproached her niece for the disgrace she was bringing upon her, and would not at first believe that the girl herself was innocent in the matter. But having presently convinced herself of this, she set her wits to work to discover who it was that had outwitted her in this way. But though exceedingly wise and versed in much magic she yet could not discover directly who the offender was, but was obliged to get her information in a roundabout way. But now the maiden's full time had come, and she was delivered of a male child, who grew in an incredibly short space of time into a strong and vigorous boy. The old chieftainess, having thought out her plan of action, now sent once more for her public crier, young Night-hawk, and bade him inform the village of the birth of a child to her niece, and tell his companions that they were all to present themselves at her house on a certain day, and bring each of them a present for the child.

This they all did, with the exception of two, each burning with curiosity to learn when the maiden had returned, and who had secured her for wife. The bidding of the tribe to her house was part of the old aunt's plan for discovering the father of her grand-nephew. By her magic powers she had learnt that if each visitor presented the child with a gift, he would accept and retain one only, viz. the present offered by his own father, and would reject with disdain those of all the others. Thus she would be able to discover the perpetrator of the deed. On the day appointed each brought his present. As they descended they offered their presents one by one to the child, who took them, only to throw them aside again the next moment. This happened until all the presents had been made, and all the visitors had assembled. As the child had shown no interest in anything that had yet been offered him, the old woman knew from this that some one must be absent. She therefore angrily demanded who had disobeyed her injunctions; and after some little delay and calling of names it was ascertained that Young Rabbit and his brother Lynx were absent. A messenger was immediately despatched for them, and in a few minutes they arrived, Rabbit descending first. As Rabbit clambered down the notched pole that served for ladder, the child now for the first time evinced some interest in what was going on, and looked up and smiled at Rabbit and held out his hand for the present. For a moment he seemed inclined to play with it, but threw it aside at once when he perceived Lynx descending. As the latter approached he crowed and laughed and clapped his hands with delight, eagerly stretching them out for Lynx's present, which he retained and immediately began to play with. The old chieftainess knew from this that the child's father stood before her. She now related to the assembled guests all that had taken place.

Pointing to Lynx, who hung his head in silence, she exclaimed, 'What shall be done to a creature guilty of such meanness? Death is too good for such a one. I will tell you what shall be done to him. . . . He sought to rob me of my niece; now that he has disgraced her he shall have her whether he will or no; but he shall possess her in loneliness; he shall not live with us. I have been thinking of changing camp for some time past; we will do so now, and leave him and the girl and child behind to look after themselves as best they may.' As they left the house every one of them, even Lynx's own brother, Rabbit, gave him a kick or a cuff, so that by the time all had gone poor Lynx was a mass of bruises and sores. When all had at length left, the girl, who had been watching the whole proceeding in shame and anger, now came forward and washed and tied up poor Lynx's battered head, mildly reproaching him the while for the trouble and disgrace he had brought upon them. Meanwhile the others were busy preparing for the departure across the water, which divided their present encampment from the country beyond. There were many among them who, while they felt no pity or compassion for Lynx, were yet sorry for the girl; and in packing up their food stores purposely left some scraps behind for her in their food-cellars. In a short time they were ready to start, and the old chieftainess giving the word, they paddled away, leaving the pair behind them. The old aunt had left very little of her store of food behind her, so that in a few days the forsaken couple found their larder empty. Then it was that Lynx remembered that there were other food-cellars in the village, and suggested that the girl should go round and see what she could find in them.

She soon discovered the food that was left behind; and, poor and scanty as it was, she was grateful for the kindness of those who had thought of her in this way, and promised herself that if opportunity offered she would not forget their kind acts. The food thus secured lasted them till Lynx had recovered from his wounds and was able to go out hunting. But the night before he was to start he had a dream, and in his dream his guardian spirit came to him and told him not to despair or be downcast at the turn events had taken; that he would assist him, and that one day he would be a great man and rule over his tribe. He was further instructed to prepare a bow and arrows after the pattern shown him in his dream, and go to the woods at the back of the village, and there he would always find game in plenty. Accordingly, next day, after relating the dream to his wife, he fashioned himself a bow and a quiver of arrows, after the pattern he had seen in his dream, and went forth to hunt. He had scarcely left the village behind him when fat deer sprang up on all sides. Having killed as many as he deemed enough for them, he returned to the village to inform his wife of his good luck, and to secure her help in bringing home the game. From this time on they had game and skins in plenty, and lived upon the fat of the land. So plentiful indeed had all kinds of food now become that that precious possession, mountain goats' and sheep's kidney fat, was as common as meat, and the boy was given a ball of it to play with; and so much had the wife thrown away through the smoke-hole that the roof was coated with congealed masses of it.

Now things were quite otherwise on the other side of the water. Soon after elk-woman and her people had settled there all the game had suddenly disappeared, and now the best and keenest hunters could find nothing to bring home after a long day's hunt. Famine was busy among them, and they were anything but happy in their new quarters. This state of things had been going on for some time, when one day Raven took it into his head to fly across the water and see how the deserted Lynx and his family were faring. Greatly exhausted by his exertions in his half-famished state, he was glad to alight on the ridge-pole of Lynx's keekwilee-house. Recovering himself he looked round him and could scarcely believe his eyes when he saw a chubby child actually playing with a ball of precious kidney fat, as if it were of no value at all. Seizing an opportunity, when the child had rolled the ball of fat towards him, he pounced down upon it and, urged partly by hunger and partly by greediness, strove to swallow it whole. But the ball was too big for his mouth and stuck in the back of his throat. The child, seeing Raven gobble up his plaything, set up a howl, which speedily brought out his mother. Perceiving what had happened she seized Raven by the neck and forced him to disgorge the ball again. Then, giving him a good shaking, she demanded from him what he was doing there, robbing the child of his plaything. Raven confessed that he had flown over, out of curiosity, to see how they were getting on, and, being very hungry, could not resist the temptation to swallow the ball of fat when the opportunity was given him. 'But how came you to be so starving?' questioned the woman; 'you are surely not short of food over the water.' 'Indeed, we are,' responded Raven; 'we are worse than short of food, we are all starving.' 'Ah!' said the woman, 'you have rightly fallen upon the lot you desired for me. Go back to your companions and tell them I rejoice to hear of their misfortunes. My husband and I shall enjoy our food the more from knowing your stomachs are aching with hunger.' She spoke thus bitterly because Raven's presence recalled their desertion of herself and child. But Raven pleaded so hard for a meal first that she relented and gave him as much meat and fat as he could eat, and told him he might come over every day and get a meal on condition that he did not tell the others. This Raven readily agreed to. When Raven first flew over he was thin and poor, but after a little while the generous diet began to show its effects upon him, and he grew plump and saucy once more, while his companions grew thinner and thinner. His condition soon attracted attention, and his comrades began to suspect that he knew of some stores of food which he selfishly kept to himself. So one day they seized him and threatened to kill him if he would not reveal the source whence he secured his food. At first Raven was true to his promise, and would disclose nothing; but seeing that his companions were in earnest, and would undoubtedly kill him if he hid the matter from them any longer, he confessed that he had been going to the old settlement, and had been generously fed by Lynx and his wife, who were living in plenty. On hearing this they determined to pocket their pride and return to the old camp the very next day. In the meantime, while they were making their preparations, Raven flew over and told Lynx and his wife what had transpired. The woman, on hearing the news, recalled the promise she had made to herself, and hastened to stock the food-cellars of those who had thought of her in her distress. She filled their cellars with the choicest game and fat, but put not a morsel in the cellars of the others. Next day, when the tribe returned, those whose kind actions had borne fruit feasted upon Lynx's game as they had not feasted for a long time before. The others, whose cellars were as empty as their stomachs, gathered round Lynx's keekwilee-house and eagerly picked up and devoured the scraps which the woman had purposely thrown out. Little Ant and several of his relatives climbed on the roof and began to eat the fat that had gathered there. For some days neither Lynx nor his wife would show themselves, but each morning they threw out a basketful of bones and pickings, which were quickly seized and devoured by the starving crowd. When the woman thought she had sufficiently humbled their pride and revenged herself for their cruelty to her, she bade her husband make a great feast and invite them all to it. This he did, and when they had eaten their fill he told them of his vision and the promise his guardian spirit had made to him. From this they perceived that he was ordained to be their chief. They accordingly denounced the old chieftainess, declaring that she should have known all this, and, deposing her, they made him chief in her place.

Thus Lynx's dream was fulfilled, and he became a great man among them from that time forward.

Tla'pas Cima'ms, or the Forgotten Wife Story.

There was once a young man who was very desirous of becoming a great 'medicine' man, or Shaman. Following the usual custom of the Indians he retired to a solitary spot that he might be alone. He subjected himself to the severest discipline, fasting till his body was so wasted that his bones almost came through his skin, but he met with no success. No dream or vision came to him; no spirit promised him its aid and help. Giving up the trial in despair, he resolved to go and visit a certain famous Shaman who lived in another part of the country. On his journey thither he came upon a secluded village through which his path ran; and, as it was near night, he resolved to stay there till next morning. To his surprise he found the village deserted, but for one old woman. Going up to her he saw that she was very old and decrepit, so old, indeed, that she could not sit upright, her body falling forward between her knees as she crouched over the embers of a decaying charcoal fire. By her side was a basket of koakoē'la, or 'husband' roots; while from every joint in her limbs and from each side of her head there grew out young fir-trees. These appeared to incommode her considerably, and as soon as she saw the young man she begged him to cut them for her. Being of an obliging nature, and seeing that she was extremely old, and probably wise and gifted with supernatural power, he complied with her request. She then begged him to make her a little fresh charcoal for her fire and place it by her side. This he did also, and then began to question her as to why she was all alone and why her people had deserted her. 'They have not deserted me,' answered she, 'they are all dead. I have outlived them all. I am very old, so old that the fir-trees grow upon me as you have seen.'

'But how have you managed to live so long?' questioned the youth. 'Because my "medicine" is good,' she answered. 'See these roots at my side? That is my "power."' I have eaten nothing but these since I was a girl. In their strength I have lived on, while all my kinsfolk have died and passed away. I have learnt, too, to read the secrets of the heart; I know your ambition and the object of your journey through the forest, But you will not attain your desire unless I assist you. This I will do in return for your kindness to me. Take this root, peel off the skin, and eat it when you are going to rest for the night, carefully preserving the root itself for the future. In your sleep you will have a dream. Come to me in the morning and tell me what you dreamt, and I will advise you of your future course.' The youth took the root, promising to do as she bade him. Before he lay down to sleep he carefully skinned the root as he had been bidden, and then ate the skin, putting the root aside. In his sleep, as the old woman had foretold, he had a strange and peculiar dream. He dreamt that he had arrived at the Shaman's house, and had been sent by him to perform three herculean tasks, which if he accomplished he was to have the Shaman's beautiful daughter to wife, but if he failed he was to be cast to a fierce and dreadful beast, which the Shaman kept in a den for the purpose of devouring the bodies of the young men who failed to accomplish his tasks. Next morning he related his dream to the old woman, who then told him the nature of his first task, adding that if he succeeded in accomplishing this he would receive help and advice from another source with regard to the others. 'You will have to clear a large tract of forest land in a given time; and so dense is the forest, and the time allowed to do the work so short, that you cannot possibly do it of yourself; but if you will be careful to follow my instructions you will be enabled to perform the task within the allotted time and outwit the Shaman. When he takes you to the field and asks if you will undertake the work, answer boldly, 'Yes, if you will supply me with a suitable tool.' He will at once consent to do this; then ask to see his mattocks. When they are placed before you laugh at him, and ask if he thinks you can use such children's tools as those. He will be surprised, and ask you what kind of tools you want. Request him then to have a mattock made for you that will take the strength of twenty men to lift. He will be astonished, but will do as you request.' 'But,' interrupted the youth, 'what shall I do with such an unwieldy instrument as that? I am not stronger than twenty men.' 'Be patient and listen,' replied the old woman. 'The root I gave you last night is a "magic" root. Eat a morsel of it now and test it.' The youth bit off a mouthful, and before he had finished chewing it he felt a strange power enter his body, and with it a desire to exercise his strength. 'Take up this log,' said the old woman, 'and swing it round your head.' The youth obeyed, and took up a log that required the strength of a dozen ordinary men to lift, and swung it round his head as if it had been a spear-haft. 'Now,' said the old woman, when he had cast the log to one side, 'you need not fear the weight of your heavy mattock; only if you desire the root to be effective you must give good heed to my instructions. You will be tempted to partake of the food from the Shaman's table before you set out to perform your task. This you must on no account do. Turn your back upon his breakfast and satisfy your appetite with the root I gave you. Eat it on an empty stomach and have confidence in its virtue, and you will successfully accomplish your labours.' The youth thanked the old woman for her good advice and the root, and, bidding her good day, continued on his way. On the following day he came to the residence of the great Shaman. As he approached the house the younger daughter of the Shaman saw him coming, and perceiving him to be a goodly, well-favoured youth, her heart went out to him, and she was moved with pity, knowing the evil that awaited him at her father's hands. When he arrived at the house the Shaman came and asked him what he could do for him. The young man answered that he sought to become a Shaman, and desired his aid and advice to that end. 'Very good,' said the Shaman, 'I am willing to help you on certain conditions. You must become my servant for a time, and must undertake to perform certain tasks which I will set you. If you succeed in accomplishing these I shall see that you are fitted to become a Shaman, and will initiate you into the mysteries of my profession, and will also bestow upon you one of my daughters for wife.' 'On these terms,' broke in the youth, 'I am willing to become your servant, and attempt the tasks you may set me.' 'Stay a while, my friend,' said the Shaman, 'you have heard but half the conditions. If you fail to accomplish either of your tasks you will be cast to the fierce beast in the den yonder,' and he pointed to a huge and fearful-looking creature which was penned up near the house, and which now roared horribly as the Shaman spoke. The sight of this ravening beast might have deterred a less determined man than this youth, but remembering his dream and the power which was his by virtue of the old woman's root, he again declared his eagerness to essay the tasks and enter upon his novitiate. 'Very good,' said the Shaman with a wicked smile, 'to-morrow morning you shall begin your work. Come and I will show you your first task.' And with that he led him to the forest. 'To-morrow before sunset you must clear and prepare for planting seventy "fathoms" square of this land,' said the Shaman when they had reached the timber. 'Very well,' replied the youth, to the Shaman's astonishment, who expected to hear him cry out and declare such a task to be impossible for any man ; 'I will do the work provided you supply me with proper tools.' 'There are plenty of mattocks in the house,' said the Shaman ; 'I will have them brought to you and you can choose your own.' When the tools were placed before the youth he laughed at the Shaman, as the old woman had bidden him, and said they were children's tools, and that he wanted a man's tool. 'What kind of mattock do you want ?' then exclaimed the Shaman, more astonished than ever at the manner of the young man. 'I will give you whatever tool you require.' 'Very well,' then said the youth, 'have a mattock made for me that will require the united strength of twenty men to move it, and I will clear your land for you.' The Shaman, marvelling much at the confident manner of the youth before him, promised that the tool should be ready for him at sunrise next morning. On the morrow the young man was up before daybreak. He went to the stream and plunged into the cold water ; he then exercised himself after the custom of the Indian youth of the old times, after which he made his breakfast of the *koakōē'la* root. This, not being very large, only served to whet his appetite ; and when the Shaman presently invited him to sit down to breakfast with himself and family, the savoury smell of the fish and venison sorely tempted him to comply, but remembering the admonition of the old woman he thrust aside his desire, turned his back upon the meal, and went forth to his task. He had no sooner left the house than he felt a rush of energy and strength to his body and limbs, and catching up the newly made mattock swung the huge implement with ease round and round his shoulders. Without loss of time he betook himself to the forest, and such was the marvellous power of the *koakōē'la* root that ere the sun had reached the zenith he had cleared the piece of land and felt little the worse for his task. He now returned to the house, and the Shaman, seeing him coming, wearing a bold and self-confident look, scarcely knew what to think; and when told that the work was done would not believe it till he had examined it with his own eyes. Finding the task really satisfactorily performed, a great hate now sprang up in his heart towards the youth, and he secretly determined to cut his life short, lest he should prove a future rival to himself and rob him of his influence and power. To this end he prepared a snare for him. Pretending to be well pleased at the manner in which he had performed his first task, he told the young man that he would not wait till he had accomplished the other tasks before giving him his daughter to wife, but would bestow her upon him that very day. The young man, nothing loth to possess so desirable a wife as one of the Shaman's daughters, asked which of the two was to be his wife. Said the Shaman, 'Choose for yourself, my son; you may have which you like.' The youth looked at the two young women, and to his surprise found them so exactly alike that he could not tell the one from the other, and was at a loss for the moment which to choose, till he caught the soft and yearning look in the eyes of the younger, whose heart he had unconsciously won, when he hesitated no longer, but chose her. 'Very well,' said the parent, 'I will prepare a house for you, and to-night you shall find both it and her ready for you.' Now the young woman's love for the youth made her suspect her father's motives, and feigning complete indifference for her future husband she sought to discover her parent's purposes. He, never suspecting that her feelings had been roused, or that she cared one jot for the youth, made no secret of his purpose. He had caused a deep hole to be made in the ground, just before the door of the chamber he had prepared for the newly wedded pair, at the bottom of which he had built a huge fire of charcoal, and over the top of which, on a level with the ground, he had placed a cunningly contrived door that revolved on a central pivot. This door was so evenly hung that it remained balanced by its own weight, effectually covering the hole and the fire beneath; but should one not familiar with the contrivance be unwary enough to place his foot on either half of the door, it would immediately give way beneath and precipitate him into the yawning furnace below, from which there was no possible escape. This was the bridal couch the jealous Shaman prepared for his unsuspecting son-in-law, and the latter would doubtless have thus miserably ended his life but for the love and warning of his bride. Having ascertained that her father entertained no doubts that his trap would successfully dispose of her lover, and that they would be left in peace, at least for the night, if he succeeded in passing the death-trap, she took the opportunity, unobserved by her sister or parents, to acquaint her husband with the whole plot, telling him how to safely cross the door. He saw from this that his young wife's help was the aid the old woman had told him would be given him after he had performed the first task, and feeling that some friendly power was working for him, he awaited the approach of night without agitation or concern. When they had eaten their supper, and the young women had retired, the Shaman pointed out to the youth the apartment occupied by his bride, and left him to join her. As he approached the door he trod very carefully, trying the ground in front of him before he put his foot down. When he had got quite near the door he felt the ground give way beneath his advanced foot, and pressing upon it a little discerned the outlines of the trap-door; and putting his foot in the centre, as his wife had instructed him, he gave a leap and crossed the treacherous spot without harm, and the warm welcome of his bride soon made him forget the danger he had run in reaching her. Next morning, when the Shaman, according to his wont, aroused his family, he was greatly astonished to see the young man appear safe and sound from his daughter's quarters; but dissembling his feelings he bade him good morrow and hoped he was ready for his second task that day. 'O yes,' responded the youth, 'I am quite ready and eager.' When he had gone for his morning plunge and exercise, the father took the opportunity of warning his wife and daughters that they were on no account to give the youth any hints or advice. 'He has some powerful medicine,' added he, 'working in his behalf, or he could not have accomplished the task I set him yesterday or escape the trap I placed for him last night. If I do not destroy him I foresee he will outwit me and deprive me of my prestige and power.' He little suspected that his younger daughter had already revealed the nature of his second task he proposed to set him, and had conspired to outwit him and assist her husband. But so it was; for before they had risen that morning she had told him that her father would change herself and sister and mother into three beautiful speckled trout, so exactly alike that it would be impossible to tell one from another without assistance from the fish themselves. Said the young wife, 'I will wag my head from side to side as I swim about: by this means you will be able to distinguish me from the others when you are asked to point me out, without exciting my father's suspicions that I am helping you; for,' added she, 'the task that awaits you to-day is to point out which of the three fish is your wife. Be careful not to point me out at the very commencement of the trial. Pretend for a while to be in doubt, and declare the task to be impossible, and only when you have exhausted my father's patience make a real and final effort.' The young man promised to do as she had bidden him, and thanked her for her good advice.

All breakfast-time the Shaman was very merry and talked much, telling the youth how many young men had come to him to be initiated into the mysteries of Shamanism and had proved themselves unworthy, and had been cast to the beast and been devoured. The youth was not to be dismayed by the misfortunes of those who had tried before him and failed. Secure in the love and assistance of the Shaman's own daughter, and mindful of his dream, he maintained, to the Shaman's secret chagrin, the same self-confident air that he had worn on the previous day. As soon as the morning meal was over, the Shaman bade his daughters fetch a large basket-tub and fill it with water. As soon as they had done this he called the young man to him and said, 'Now you must essay your second task, and if you fail, notwithstanding your success of yesterday, I shall cast you to the beast.' Transforming his wife and two daughters therewith into three speckled trout, so exactly alike that it was impossible to detect the slightest difference between them, he cast them into the basket of water and bade the youth come near. After watching them for a moment he asked the young man which had the smallest tail. 'It is impossible to say,' replied the youth; 'they seem to me to be exactly of the same size.' 'Which has the largest head, then?' questioned the Shaman. 'I cannot say,' said the youth. 'Which has the finest fins?' 'They are all equally fine,' was the answer. And thus the Shaman questioned him upon all their points, always receiving a similar answer from the youth, as his wife had instructed him. The Shaman then put the real and final question: 'Which of the three is your wife, my youngest daughter?' 'Really, I don't think I can say,' pretended the youth; 'it seems impossible to determine.' 'Oh, but you must,' declared the Shaman, now so delighted that he could scarce hide it, 'or pay the forfeit.' And as he spoke he pointed to the beast, which roared horribly at the same moment. The young man then put forth his hand as if to point out the fish he thought his wife, but immediately withdrew it again with a show of doubt and hesitation. He repeated this manœuvre several times until the Shaman, losing patience and believing that the youth was now in his power, declared he must hesitate no longer, but make his choice and abide by the result. The youth then closely watched the three fish for a moment, and seeing one separate itself a little from the other two and shake its head vigorously, he quickly pointed to it and said, 'That one is my wife and your younger daughter.' As he uttered the words the three fish were transformed back to women again, and stepped out of the basket. The Shaman was so disappointed at the turn events had taken that he could scarcely hide his feelings, but making pretence, he congratulated the youth, declaring that one day he would become a very great Shaman if he were lucky enough to be successful in his third and final trial, which was fixed to take place on the morrow.

The next morning, before they rose, the young wife informed her husband that the task which awaited him for that day was a race with her father, who was so exceeding fleet of foot that no man had ever successfully competed with him. 'You cannot of yourself,' said she, 'hope to beat him—his medicine is too strong for that. I alone can aid you, and if you will place your trust and confidence in me I can promise you success. When you find my father gaining on you in the race and your strength failing, you must fix your eyes steadfastly upon my face, and you will then find yourself able to outrun him. Do not neglect my instructions, or ill will it be for both of us.' He thanked her for her help and advice, and made up his mind to do as she had told him if he found he was losing ground.

The Shaman presently called him aside and informed him that he must now prepare himself for the third and final trial, 'which,' said he, 'is a race with myself.' The youth prepared himself accordingly, and presently stood side by side with the Shaman, waiting for the moment to start. The three women had gone to the other end of the course to see the finish. The signal being given they started, and ran neck and neck for the greater part of the way. But as they approached the goal the Shaman began to make use of his medicine and leave the youth behind. The latter strove again and again to overtake the Shaman, but all his efforts were in vain: he found himself slipping farther and farther behind, and it was only when his strength began to fail him, and the Shaman was almost at the goal, that he recalled his wife's instructions. Quickly fixing his gaze upon her face, he felt in an instant a sudden rush of energy to his limbs as her eyes seemed to burn through his brain, and his feet seemed as if they had taken wings to themselves, for they now carried him along without any effort of his own, and landed him at the goal several yards in advance of his father-in-law, whose rage and disappointment were now so great that he could not speak for anger. But still he dissembled and acknowledged his son-in-law's victory, and forthwith undertook to initiate him into the mysteries of his profession if he would settle down with him and become his pupil. This the youth consented to do, being still wishful to become a Shaman. But the Shaman's daughter, his wife, was troubled in her mind, knowing that her parent would never spare her husband's life, but would continue to plot against him till he had destroyed him. So when night came, and she had an opportunity of conversing with him alone without arousing suspicion, she communicated her fears to him concerning his safety under her father's roof, and counselled immediate and secret flight to his own village and home. The youth assenting to her plan, they set out together that very night, making all the haste possible that they might be well advanced upon their journey before they were missed. In the morning, when the Shaman roused his family as usual, he was surprised to find his daughter and son-in-law absent, and as the day advanced, and there was no appearance of them, he became convinced that they had fled together from him. Said he to his wife, 'Now I understand where his assistance came from. Our daughter has betrayed me, and now run away with her husband. But they shall not escape me thus. I will after them and bring them back.' And as he spoke he sought for their trail, which, as they had made no attempt to hide it, trusting to their start, he soon discovered and hastened to follow up. With the aid of his Shamanistic powers he was able to travel much faster than they; and he had not pursued them long when the runaway daughter cried out to her husband: 'My father is pursuing us and is close upon us; I know it by the trembling in my body. Now stay a moment, and I will use my medicine.' Forthwith she transformed her husband into a little sugar-tree[1] where he stood, and herself into another close by over against him; and where a moment before two human beings had stood there now grew in their place two old and partly decayed sugar-trees. The transformation had scarcely been effected when the Shaman came up. When he reached the sugar-trees he found the trail suddenly stop, and look and search as he would he could find no continuation of it. Casting his eyes around him, he presently perceived that the trail ended at the sugar-trees, so having the power to converse with trees he addressed them, and asked if they had seen a young man and woman pass that way. The sugar-tree that was his daughter replied that no one had passed by that way since they had grown there. 'How long have you been growing here?' questioned the Shaman. 'Oh, we are very old,' said the daughter. 'Cannot you see how decayed we have become?' Never suspecting that he was conversing with his daughter, after searching all round again and finding no clue to follow, he gave up the pursuit and turned back homewards again. When he was out of sight the daughter resumed her proper form, transforming at the same time her husband to his own shape, and both continued on their way as fast as they could. The Shaman, on reaching his home, was asked by his wife why he had returned alone. He related his experience, telling her that the trail was clear and easy till he came to the sugar-trees, and then it ceased suddenly, and no trace of the fugitives could be found beyond. 'You silly man,' said the wife, 'don't you see that the sugar-trees were your daughter and her husband? You know that she possesses the "power" as well as you. Hasten back after them, and don't be fooled by her again.' Perceiving that she must be right, he started after the run-

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[1] The 'sugar-tree,' called by the natives *qwa'hit*, is a species of pine—the white pine of the district, as far as I could gather from my informant's description of it. When the tree is first tapped the sap is sweet and not unpalatable, but after a day's exposure to the atmosphere it becomes disagreeable and unpleasant to the taste.

aways once more, and presently arrived at the spot where the sugar-trees had stood, which were now nowhere to be seen. Desperately angry at finding he had been outwitted again by his own daughter, as his wife had suggested, and perceiving the trail broad and clear before him, he hastened to overtake them once more. It was not long after this that the young wife cried out to her husband, 'My father is pursuing us again, and will speedily overtake us and seize us if I do not do something to prevent it. I know it by the trembling in my body.' Immediately she set to work to gather two bundles of brushwood. This done, she transformed them into two wretched, broken-down huts, and herself and husband into a pair of decrepit and grey-headed old people. She had no sooner accomplished this second metamorphosis than her father arrived, and finding the trail stopped short here, he accosted the old couple and asked them if they had seen two young people pass that way. The daughter answered for both again, and replied that no one had passed that way for many years. 'Have you been living here long?' questioned the Shaman. 'We were young and active when we first settled here,' answered the daughter; 'now you can see for yourself that we are old and grey.' 'It is strange,' replied the Shaman, 'here are their tracks to this very spot, and no sign of them beyond. Perhaps they have hidden themselves in your houses.' 'You are welcome to look,' said the woman, 'but I am sure they are not there.' The Shaman then made a close search of both hovels, but found no trace of those whom he sought; and after a fruitless effort to discover the trail beyond the huts gave up the search and returned home once more. As before, no sooner was he gone than the pair, resuming their proper forms, started off again on their journey without delay. When the Shaman arrived home he related his second experience to his wife, who laughed at him again for not perceiving in the old pair another ruse of his daughter's. 'The old man and woman were your daughter and her husband without doubt. Return quickly and you will still secure them.' The Shaman set out yet a third time after the runaways, and coming to the spot where the cottages had stood a little while before discovered nothing there but two heaps of brushwood, beyond which he now clearly discerned the tracks of the fugitives. Taking up the trail again he hurried after them. As he was about to come up with them the young woman cried out, 'I am all in a tremble again: my father is close upon us. I must use my power once again, and if we succeed in deceiving him this time he will molest us no further.' And with that she spat upon the ground and the spittle became at once a lake. She then transformed herself and husband into a pair of mallard ducks, and entering the water bade her husband follow her. They had been in the water but a few moments when the Shaman came up, and finding the trail lead into the water he stopped and looked about him. Understanding the language of birds he now accosted the ducks and asked them if they had seen a young man and woman cross the lake. The daughter, answering for both, as she alone knew the language of birds, replied shortly that they had not. The Shaman then requested them to swim over to the other side of the lake and see if they could discover any tracks leading out of the water. Said the female duck 'Go, and look for yourself; we cannot wait upon you.' The Shaman, though by this time weary and footsore, dragged himself round to the other side of the lake, but perceiving no footmarks there concluded that the fugitives had drowned themselves, and presently returned home and gave up the chase. The young people, starting on their way once more, shortly came near the young man's home. As they approached the village he said to his wife, 'Now, I want you to remain here in the wood while I go forward and prepare my mother and father for your arrival.' She demurred to this, asking why she could not accompany him. 'Oh! that would never do,' said he; 'my parents must have time to prepare for your reception. I will only go forward and inform them that I am bringing home a wife and then return for you.' She continued to demur to the arrangement. 'Have you any brothers?' questioned she presently. 'No,' he answered, 'I have no brothers, only two sisters.' 'Promise me, then,' said she, 'that if I let you go you will not let your family kiss you before you return to me.' 'Why do you wish me to make that promise?' asked he. 'Because if your sisters or your father and mother kiss you before you come back to me you will forget all about me and will not return, but leave me here all alone in the woods.' The young man, who was very fond of his wife, declared that was impossible; but willing to gratify her he readily promised to do as she requested, and bidding her have no fear of his speedy return he left her there and entered the village. He had not got far before his two sisters perceived him coming, and rushed in to inform their parents, who no sooner heard of his arrival than they ran out to meet him, followed by their two daughters. When they got near they embraced him fondly, and he, in the pleasure of meeting them again, forgot all about his promise to his wife, and suffered himself to be kissed by them. And as they led him into the house all recollection of his young wife anxiously waiting for him at the edge of the forest left his mind, and he forgot her as completely as if she had never existed. When he had been absent some hours and night began to come on without any sign of him, she began to fear that he had broken his promise; and as day after day went by she became certain of the fact. So she built herself a little house on the edge of the village close to the roadway, and at the back of it she added a small lean-to. When she had done this she took a lump of clay, and after kneading it she made from it two clay birds. She next transformed the clay effigies into real live birds, and placed them in the lean-to at the back of her house. Several days had now elapsed since she had lost her husband, who, having completely forgotten that he had ever been married, at the suggestion of his parents began to look round for a wife. Having chosen a maiden that suited his fancy, he asked his parents to take the necessary steps to bring about the marriage. Negotiations were opened, presents accepted and exchanged, and a day was fixed for the ceremony. The father of the bride-elect was desirous of marking the event in a very conspicuous manner; so he gave notice that a great feast would be held in honour of the occasion, and sent out invitations far and wide. He also invited all those who possessed any curious or interesting things to come and exhibit them, being determined to make the feast a memorable event. The forsaken young wife at the edge of the village heard the news of the approaching marriage of her husband in some mysterious way, and laid her plans to prevent it accordingly. A day or two before the feast a young man chanced to return from the forest, whither he had gone to gather roots for the feast, by the path that led past her hut. As he passed the door she came out and asked him what he had in his basket. 'They are roots,' answered he, 'that I have been gathering for the feast.' 'Ah!' said she, 'that is just what I want for my tame birds. I will buy them from you.' 'But I cannot sell them, returned he; 'they are for the feast. But let me take your birds instead;

we want all the meat we can get.' 'No, I do not want to part with my birds,' replied she; 'but come in awhile and talk to me.' The youth, perceiving her to be a very agreeable and pleasing young woman, nothing loth, acceded to her request, and entered the hut with her. She now pretended to make love to him, and he, falling into the snare, desired to spend the night at her house This was what she desired for her purpose, and bade him welcome. When they were about to retire for the night, and he had disrobed himself, a sudden commotion took place among the birds in the lean-to. 'Oh!' cried she, 'I have forgotten to place my pets on their perch. Do go out and set them on the perch for me.' He wanted her to leave them as they were, but she insisted that he should first set them on the perch before he lay down. Thinking it best to humour her, he went out, undressed as he was, and tried to set the birds on the perch; but no sooner had he placed one on it than the other tumbled off again. When he had spent a little time thus to no purpose, he cried out to her that they kept falling off the perch, and that he must leave them as they were. But this she would not hear of; he must set them on the perch or he could not return to her. Being anxious not to vex her, this he again tried to do. But so contrary and perverse were the birds that they fell off as fast as he put them on. As he now began to feel cold in his undressed state, he begged again and again that she would allow him to leave them and return to her; but each time she made his return conditional upon his permanently setting the birds on the perch, and laughed at him for his stupidity in not being able to do so simple a thing. But do what he would the birds slid off their perch as quickly as he placed them on it, and dawn began to appear before he at last succeeded in getting them to remain there. Glad that at length he might now return to her, he eagerly rushed into the house as the first beams of the sun shot across the sky. He found the young woman up and dressed, and when he would fain have spent a little while with her in amorous dalliance she coldly bade him hasten away before the village was astir, and he was seen leaving her house by the elders, thus bringing disgrace upon himself and her. This argument appealed to him so strongly that he forthwith caught up his clothes, and without stopping to put them on ran from the hut to the village, and got home before he had been seen by any one. In his haste he had left his basket of roots behind him, which was just what the Shaman's daughter had planned for. But such an experience as the youth had gone through could not be kept long to himself; and before the day was over he had related it to several of his comrades, one of whom, fired by his account of her attractions and beauty, determined to pay the young woman a visit himself that same evening. 'You will not succeed,' said the first youth, 'any better than I did; she is not so easily won as you think.' 'Oh, won't I?' retorted the other; 'I will carry some string with me and tie the creatures to their perch.' So when evening arrived he took some string in his clothes and a basket on his arm with some roots in it, and passed by the young wife's house, as his comrade had done. She came to the door and asked what he had in the basket. 'I am taking home some roots for the feast to-morrow,' said he. 'Oh, sell them to me, won't you?' requested she; 'I want some roots for my birds.' 'What birds have you got?' questioned he; 'we want all the animals we can get for the feast to-morrow. Won't you exchange them for my roots?' 'I will see,' said she. 'Come in and show me your roots.' He entered the house with her, when she speedily bewitched him with her charms and beauty, and made him ready and willing to do whatever she bade him. He said he would like to spend the night at her house. To this she pretended to assent, and when he was about to lie down, having disrobed himself for the night, a disturbance taking place as before in the bird-house, she begged him to slip out quickly and set her birds on the perch for her, declaring they would give her no peace if they were not placed on the perch. Thinking himself a match for the stupidity or perversity of the birds, he made no demur to this, and as he thought he would be returning in a moment or so he did not trouble to clothe himself, but went just as he stood. He experienced just the same difficulty as his comrade had done the previous night. The birds would not stay on the perch; and when he tried to tie them with the thongs he had brought he found that the task was not so easy as he had imagined. Again and again he thought he had securely fastened them, but just as he turned to leave the birds slipped each time from the perch, and set up such a cackling that he was fain to try again. At last he succeeded in getting them to remain on the perch, but by this time the morning was breaking, and as he entered the hut the sun showed himself on the edge of the horizon, and he knew he could safely linger no longer. Moreover, the young woman was now cold and distant to him, and repulsed his advances, bidding him return to the village before he brought disgrace upon them both. Resolving that on his next visit to her he would not be so easily fooled, he caught up his clothes and ran hastily into the village. The talk of the young men among themselves soon noised abroad the fact that the stranger on the edge of the village possessed a pair of remarkable birds. This presently reaching the ears of the father of the bride-elect, he sent a special messenger to request the young woman to be present at the feast and exhibit her odd pets. This was just what she had all along been working for, and she readily consented to be present and show her birds. Accordingly she came, and stood among those who had some tricks or exhibitions to make; and when they had gone through their parts she came forward and placed her two birds on a mat in front of her husband and the chief guests. Her husband scarcely noticed her, and certainly no thought of his relation to her entered his mind. When she had set the birds down she took from a basket at her side some of the roots she had secured from the youths and threw them to the birds. The male bird instantly gobbled them all up, driving the female away; at which, to the great astonishment of all, the hen bird began to speak in human language and upbraid and reproach her greedy spouse for his selfishness and gluttony. Said she, 'Why won't you let me eat of the roots? I did not treat you like that. Don't you remember how kind I was to you when my father would have killed you by letting you walk into the hidden fire? And this is the return you make to me! I did not think you could be so unkind and forgetful.' Everybody wondered what the bird meant by such strange words. When it ceased speaking the young Shaman was seen to look perplexed and puzzled, as if he were trying to understand something that was not yet clear to his mind. The young woman now threw the birds some more roots, whereupon the male bird did as before, drove the other away, and ate the roots himself. Again the hen bird reproached him, saying, 'How can you treat me so unkindly? Don't you remember what I did for you when my father changed me and my sister and mother into trout and you had to declare which fish was your wife or be thrown to the fierce beast and devoured?' Her words, however, made no impression upon the cock, who each time the young woman threw them roots drove his mate off and ate them all up himself. But as the hen recalled to the memory of the selfish cock her deeds of past kindness one after the other, which corresponded exactly to the acts of the young Shaman's lately forsaken wife, his memory became clearer and clearer until in the last scene of this little domestic drama of the birds, when the hen said, 'Didn't I tell you that you would forget and forsake me if you allowed your sisters and parents to kiss you before you returned to me?' the full memory of the past suddenly rushed to his mind, and in the young woman before him exhibiting her birds he recognised his forsaken and forgotten wife. He sprang up with a great cry and embraced her before the whole assembly, calling her by all the dear names he could think of. His action caused great astonishment to those present, but he explained that the stranger was his wife, and told them how he had won and lost her. Even the bride-elect and her relations could not complain, and he was permitted to withdraw from the proposed marriage. Compensation in the form of presents was made to the father of the disappointed young woman who had so strangely been robbed of her prospective husband, and another suitor was found for her.

Story of the Adventures of Snikīā'p[1] *the Coyote, and his Son N'tlikcu'mtum.*

In the old, old days Snikīā'p lived all alone by himself. He had neither wife nor children. He much desired a son, and being a medicine-man of great power it was not difficult for him to obtain his desire. One day he got a lump of pitch,[2] and, working it in his hands for a while, fashioned it in the form of a human being. Having done this he laid it on the ground and stepped over it three times, saying at the same time, 'Rise up.' After the third time the effigy rose upon its feet and became a living being. He now bids his son to be exceedingly careful never to go where it was hot. 'Harm will come to you, my son,' said he, 'if you do. When the weather is very warm you must go and swim in the river, and when it is cool you can safely come home again.' The boy, who steadily grows, followed his father's instructions carefully for a time; but after a while he gets tired of passing the best part of the day in the water. So one day he finds a large flat stone on the bank and lies down upon it in the sun. The sun's heat soon begins to act upon him, and in a short time he melts away. When evening came and he did not return as usual, Snikīā'p goes out to look for him, and presently discovers the melted pitch on the ground. He now determines to create another son for himself who

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[1] Dr. G. M. Dawson has recorded a brief account of the doings of Snikīā'p the Coyote, from notes supplied him by Mr. J. W. Mackay, in his 'Notes on the Shuswap People of British Columbia,' *Trans. Roy. Soc. Canada*, sect. ii. 1891. According to my informant, Chief Mischelle, of Lytton, an exceptionally intelligent and well-informed man, the name should be written as I have transliterated it. I have heard it called Shnikīā'p by the Indians, and also by Mischelle himself once. In the mouth of the Indians of this region the dental sibilant *s* commonly changes into the corresponding palatal *sh*, the speakers being apparently unaware of the change themselves. According to Dr. Dawson the Shuswaps of Kamloops call this being *Skilā'p*. Snikīā'p is the N'tlaka'pamuQ for Coyote. The Coyote always goes by this name in the stories (see below). This *Skilā'p*, or Snikīā'p, is frequently confused in the stories with Skoē'qt-koatlt, the Culture-hero of the N'tlaka'pamuQ. See the writer's account of the doings of this hero in the *Transactions* of the English Folklore Society for this year.

[2] Dr. Dawson has also recorded a brief account of a story similar in part to this in his 'Notes,' only in the Shuswap version it is a lonely grizzly woman who creates a son in this way for herself, and the after incidents are also different.

should not be subject to the disadvantages under which the other had laboured. As he was thinking out of what material he should make him this time, his eyes fell upon a jade boulder lying on the bank. 'Oh!' said he, 'that is a fine material. I will make a jade son.' So he took the jade boulder and fashioned it into the form of a boy, going through the same ceremony of stepping over it three times as before. When the stone son was come to life he admonished him never on any account to go near the water or try to swim in the river, or he would surely suffer for it. The jade-lad observed his commands for some time, but being very hot one day, and the water looking cool and tempting, he forgot his father's injunctions and plunged into the river to bathe. Immediately he sank to the bottom and was drowned. When Snikīā'p learnt that his stone son had disobeyed his injunctions and was drowned, he made yet another son for himself. On this occasion he fashioned him from the fibrous matter of certain vegetables and shrubs. He observed the same ceremonies as before. This time the boy could do anything or go anywhere without harm. When the boy had grown into a big lad, Snikīā'p proposed that they should go and pay a visit to a great tribe some way off. The people of this place were celebrated for their skill and power in hunting and fishing, and in wood splitting. Said Snikīā'p to his son, 'My medicine informs me that they will try to kill us by means of a great conflagration they will bring about. You must therefore practise jumping until you are a great jumper. They will try to kill you first in another way. They will give you a fine-looking woman for wife, and also a spear, and send you to spear salmon. When you go to the river you will see salmon with hair on them, and painted salmon, and animal salmon with legs. Be careful not to spear any of these. Spear a good eating salmon and hold this rush in your hand all the time,' and Snikīā'p gave the lad a magic rush. 'When you have speared your salmon,' he continued, 'hold on tight to your spear, and you will be pulled into the water. Don't be alarmed at this; you will not drown. As soon as you are in the water open the rush I have given you with your fingers and get inside of it. You will find that you can do this, and you will then float down the river. In a little while you will drift to the bank. Get out then, and you will see the salmon again. Use your spear again when a good salmon passes you and spear two. Take these home with you. When you arrive you will find them making preparations to kill me. When they see you they will desist.'

When Snikīā'p and his son arrived at the village of this tribe, everything happened as Snikīā'p had foretold. The boy followed his father's instructions, doing exactly what he had told him. On getting back with the fish he finds the people about to kill his father, not expecting his return, thinking he would fall into the snare they had set for him and be drowned. When they see him approaching, they desist from their attempt to kill his father and propose that they should all go hunting. This they do; and when they are out they fire the bush in several places, so that Snikīā'p and his son are surrounded by a great ring of fire. They are both much burnt and scorched, and only manage to escape with their lives by taking immense leaps over the burning grass and timber. The fire has spread everywhere and no spot is safe. 'We must find a trail,' said Snikīā'p, 'or we shall be lost.' After jumping about a good deal they at last come out upon a broad trail. They lie down on this with their faces to the ground, and the fire passes by them, having nothing to feed upon in the beaten path. But they were much scorched by the heat, and the

Coyote has ever since worn a yellow skin in consequence. After a time they get up and follow the trail, and presently come upon a strange village, where the people are kind and hospitable. The son now marries two wives, the daughter of the eagle and the daughter of the duck. The first had red hair and a red face, and the other had light hair and a white face. The youth now travels about a good deal; he is also a successful hunter. He grows rich and becomes the possessor of many shell beads [1] (Stlak′), of a species of the dentalidæ, and fine clothes. A son is born to him by his eagle wife. One day he goes out hunting with his father and his wives and child. Since he has been married his father, who now desires a wife, has envied him very much and cast longing eyes towards his daughters-in-law. At night they camp out, and the old man kindles a fire of cedar wood. This, after the manner of cedar wood, shot out so many sparks that the eagle-wife drew back from the fire to escape the sparks which fell upon her dress. The duck-wife, on the contrary, sat on, only pulling up her legs. In sitting thus she exposed the lower part of her body and legs to her father-in-law, Snikīā′p. From this time he schemed to deprive his son of his wives and take them for himself. He therefore climbs a tree, and in its topmost branches builds a bird's nest, defæcates in it, and transforms the excrement into young eagles. This he did on the second day of the hunting, when his son was absent. He had remained at the camp for the purpose. When the son returns in the evening he hears the cries of the eaglets and looks round to discover the nest. Snikīā′p now comes forward and says, 'I discovered an eagle's nest in this tall fir to-day, and by the sound of the birds they must be almost ready to fly. If I were you I should climb the tree and get them. Eagle's feathers would look well with your other ornaments.' Now, as eagle's feathers were a great prize, not easy to get, the youth determined to follow his father's advice and climb the tree and secure the young birds before they flew away. The crafty father was not only desirous of securing his son's wives for himself, but also his handsome robes, and so when his son would have climbed the tree as he stood in his clothes he suggested that he should first take them off and leave them at the foot of the tree for fear of injuring them. The son, suspecting no guile, did so, and climbed the tree naked. When the son had climbed a good way up the tree the father began to draw and distort his face, screwing up first one eye and then the other. Thereupon the tree began to grow up—up it went into the clouds, carrying the climber with it. Presently, when the point shot through the clouds, they closed upon it like a vice and held it fast. Meanwhile the son had reached the nest; but when he got there, instead of young eagles, he finds only human excrement. He now seeks to return, but finds his way down the tree barred by the clouds. He cannot get down. He now perceives that his father has duped him, and he sits down and cries.[2] Presently he gets up and walks forward. He continues walking all the rest of that day till night comes on. He now feels cold, for he has no clothes on, but he lies down and covers his body as best he may with his long hair. The next day, and for several following days, he walks on till he hears a sound of knocking. He now looks about him, and the smell of

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[1] My informant told me that the natives used to get these shells from the Okanagan Lakes, and not from the coast.

[2] In the stories of the Indians men are often found to cry. Crying on the part of a man seems not to have been regarded as unmanly.

smoke strikes on his nostrils. Presently he spies a little framehouse covered with mats. When he gets near he peeps in and sees there two old women who are both blind. He now perceives that the knocking proceeds from them. They are pounding up fir branches for food. One of them presently gathers up the pulp and passes a portion of it to the other. The youth intercepts the food and eats it himself. The old woman who should have got it now begins to grumble at her sister for not giving her a share of the food. 'I did give you your share,' retorted the other. 'I put it into your hand. I felt you take it.' The other declared she hadn't got it. 'Well, here's some more. Hold out your hand and be careful to take it this time.' The other held out her hand, but the young man intercepted the food again, and ate it himself. The old woman who was being thus robbed now began to get angry, and upbraided her sister for selfishly keeping all the food for herself. The other defended herself, and declared she had passed the food and felt her take it. 'Now, give me your hand once more and let me put it in the palm of it,' said she. Again did the youth seize the food, and the two old women now began to revile each other. Presently one of them began sniffing and smelling, as if she scented something strange. Said she, 'I smell N'tlikcu'mtum.'[1] 'How do you know it is N'tlikcu'mtum?' said the other; 'you have never seen him.' 'Well,' answered the first, 'there's nobody but ourselves and the spider and his wife in this country. They are not here, and you say you didn't get the food I put into somebody's hand, so it must be N'tlikcu'mtum.' The youth now reveals himself and speaks to the old women. He chides them for quarrelling, but as they have done him no great harm, only called him N'tlikcu'mtum, he will not put an end to them outright, but will transform them into something useful. Taking one of them by the nose, he said, 'You will be good meat for the hunter when he is far from home and bigger game is scarce,' and therewith threw her to one side of him and she became a willow-grouse. He then took hold of the other in the same way and threw her into a 'sugar-tree,'[2] and she straightway became a black-grouse, or tcuk-tcukt,[3] commonly known as the 'booby-grouse.' 'You will be of service now too,' said he, 'and hunters will easily snare you and pull you off the branches by noosing you. You will both of you now be much happier because you can both see to gather and eat your food when you are hungry.' Thus were the willow- and black-grouse brought into being. He now proceeds on his way, and seeing some pretty flowers growing by the side he plucked one. It came up by the root in his hand, leaving a small hole in the ground. Now, as the crust of this cloudland earth was very thin, this hole went right through to the other side and let the wind up. It rushed through with some force, and he put his foot over the hole to stop it up. From this point he travelled on, still in his naked state, till he came to some forest land, the sight of which much cheered him. Presently he sees some smoke rising in the air. He hastens in its direction, hoping to find somebody who will help him. On getting nearer he perceives a keekwilee-house before him. He approaches it quietly and peers down the smoke-hole, and sees an old man sitting within as naked as himself, engaged in

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[1] This term has reference to the dirty trick played upon him by his father. It is the name by which he is known from this time forward. I was unable to obtain its exact signification, but it is connected with the eagle-nest incident.

[2] See note above on this tree.

[3] Tcuk-tcukt means tame, and refers to the tameness of these birds.

rolling Spa'tzin (*Asclepias speciosa*) on his thigh into rope.[1] This old man was Skā'kit, the Spider, whose home is in the clouds. On seeing the shadow caused by the youth he looked up and perceived him. As soon as his eyes fell upon him he began to weep and lament. 'O dear wife,' said he, 'here is our grandson all naked and cold. Bring some blankets and skins for him.' To the youth he cried out, 'Come down, dear grandson; I am so sorry for you. I know how badly you have been treated by your father.' The youth descends, and they cover him with blankets and make him lie down by the fire and give him food to eat. Next morning the grandson rises early and goes out to bathe in the stream. As he leaves he sees his grandfather, Skā'kit, busily spinning the Spa'tzin grass into rope, coils of which lay about the house. After some days had elapsed, and he had recovered from the fatigues of his long journey, he began to grow weary of doing nothing besides watching his grandfather spin Spa'tzin into rope. So he said to his grandparents, 'Have you any game in this country? I should like to go hunting.' 'We always snare our game here,' said the grandfather. 'I never shoot, although I have an arrow.' 'Give me yon arrow, grandfather; I am a great hunter and I will shoot you lots of deer.' Skā'kit gave him the arrow, and thereafter he went out hunting every day. One day, as he was leaving, he said to his grandfather, 'Why do you spin so much Spa'tzin? You are always making rope; what do you want so much for?' 'It is for your sake I spin so much,' responded the Spider. 'I am going to help you get back to your own country again.' Said the youth, 'I am happy here with you; I don't wish to leave you.' 'That is quite right and proper for you to desire to stay with us,' said Skā'kit; 'but this is no country for you. For me it does not matter much where I live. I can go where I want to. I can just stick my thread on anywhere and climb up or down as I wish, or let the wind carry me where it will. But you can't do this, you see, and you ought to return to your eagle-wife and little son. They want you very much, and are grieving over your absence. I shall soon have enough rope now for my purpose.' The youth said no more, but the next time he went out he plucked four hairs from the lower part of his abdomen and threw them on the ground. Immediately three or four acres of the land adjoining the stream became covered with fine Spa'tzin grass. When he returned home he asked his grandfather where he got his supplies of Spa'tzin from. 'Oh, we have to go a long way to get it,' answered he; 'it does not grow hereabout.' 'That's odd,' said the youth; 'I certainly thought I saw a fine tract of it just beyond the stream. When you go down to the stream next, just see if I am not right.' Skā'kit went down to the stream shortly after, and found the grass growing there as his grandson had said, and as it was unusually fine and long he now soon finished his rope. When this was done he bade his wife bring out the goat-hair blankets she had woven. The grandmother fetched out four dozen of these. 'Now bring the dried meat and fat,' said Skā'kit. And she brought out four dozen prime pieces. He then told her to get the cradle-basket she had made for the occasion. When all lay before the Spider he said, 'The pack will be too big; we must make it smaller. Shut your eyes, both of you, and don't open them till I tell you.' They did so. He then closed his own, and waving his

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[1] *Spa'tzin* is the *Asclepias* or great milkweed, yielding a fibre grass from which the natives of this region make all their fish-nets, lines, &c. It grows sometimes three or four feet long, and is then highly prized. It has given the name to Spatzum Station on the Canadian Pacific Railway.

hand over the blankets and meat the four dozen of each was reduced apparently to two dozen each. 'It is still too big,' said he. 'Shut your eyes again and I will make it smaller still.' He did the same as before, and the two dozen blankets and pieces of meat were reduced to the compass of two of each kind. 'Now,' said Spider to his grandson, 'I will tell you what we intend to do. We are going to put you and your pack in this cradle, and cover it up and let you down through a hole by the Spa'tzin ropes to your own country again. But you must be careful to heed my instructions and do exactly what you are told, and then all will go well with you. Between us and your country are three different zones or lands through which you must pass to reach your own. The first of these is the land where we now are. This is Cloudland. After that comes Water-land. That is where the rain comes from. Next to that is Fog- or Mist-land. After that comes the Earth, your country. Now when we let you down from this place, after you have descended some distance you will feel the basket stop. You must on no account get up or look about you. Lie down in your basket and rock it from side to side. In a little time you will break through the obstruction and descend again. This will occur in your descent four times. Do as I have told you each time. After the fourth stoppage you will find that you descend no more. Open your basket then and get out, and you will find yourself in your own country. When you get out pull the rope four times, and I shall then know you have landed all right, and we will pull up the basket again. Now get into the basket and lie down, and we will cover you up. Take this sword with you,' continued he, 'as a present;' and the grandfather gave him a long stone sword. The youth now got into the basket, and when they had covered him up the old man lifted up a large stone that lay at the base of the ladder and disclosed a deep hole. Down this Skā'kit and his wife, standing on either side of the hole, let the basket containing N'tlikcu'mtum and his presents by the Spa'tzin rope. When the basket had descended about a half-score feet it stopped, being buoyed up by the resistance of the wind that blew up through the hole. Finding the basket would not descend, notwithstanding the rocking of N'tlikcu'mtum, Skā'kit bade his wife stoop over the hole and make the basket heavier. The old woman thereupon squatted down over the hole and scratched her thigh and leg till the blood ran freely and dropped down upon the basket cover, but before it reached the basket it was changed into big flakes of snow. This so weighted the basket that it was able to overcome the resistance of the wind and descend again. Skā'kit and his wife now commenced to dance and sing as they lowered the basket. The song was a repetition of the following term, tzukā'-thīꞯa, thus uttered: tzukā'-thī-ī-ī-ī-ī-ī-ꞯa, tzukā'-thī-ī-ī-ī-ī-ī-ī-ꞯa, &c.

In the meantime the youth experienced the stoppages his grandfather had warned him of, and each time he felt the basket stop he rolled it from side to side as he had been instructed. After the fourth time, finding the basket remained stationary, he threw open the lid, and on looking out found himself in a fine country. So he steps out and perceives that the basket had landed on a large flat stone, close by what is now known as Lytton Creek.[1] He now pulled the rope four times in succession, and the basket is presently withdrawn to the upper regions again. He now takes

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[1] The old Indians point out a stone near the creek which they believe is the stone mentioned in the story.

up his pack, but finds it and the big stone sword rather much to carry at once. He decides to leave his sword there where he descended and get it some other time. He thrusts it into the trunk of a tree that grew near the spot to hide it, where, as the old Indians believe, it may be seen to this day in the form of a peculiar knot that traverses the whole width of the trunk. On looking about him he now sees tracks of many people, as if a large party had passed that way. These he follows, and presently perceives at some distance before him two old women who are swinging fir branches from side to side of them as they proceed along. He wonders why they are doing this, and on overtaking them questions them about it. They tell him they do it to mark their sympathy for a very sad and disconsolate young widow who is a little way ahead of them. 'Why is she so disconsolate?' asks he. They answer: 'She mourns continually for her young husband who has been evilly treated by his father, who sent him into Cloudland, from which he cannot return.' 'Oh yes, he can, and has!' said he. 'I am the young woman's husband, and I have just descended by the help of my grandfather, Skā′kit. Look at me and you will see for yourselves.' 'We can't see you,' said the old women. 'Why?' said he. 'Are you blind?' 'No,' answered they, 'but we can't see you.' 'Look on your right and tell me what you see there.' 'We can see Cīa′kūt' (Thompson River), said they. 'Tell me now, what do you see on your left?' then demanded he. Said they, 'We see N'toktī′auk' (Fraser River). 'Yes, you can see,' said he. 'Now look at me again.' And with that he waved his hand before their eyes and became immediately visible to them, and they knew him. Then said he to them, 'You did wrong to walk as you did; I must punish you. But as you did it out of sympathy for my wife your punishment shall not be severe.' He thereupon transformed them into maggots, and then proceeded to overtake his first wife. As he approaches, his little son, who is sitting on his mother's shoulder, looks back and sees him coming. He cries out, 'Papa! papa!' This makes his mother's heart ache afresh, and she chides him and bids him be quiet. But the child still cries out in a joyful tone, 'Papa!' The mother gets angry and strikes the child with a stick she is carrying in her hand. Still the child calls again, 'Papa!' By this time the father is at the mother's side, and takes her by the arm. She does not look round to see who it is, but cries out in a sad, weary way, 'Oh, let me alone! let me alone! Why are you always worrying me?' 'Look up,' said the husband; 'I am your husband come back to you!' Recognising his voice she looks up and embraces him warmly, and they both cry for joy at meeting again. They sit down together, and the father takes his son in his arms and plays with him. They have cried and rubbed their faces so much that they are quite smeared and dirty. To remove these stains he causes by his power a spring to bubble up where they sat. At this they wash themselves. This spring is said to be the one close by the trail that leads from Lytton to Britta′nī, a summer resort of the Lytton tribe, about four or five miles north of the old camp site, lying in a very beautiful little valley between the Thompson and the Fraser. On this occasion it would appear the whole tribe had gone to the valley. While they thus sat talking and enjoying each other's company the larger of the two maggots, into which the two old women had been turned, passed by. They enjoin upon her strictly not to reveal his presence to any one in the camp. She is only to tell their slave, Little Crow (CloQ′), to build their tent somewhat apart from the rest. The slave did as she was told, and aroused the other slave, Big Crow's (Ca'haQ) curiosity. Ca'haQ was servant to the second wife, who now lived with Snikīā'p, her father-in-law.

N'tlikcu'mtum and his faithful wife did not come into camp till it was dark, and no one was aware of the former's presence. After they had retired Big Crow crept up to the tent to listen. Now the young wife had been in the habit of crying and mourning every night for the loss of her husband. Big Crow was aware of this, and wondered why the young wife was not crying as usual. She peeped into the tent and noticed a fine white blanket, which seemed to cover two persons. This further roused her curiosity, and she ventured to enter the tent very softly. But the woman heard her, and looked up and said, 'What do you want?' Ca'haQ answered: 'Oh, I came in to see how you were.' 'I am all right,' responded she in a happy tone of voice, wholly unlike her usual tones. This the Crow noticed at once, and asked, 'Is any one here with you to-night?' 'What makes you ask that question?' queried her mistress. Answered Crow: 'To judge by the sound of your voice you seem much happier than usual.' 'You are right, I am happier,' said the young wife; 'I have reason to be. My husband has come back to me.' The slave now began to cry for joy and sympathy. Said the young man, 'You must not cry like that. Come here to me.' Ca'haQ went over to the young man's side. The wife now asks her if she had had her supper, and, on finding she had not, gave the slave a good supper from the meat her husband had brought. The young man then said she might tell the people he had returned, but they were not to disturb him by visiting or coming near him that night. The Crow was delighted to be the bearer of such news, and soon communicated the fact of the young man's arrival to all the camp. Everybody expresses pleasure at the news, and they are all glad and desirous of seeing him and hearing of his adventures; but they respect his wishes, and leave him alone with his faithful wife and child for that night.

The father of the youth, among the rest, had heard of his son's return, and early next morning came in crying and snivelling. The son took no notice of him. That day he gave a great feast, to which everybody was invited. After they had eaten their fill of the store of meat and fat he had brought with him, he shared with them the blankets his grandmother had woven and packed up for him. He cut several in two so that all might have a share. The next day he went on to Britta'nī, and built there a large camp. He was now made a chief, and became a great man among them. One day, when he was out hunting with the others, the desire came into his heart to punish Snikīā'p, his father, for the deception he had played upon him. Next day he said to his father and the others, 'I shall go out alone to hunt to-day.' They agreed, and he went off alone. He presently shot a deer, and disembowelling it made a rope from the guts. This he then transformed into a woollen rope. He now placed the meat of the deer on his shoulders and returned towards home. When he reached the stream that crossed his path he took half of the meat and tied it with the rope he had made to a tree that overhung the brook. The rest of the meat he took on with him. In the evening he informed his father that he had left half of the deer's carcass suspended from a tree by the brook, and that he desired him to go for it in the morning. 'All right,' said the father. Accordingly next morning Snikīā'p set off to bring the meat home. As he left the son shouted out to him to be very careful of the rope the meat was tied with, as he prized it very much, and didn't want it lost or broken. The father promised to be very careful of it. He had no difficulty in finding the meat, which he took down from the tree and slung across his shoulders; but as he was crossing the stream the rope broke, and the meat and rope fell into the water together. The old man immediately jumped into the stream to secure the rope. He did not care so much about the meat. 'I must not let the rope be carried away,' said he, 'or my son will be grieved and angry.' So saying, he caught hold of it; but as he did so the current swept him off his legs, and he was carried, rope and all, down the rushing stream to the Thompson, and from thence into the Fraser and far down that river. He was stopped at last by a barrier or weir, which was built across the river near its mouth. As he approached the weir he transformed himself into a small smooth board. Now this weir was held by four witch sisters.[1] As Snikīā'p floated towards the barrier in the form of a piece of wood, the youngest of the sisters, who had gone to see if any drift wood had lodged against the weir, observed the wood, which was about thirty inches long, and thought it would do well for a dish, and straightway fished it out. She took it home with her, and the next time they cooked a salmon she laid it on the board. As they were eating it the fish seemed to last them a very little while, and when it had all gone they were far from being satisfied. 'I haven't had enough,' said one. 'I don't seem to have eaten any,' said another. 'We will cook another fish,' said the third; 'I can eat some more myself.' So another salmon was cooked; but this disappeared as rapidly as the former one, and they are still feeling hungry. Said the eldest of the sisters now, 'I think there is something wrong with this dish. I shouldn't wonder if it isn't that Snikīā'p that was drowned.' 'That can't be,' said one of the others. 'How could he turn into a piece of wood?' Oh, he is a very powerful wizard,' said the eldest. 'Let us throw it away anyhow,' said another; 'throw it into the fire and burn it.' This was done, and the seeming piece of wood began to burn. As soon as the fire began to consume it the board began to cry like a child. This affected the youngest sister, who wanted to save it from the fire. 'No, no,' said the eldest; 'let it burn.' 'I want to save it; it must not burn,' declared the youngest. And she straightway took it out and washed it and dressed its burns, which soon healed up. The piece of wood now becomes a baby boy, who soon grows up and plays about the weir, and observes all that the sisters do. One day, when he had grown to be a big boy, the sisters all go for a walk, leaving him behind. Now they had four boxes in the house, in which were stored the wind, the smoke, the flies, and the wasps. These boxes had never been opened in the child's presence, and he was curious to know what was in them, for he had been forbidden to go near or touch them. On this occasion they warned him not to touch the boxes; but when they had gone, his curiosity got the better of him, and he opened the one containing the smoke, which came out and nearly choked him. The sisters are soon made aware of what

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[1] The story at this point seems to go over the same ground and be mixed up with the story of Skoē'qt-koatlt. In the story of the great hero Skoē'qt-koatlt it is he who comes in contact with these four women, and with the help of his brothers breaks their power and destroys the weir, letting the salmon up the river. However, the detail of this is different from that recorded by me in the story of Skoē'qt-koatlt. See the writer's paper on this fabulous hero in the *Transactions* of the English Folk-lore Society for the current year.

has happened, and rush home quickly, and collect the smoke and return it to the box, scolding him the while, and telling him not to be so disobedient again. The boy pleaded forgetfulness, and promised to let the boxes alone for the future. The women set out again on their walk. When this boy, who had Snikīā'p's soul within him, and Snikīā'p's cunning and experience, was left alone the second time, he went out and examined the salmon-weir. He perceives that it prevents the salmon from getting higher up the river. The sisters presently return, and he is called away for that time. One day they say they are going out for the morning. The boy says he wants to go too, but they tell him they cannot be bothered with him; he must stay at home and look after the place. As soon as the women have gone, Snikīā'p opens one of the 'medicine' boxes, and the wind escapes and a gale arises. He then opens the other three boxes, and lets their contents out also. He now proceeds to the centre of the weir, and makes an opening in it through which the salmon swim up river. The sisters soon perceive what has happened, and rush home. They set to work to gather their scattered property, but can only secure some of the smoke and flies. The wind gets away beyond their power to recall, and they lose it entirely. Snikīā'p now changes into an old man again, and runs away, feeling happy and in good spirits. He has let the salmon up the river, and the people above will be able to get them now. There is only one drawback to his feelings of satisfaction—the smoke and flies are troublesome, and the wasps are very annoying. However, he goes up river, shouting and singing, and in good time gets back to the camp at Britta'nī. As he enters the camp he shouts to the people to come and see the salmon he has brought up the river. He does not remain there, but goes up the river shouting to the people that he has brought the salmon. By-and-by he gets tired, and walks quietly and slowly. He picks some green branches and carries them over his shoulders. As he passes the villages along the river he asks the people what they would like to have. They answer, 'We want some of the mountain-sheep fat that grows on the neck and smells nice.' 'Can't give you that,' replied Snikīā'p. They then mention another rare luxury—the back of a salmon. He declares they can have all they want of that, and bids them go to the river, and they will find it full of salmon. He arrives in time at Bridge River, where he makes a fall to stop the salmon from going further by stepping to and fro across the river three times But he does not make the fall high enough, and many of the salmon jump it and get up the river. From thence he goes up the North Fraser, and brings the steep banks of the river together to form a cañon, so that the people there can more easily catch the salmon. He presently crosses the river, and passes over into the Shuswap country. At this time he is wearing a handsome buckskin shirt. He wanders all round the country, and in time gets back to Lytton. No one recognises him when he returns, he is so altered; and he keeps up his disguise by speaking a strange language and pretending ignorance of the N'tlaka'pamuQ tongue. The people inquire among themselves who there is that is acquainted with the other languages of the country. Some one says that Pū'īyauQ, an old woman, knows several tongues besides her own. She is sent for to see if she can hold converse with the stranger. She begins by speaking Sk·quamic. Snikīā'p shakes his head at this. She now tries him with the Yale tongue. Again he shakes his head. She next tries Okanakan, but with no better success. Then Shuswap, then Lillooet, then Carrier;

but he shakes his head at all. She knows no others, so the attempt at communication fails. The people regard him as a great medicine-man, and wonder if he will heal a sick woman they have among them. They take him to the woman. He nods his head to indicate that he understands their wishes and will do as they desire. He builds a sweat-house and puts the woman in it, and made to go in with her himself. Big Crow, who has been observing all that took place, is suspicious of the man, and when Snikīā'p would have entered the sweat-house alone with the woman, she called out to the others that he was an impostor; that no true medicine-man would enter the sweat-house with his patient. But the people are angry at Big Crow; but she declares she is right, and that he only wants to enter the sweat-house with the woman for evil purposes. She gets angry because they side with the stranger against her, and she takes a club and hits Snikīā'p over the head with it. He screams out at the attack, and everybody recognises the voice of Snikīā'p, and discovers that he has been trying to trick them. They fall upon him and beat him well. He begs for mercy, declaring that if he did wrong in the past he has also wrought much good for them by breaking down the witches' barrier across the river and letting the salmon through, and by giving them the cool wind which, since its escape from its prison, had blown up river continuously. They presently allow his claim for mercy, and let him off without further punishment. From this time the salmon came up the river regularly, and the prevailing wind of the region is an up-current breeze which keeps the air cool even in the hottest weather. These two blessings the old Indians believe were due to Snikīā'p the Coyote, whose memory they keep alive by this and other stories of him and his doings.

Matq, or the Fire Myth.

Long, long ago the Indians on Fraser River had no knowledge of fire. Beaver, who travelled about a good deal in the night prospecting the rivers, learnt from some source that away in the far north there lived a tribe who knew how to make fire. He determined to seek out this tribe and steal some of their fire and bring it back to the 'Stalo' (*i.e.* Lower Fraser River) Indians. He told his brother Eagle to wait for him at a certain point on the Fraser while he went down the river to the coast to tell the people of the settlements along its banks that he was going to steal the fire for them in the far north. When he reached the coast he met a large tribe there. He begged from them the gift of a pair of clam-shells in which to stow away the fire he should steal. They gave him the shells and he then returned to his brother, and the two set out together for the far north. 'You go through the air,' said Beaver to Eagle, 'and I will travel by water.' They continued their journey in this way for many days and nights, Beaver travelling by the Fraser. When they arrived near the village of the people who possessed the fire, Beaver called his brother to him and told him his plan of action. 'To-night,' said he, 'I will build a dam across the water, and then burrow from the dam along under the ground until I come up under the house where the fire is kept. They will spear me sooner or later, and take me to the village, but although they will spear me they will not be able to kill me. In the meantime I shall build myself a house in the river, and when they see it they will come out and spear me. When they have speared me they will take me to the house where the fire is kept to skin me. I shall put the clam shells inside my skin, and when the knife is nearly through to the shell beneath I shall open my eye and you will see a great flash of light in the sky. You must be close by, and when you see the flash you must fly over the house and attract their attention. They will leave me for a moment and run out to try and shoot you. When they are gone I shall seize the opportunity and open my clam shell and fill it with fire. I shall then clear away the soil from above the passage I have made from the river to the house, rush down it, and come out in the deep water of the river above the dam.'

Eagle approved of the plan, and promised to do his share according to his brother's instructions. All that night Beaver worked at his dam and the passage. By morning all was ready. When one of the women went down to the stream to fetch her water next morning she found to her surprise a large lake where before was only a small stream. She dropped her pail and ran home, and told the people that a beaver was in the stream. Everybody rushed for his spear, and all made for the stream. Some one suggested breaking the dam and catching him in that way. This they did; and when the water was getting low Beaver came out of his house and swam about as if trying to get away. He played with them for a little while before he would permit them to spear him. Finally they speared him and carried him with great rejoicings to the house. Everybody now wanted his teeth, or his tail, or his claws. They presently set about skinning him, but as the point of the knife touched the shell hidden beneath the skin of his breast Beaver opened one eye. Now, the boy who was holding his leg saw the action, and told the others, who only laughed at him. Just at that moment Eagle, who had seen the signal, came soaring over the house, making a great noise, which diverted everybody's attention from Beaver. 'An eagle! an eagle! Shoot it! kill it!' shouted everybody, and all ran for their bows and arrows except the boy who was holding Beaver's leg.

This was the moment Beaver had planned for. Shaking himself free from the boy's hold he took out his clam shells, quickly filled them with fire, and before the boy had recovered from his astonishment plunged head foremost down the passage hole and made for the river. The boy's cries speedily brought the people to him, and he told them what had happened. They now tried to dig out the hole down which Beaver had disappeared, but they no sooner tried than the water rushed up and stopped them. Beaver reached the stream safely, and from thence made his way to the Fraser, where he was joined by his brother Eagle. As they returned down the river Beaver threw fire on all the trees they passed, but mostly on the cottonwood trees, and thus it was that the wood from these trees was the best for making fire with from that time onward. He continued to do this till he had reached the coast again, and all his fire was gone. After this he assumed a human form and taught the Indians how to make fire by means of the drill worked between the hands. He also taught them how to preserve the fire when once secured in the following manner. He procured a quantity of the inner bark of the cedar tree and made it into a long rope. This he then covered with the bark of some other trees which burnt less readily. When one end of this rope was lighted it would continue to smoulder for several days, according to the length of the rope. When the Indians were travelling and likely to be away from camp several days they always carried one of these fire-ropes, called by themselves Patla'kan, coiled round their shoulders.

After this great gift to them the Indians thought very highly of Beaver, and he was usually called by them 'our head brother' because of his wisdom and goodness.

Painted Blanket Myth.

When Beaver had finished his instructions to the 'Stalo' Indians he returned to the Thompson River, and hearing there that a young medicine-man possessed a remarkable figured blanket which his father, a very great and wise Shaman, had made for him, he determined to secure this treasure for himself. Accordingly he and all the people of his village started off to find the young Shaman's dwelling. After travelling a great way they finally discovered his home, and having told him the object of their journey was to see his wonderful blanket, begged to be allowed to look at it. But this the young Shaman was unwilling to do, knowing they would take it from him if they once saw it. Disappointed by his refusal to show it, some of them determined to kill him, and afterwards steal and make off with the blanket. Their designs were revealed to him in a dream by his guardian spirit, and he resolved to outwit and punish them for their evil intentions. Leaving his house he went and camped on the edge of a steep precipice, taking with him the bladders of several animals he had lately killed, and which he seems to have kept for the purpose. He also took with him his snow-shoes. He wetted the bladders and blew them out and secured their mouths. He had not been settled long when several of the men came over to him with the intention of murdering him and then securing his magic blanket for themselves. But he, knowing their intentions, was prepared for them. Taking his snow-shoes and the bladders of wind, he placed them under his blanket in such a manner as to make them appear like a dog at his side. He sat with his face towards the precipice, between him and which there was but a narrow strip of ground. In the dusk the edge of the precipice was not discernible. As the men approached he cried out to them not to come too close to him, as his dog was very savage and fierce. They therefore went and sat down some little way from him, just on the edge of the precipice with their backs towards it, and their faces towards him. As they seated themselves the young Shaman shifted his seat so that he sat upon one of the bladders, from which he now permitted the wind to escape in sudden jerks and gusts, which made a noise like the angry growlings of a fierce dog. The men grew alarmed; the more so as he now pushed forward the toes of his snow-shoes, which to them seemed the dog's fore-paws. At the same time the youth cried out, 'Take care now, take care! You have made my dog angry and dangerous,' and at the same moment he pushed the snow-shoes farther towards them. In their fear of the dog they moved back a little, and the young Shaman moved with them as if he were trying to restrain the dog. Opening a second bladder, and pushing the snow-shoes again towards them, the two things together caused them to retreat still farther until, all unknown to themselves, they sat upon the very brink of the precipice. He now opened the third bladder, which made a horrible noise as the wind escaped, and at the same time pushed forward the snow-shoes again. Thinking to avoid the supposed dog they all moved backward, and before they had realised their danger were over the brink and falling headlong down the precipice, at the bottom of which they were dashed to pieces. Thus did the young Shaman outwit his would-be murderers and robbers. He now determined to run away and hide himself from the annoying curiosity of the rest of the tribe; but before he had gone far Beaver found his trail, and led the people after him. They overtook him at nightfall, whereupon he climbed a high tree. 'Well,' said Beaver, 'he cannot get away from us now. Let us camp round the tree, then when he descends in the morning we will ask him again to show us his wonderful blanket.'

They made their camp at the foot of the tree, and felt sure he could not get away without their knowledge. But before the night was half over the young Shaman called his magic powers into play and caused them all to fall into a deep sleep. Beaver, who was watching, felt the sleep stealing upon his senses, and resisted the spell for a long time; but the Shaman was too powerful for him, and he, like the rest, at length fell into profound slumber. As soon as Beaver and his party were asleep, the young Shaman descended from the tree and continued his flight. It was late the next day before they all awoke from their magic sleep, and they were scarcely surprised to find that the young man had gone. But Beaver had no intention of being beaten in this way, and encouraged them to take up the trail and follow him again. They travelled fast, and overtook him just about nightfall. Again he hid himself in a high tree, and again they encamped at its foot, determined not to give way to sleep this time. But one by one they all dropped off to sleep, again being wholly unable to resist the Shaman's power, with the exception of Beaver. This time he was proof against the spell of the Shaman, who presently began to descend the tree. As he reached the ground he saw that Beaver was wide awake and watching him. From this he perceived that he must give way, as the medicine of Beaver was stronger than his own. He therefore presented Beaver with the wonderful blanket, and went his way. Beaver now carefully examined the blanket, and found it to be covered with pictures of all kinds of utensils and weapons. These pictures represented the originals of all the articles used by the Indians, with the exception of the fish spears which had been given to the Thompson Indians by their culture hero, Benign Face.

Beaver now cut the blanket up into pieces according to the patterns of the paintings upon it, so that each piece represented in outline the form of some tool, or utensil, or weapon. From these patterns, under the instruction of Beaver, the people are said to have made everything they had in use in the way of weapons or tools when the whites first came in contact with them. Throughout this adventure Beaver had worn a human form, but after he had taught the Indians how to make useful things for themselves from the patterns on the magic blanket, the young Shaman transformed him into an animal, under which guise he is still recognised by the wise Indians. Thus did the Shaman revenge himself upon his adversary. But this act did not satisfy him for the loss of his blanket and power; he would revenge himself also upon the people for whose sake Beaver had won the blanket from him. Up to this time they had not returned home, but when Beaver was transformed into an animal they began to think of doing so.

Koakoë'la, or Husband root Myth.

They had, however, no sooner started than the young Shaman caused them to become bewildered and lose their way and each other. They wandered about looking for the path and each other for days, and though they all got back eventually, with the exception of one woman, they suffered many hardships by the way. This one woman could not find her way back, and had to build a shelter in the woods and support herself upon roots and berries as best she might. After she had lived some while in this lonely state, as she could not get a man for a husband, she determined to take for husband a certain kind of root. This root now goes by the name *Koakoē'la*, or 'Husband-root.' By this root-husband she became the mother of a male child. When the child had grown into a strong youth he one day asked his mother where his father was. The woman was ashamed to tell him what kind of a father he had had; she dissembled therefore, and told him that his father had been drowned. On hearing this the youth went to the river and reproached it for drowning his parent. The river denied the charge, declaring that his father had not been drowned. Upon hearing this he returned to his mother, and said, 'Mother, you have deceived me; my father was not drowned. Why don't you tell me truly where my father is?' The mother still prevaricated, and said, 'Your father is dead, my son; it is true he was not drowned; he fell from a lofty tree and was killed as he was trying to take a hawk's nest.' The boy, to whom the language of all nature was familiar, now reproached the trees for the death of his father; but they one and all denied it. He returned again a second time to his mother, and entreated her to tell him the truth concerning his father, and where he was. The request was too embarrassing for his mother to comply with, so she put him off again by declaring that his father had fallen over a precipice and broken his neck. But when the youth taxed the precipice with the deed it indignantly denied the charge. As he was returning home he found his feet catching in a certain kind of root, which constantly tripped him up. As this had never happened to him before, he wondered what it meant. When he got home he said to his mother, 'Mother, I see you do not intend to satisfy my longing to know who and where my father is; you have deceived me these three times. I shall not ask you again; but, tell me, why does this root trip me up all the time to-day when I walk in the woods?' and he held a root in his hand similar to that which his mother had taken for husband. The mother turned away and would not answer him, though she perceived that the knowledge he sought would soon be made known to him. He now determined to prepare himself to become a Shaman. He therefore left his mother and lived apart by himself, and fasted and exercised his body till a Shaman's dream came to him, and with it great Shamanistic power. In his dream he learnt also that he was the son of a root. This knowledge made clear to him at once why his mother had sought to deceive him about his father. He now determined to seek out the tribe to which his mother belonged. In the course of his journey he came one day upon a great concourse of people watching a game of ball. They asked no questions of him as he joined the players; but when he presently struck one of his opponents' legs they got angry and mocked him, calling him the 'son of a root,' and from this time forward he was known by the name Koakoē'la.[1] He was so struck with shame at this taunt that he covered his face with his hands. Some of the people are sorry for him,

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[1] Dr. G. M. Dawson has given the name *Kwil-ī-elt'*. In his account of this hero he records deeds performed by him which were done by his friend Skoē'qtkoatlt, according to my informant, Chief Mischelle, of Lytton. Compare Dr. Dawson's account in his 'Notes on the Shuswap People of British Columbia,' *Trans. Roy. Soc. Canada*, 1891, with the writer's account of Skoē'qtkoatlt in *Transactions* of the English Folklore Society for 1899.

and try to cheer him up. But he cannot endure the thought of having his birth thrown in his teeth every time any little disagreement occurs; so he goes away by himself again and undergoes a longer fast and training than before. In course of time he becomes a very great and powerful Shaman whom everybody fears and respects, and no one again ventures to remind him of his 'Koakoē'la' descent. Some time after this he meets the hero Sqoē'qtkoatlt[1] and his two brothers. Each endeavours to test the other's powers; but finding they are equally strong and invincible, they desist from their efforts and become great friends. The Shaman youth, to show his powers, made with his finger three small holes in the rock, and caused them to become instantly filled with a savoury soup. He then gave Sqoē'qtkoatlt's two brothers a spoon each, and told them to eat the soup. 'That is soon done,' said one of them; 'it is but a spoonful.' 'Well, try now,' said Koakoē'la, 'and see if you can eat it in a spoonful.' Laughing, they both dipped their spoons in and emptied the holes at once, but before they had swallowed the soup the holes were full again. And this continued till each had taken as much as he could eat, yet the holes remained full. Sqoē'qtkoatlt, who understood the trick, looked on and smiled. When they could eat no more the Shaman laughed at them, and bade them continue and persevere, and perhaps they would exhaust his supply. They said they could eat no more. 'Oh yes, you can,' said the Shaman; and taking them in his arms, he shook them so well that on being placed on their feet again they found they could eat some more. So they attacked the holes of soup again; but eat as much or as fast as they would the holes always remained full. They presently confessed themselves beaten, and gave up the contest. 'Ah!' said the Shaman, 'you don't know how to do it. It is quite simple. Watch me.' And dipping the spoon in each hole, he emptied them in a moment. What happens to the Shaman after this my informant was unable to relate, and the story came to an abrupt ending here.

This meeting of Koakoē'la and Enpatcī'tcīt, or the three Bear brothers, is said to have taken place at the Indian village of Nikai'ah, on the Fraser, a little below the junction of this river with the Thompson; and the little holes said to have been made by him, as related above, are pointed out in the rock by the Indians to this day.

Ōi'tcūt Story.

(She burns herself.)

Once upon a time the Loon was a very great man in his village. He had a very beautiful daughter whom he kept secluded in the privacy of his keekwilee-house. She was permitted to leave the house only at night or very early in the morning. Besides this beautiful daughter he had a son into whose heart came one day evil thoughts towards his sister. One night, when all were asleep, he crept to her bed and lay with her in her sleep. As he was about to leave her she awoke and found him at her

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[1] For an account of this hero see my paper in the *Journal* of the English Folklore Society. In this paper I have written the name thus, *Sqaktktquaclt*. After hearing some half-dozen Indians pronounce it in my last visit, I believe it is best spelt as I have here given it. Dr. Boas has written a short account of this hero in his *Indianische Sagen*, Mr. Hartland informs me, in which he writes the name thus, *Q'oēqtlk·otl*. The name is not an easy one to write in English, but there can be no doubt that the word begins with a sibilant and ends with a dental in the mouth of a Lytton Indian. My phonology is the same as that of Dr. Boas.

side. As the house was in darkness she could not tell who he was, and presently he stole away on her scolding him for his intrusion. When he left her side she watched the smoke-hole to see if he left the house, but seeing no shadow against the sky she came to the conclusion that he was an inmate of the house. As there were several families in the same keekwilee-house, it never entered her mind to suspect that the intruder was her own brother. After a few weeks had elapsed the maiden found herself with child. She was greatly distressed when she discovered her condition, the more so as she knew not the man who had brought this trouble and disgrace upon her. The least she could do before she told her parents of her condition was to discover his name. Suspecting that he would sooner or later pay her a second visit, she resolved to lay a trap to discover his identity. She thereupon begged from her mother some paint of two colours, black and red. 'What do you want with paint?' said the mother; 'you cannot paint yourself.' 'I don't wish to paint myself,' replied the girl. 'I need it for some other purpose,' and she teased and worried her mother till she gave her what she wanted. Before retiring that night she took some grease and mixed it with the paint, after which she covered the insides of both of her hands with the mixture, red on one and black on the other. Thus she awaited the next visit of her betrayer. One night he stole again to her couch and lay with her again as she slept. She awoke earlier this time, and before he left her she endeavoured to make him speak to her, so that she might discover his identity by the sound of his voice; but this he would not do. Finding he would not thus betray himself, as he sought to leave her she made pretence to detain him by putting her arms about him. While she held him thus for a moment she impressed the palms of her paint-smeared hands firmly upon his shoulders and left a clear imprint of them there in red and black. He now left her, all unconscious of the tell-tale marks she had placed upon him. 'In the morning,' said she to herself, 'I shall know him by the pattern on his shoulders.'

Now it was customary for Loon to call all the young men of his household early in the morning to go out to swim, and exercise themselves in various kinds of sports. After the youths had taken their swim in the river they would paint themselves in fanciful designs, and then contend together in racing and other exercises. On this particular morning the girl begged so hard to be allowed to go out for once and see the games that at last her mother consented. She bade her daughter put on her best robes. This the girl did, and clothed herself in a beautiful soft elk-hide dress, which was covered throughout with handsome bead-work. On presenting herself to the neighbours she was regarded with much astonishment by all, but she took no notice of any of them, her whole attention being given to scanning the backs of the young men before her. She passed them one by one in silent review before her, but could discover on the shoulders of none of them the imprint of a pair of human hands in red and black. She was puzzled, as she knew very well that the paint could not be washed off in the water. She never thought to look at her brother until presently he ran close by her and exposed his shoulders to her gaze. In a moment her eye caught the impression of her hands in the red and black paint upon his back.

At first she would not believe her sight, but when she could doubt no longer she gave a shriek of pain, and putting her hands to her face cried aloud and rocked herself in her distress and grief. The bystanders thought the brother had accidentally struck her in the face as he was passing, and chided him for his carelessness ; but she said nothing, only sat rocking herself and sobbing. Presently she got up and returned to the house. All that day she cried and wept for the shame her brother had brought upon her and her parents. That same night her brother stole again to her couch. She was awake on this occasion, and repulsed him, telling him she knew who he was, and upbraided him for his selfishness and the wrong he had done her. 'How do you know I am your brother ?' said he. 'Your voice would tell me now if I did not know before,' replied she ; 'but I discovered who you were this morning.' She then told him what she had done on his last visit to her, and how she discovered him that morning, and also the condition she was in. 'How could you bring this shame upon our father ?' she continued. 'When the people know they will point the finger of scorn at him, and he will be dishonoured among them ; it will kill him with shame. There is but one thing for us now to do. We must go away somewhere by ourselves and never come back again, so that none may know the disgrace you have brought upon us. Let us go away now at once before it is light and the people are stirring.' To this the brother presently assented, and they stole away in the dark together.

As the girl left her father's keekwilee-house she pulled off strips of the bead-work of her dress, and as she went she hung bits of it on the branches of the trees or on projecting points of rock every ten steps she took. This she continued to do until she had stripped and hung up all the bead-work on her robe. They had been journeying ten days before this happened through the pathless forest. When she had hung the last bit she stopped and said to her brother : 'We will stay here, we have gone far enough now.' So they stopped there, and he built a house for them. After a few months had passed the girl gave birth to a child, a fine, healthy boy, who speedily grew up to be a strong youth. One day he ran crying to his mother, asking her why he had no grandmother or grandfather. The poor mother's heart bled at the child's question, as she told him all his relatives, save his father and herself, were dead. When the lad had grown to be a sturdy youth the mother told the brother it was time for them to make the final preparations. They had often talked together in their loneliness, as the child was growing up, as to the course they would pursue when he had grown to be a big boy, and he now took his weapons and went out to hunt. This he continued to do day after day until he had brought home enough skins of the mountain sheep and goat for her to weave twelve large blankets from their wool, and also lay by a nice store of dried meat and kidney-fat. When their tasks were completed the mother called the lad to her and told him that she had deceived him when she had said he had no other relatives but herself and his father. 'Ten days' journey from here,' said she, 'lies the village of my father and his tribe. You are now big enough to make the journey thither alone, and we propose to send you to see your grandparents.' 'But why don't you come too ?' questioned the boy. The mother found it difficult to satisfy him on this point, but he presently consented to make the journey alone and come back and bring them later. 'But how shall I find the way ?' said he. 'That will not be difficult,' replied the mother ; and taking him to the edge of the forest she showed him a bit of bead-work hanging from the lower branch of a tree. 'You see this bead-work ?' said she. 'Well, every ten paces on your way you will find another piece. If you look out for these and follow the course they mark, in ten days you will come to your grandfather's village.' 'But how shall I know my grandparents when I get there?' queried the youth. The mother answered: 'You have an uncle who has but one eye; when you find him all will be well.' She then instructed him in many things which only medicine-men know—how to make himself invisible, and many other things. In the meantime his father had been busy stacking a huge pile of pine-logs in the keekwilee-house. 'Why is father stacking so much wood in the house?' asked the boy. 'Winter is not coming on. Why do you want so much wood now?' The mother answered, 'Your father and I have a use for it, my son; we have a great task to perform when you have gone.' The boy was curious to know what this was, but his mother would say no more. Everything being ready, the time now came for the boy to start. His mother made a pile of the blankets she had woven, in which she wrapped a large supply of their dried meat and fat, and told her son he was to take the blankets and meat to his grandparents as a present. The youth put the bundle on his shoulders, and though it was bulky and heavy he found no inconvenience from it, as his mother had uttered 'medicine' words over it, which made it light and easy to carry. He now bade them good-bye and set out on his long journey. His parents watched him go, and shed many tears as he passed into the forest out of their sight. Then taking each other by the hand they went back towards the house. 'Come, brother, our work is nearly finished; let us complete it,' said the woman. When they entered the house they lit a fire at the base of the pile of pine-logs, and, climbing upon the top together, they lay down side by side, hand in hand. In a few moments the flames from the pitch enveloped them, and in a short while the pile was consumed, and they with it.

Thus had they planned to wipe out the disgrace which had darkened their lives.

In the meantime the son of the unhappy pair had been making his way through the forest as his mother had directed him; when, coming to an eminence and, disregarding his mother's injunctions not to look back after he had once started, he cast his eyes in the direction of his home, and was startled and shocked to see flames and smoke coming from the roof of the house. Casting down his bundle without a moment's consideration, he ran back upon his trail as fast as his legs could carry him; but he only arrived in time to see the roof fall in. The heat was too great for him to go near the ruins; he could only watch the flames consume the last timbers of his home. He wondered what had become of his parents, and feared they had been destroyed in the fire. Presently he groped his way among the charred remains, and saw enough to convince him that his parents had perished. He could not understand it all, and sat crying all that day and the following night. During the night he had a dream which revealed to him many things. He learnt why his parents had left their home, and the punishment they had planned for themselves, and that they had deliberately burnt themselves to death in expiation of his father's offence. Very sad at heart he turned his back next morning upon the ashes of his parents and old home, and once more set out on his journey. Finding his pack, he continued his way through the forest, following the guiding strips of bead-work, until at last he arrived at the village of his grandfather. He now recalled what his mother had told him about his one-eyed uncle, and looked about for such a person. He saw presently a little old man before him, and as he approached him he deemed it wise to make himself invisible for the time. He now saw that the little old fellow was shooting on the ground with his arrows. He saw too that he had but one eye, and wishing to test whether he was his uncle or not he placed his foot on the spot at which the little man was shooting, and caught one of his arrows between his first and second toes. When the little fellow went to get his arrows he could not draw this one away, as the youth held it tight between his toes. He now spoke to the little man, who was much frightened at the sound of a voice so near him when he could see no one. The youth told him not to fear; that it was his 'medicine' that prevented him from seeing who he was. Making inquiries he soon discovered that his grandparents were still alive, and that the little man before him was his uncle. When he told him that he was his nephew he would not believe it. To prove to the uncle that what he said was true, he asked him if he could remember how his lost sister used to speak. 'Oh yes,' said he; 'I can remember quite well.' 'Was it like this?' said the youth, and he imitated his mother's voice. 'Yes, yes!' said the uncle, 'that is her voice.' 'Now look at me,' said the nephew, 'and tell me if I am like your sister or brother.' And as he spoke he made passes in the air with his left hand, and became immediately visible to his uncle, who knew him at once to be really his nephew from his likeness to his lost brother and sister. The lad then told the little man the story of his mother's and father's life, and the reason of their mysterious departure from the village, and bade him go to tell his grandmother privately that he had come. 'But she will not believe me,' said the uncle, 'and will be angry with me for trying to fool her.' 'Stay, then,' said the youth; 'I will give you some proofs of my presence to show her, and then she will not doubt you. Tell me, what is the matter with your eye?' 'I am blind in it; I was born so,' replied the little uncle. 'Well,' answered the youth, 'I will give you sight in it with my "power," and you can then show it to my grandmother if she doubts your word.' With that the nephew passed his hand over his uncle's eye four times, and the latter's blind eye was made whole, and he saw with it for the first time in his life. Full of wonder and admiration for his nephew's power, he ran off to tell his mother. When he first whispered the tidings in her ear she was angry with him for attempting to fool her, as she thought, but when he showed her his blind eye restored she could no longer disbelieve him. Immediately she ran out to find her daughter's son, and was much delighted to find so comely a youth claiming her as his grandmother. When she questioned him concerning his parents he repeated to her the story of their lives as he had told his uncle, and as it had been revealed to him after their death. The old woman wept[1] as she listened to the tragic end of her children. When the grandfather was made aware of his grandson's arrival, and had also heard the account of his lost children's death, he called all the village together and informed them of the youth's arrival and the events which led to his parents' voluntary death. Meantime the old lady bade the girls clean up the house and strew clean fir branches on the floor in honour of her grandson's coming. When he entered the house he undid his pack and presented his grandmother with his parents' presents. The old woman spread out

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[1] My informant told me that this story would always make the women and girls weep whenever they heard it related. It is one of their favourite stories.

the twelve beautiful blankets, and set the meat and fat ready at hand for the feast which the chief now proclaimed. The whole village now came together to see the youth and the presents he had brought his grandparents. During the feast the story of his mother's and father's life was retold again, and their sad end drew tears from all the women present. At the close of the feast the grandmother told her neighbours that they would see her grandson no more, as she intended to keep him secluded as she had his mother; which thing she did, and the lad never left the keekwilee-house except at night when all the village was asleep, or early in the morning before they had arisen.[1]

Now it had happened that when the people had been invited to the feast two old witch-women had been overlooked, as their dwelling was somewhat apart from the others; and when they heard later of the occurrence they were angry, the more particularly as they were very curious to see the boy. They determined to be revenged for the slight, and to see the youth at the same time whose advent had been a nine days' wonder in the village. So one day they took some human ordure, and mixing it with earth fashioned it in the form of birds. By their witch-power they then transformed these clay effigies into real live birds of beautiful and attractive plumage. They had not long completed their task when the little uncle chanced to come that way, and seeing the pretty strange birds he much desired to secure them for himself. Having his bow and arrows with him he tried to shoot them. He struck them again and again, but could not kill them. The most that he did was to knock a few feathers out of them. 'Ah!' said he to himself, 'I wish my nephew were here; he would be able to kill them all right.' And so saying he gathered up the brilliant feathers to take home to show him and his mother. Calling his mother's attention to the beauty of the feathers, and telling her of his ill success with his shooting, he begged her to let his nephew come out for a little while to shoot the birds for him. The old mother would not at first hear of it, but on the nephew himself expressing an earnest wish to go out with his uncle to secure the birds, she presently gave way, and permitted the two to go off together. The youth easily shot and killed the birds. To carry them home he put them inside the breast of his shirt next his skin. While the shooting had been going on the two spiteful old witch-women had taken a good look at him, and so won their desire.

As they were returning home the youth complained of an unpleasant odour. 'What is this nasty smell?' said he. 'Where can it come from? Have you not stepped on something nasty, uncle?' But as he spoke he felt something wet and cold against his skin under his shirt. Pulling open his shirt, he saw inside, where a few moments before he had placed the beautiful birds, now neither birds nor feathers, but the nasty material from which they had been made by the witches. Perceiving he had been tricked, and horribly disgusted, he cast his garments aside and plunged into the river to cleanse himself, bidding his uncle at the same time fetch him some clean garments. After he had washed himself and put on clean clothes, he felt so mortified and ashamed that he determined to leave the spot and go and live by himself in the woods. He informed his uncle of

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[1] This curious habit of seclusion seems from the stories to have been quite a common custom. Instances occur again and again, particularly in the families of chiefs.

his intention, and invited him to accompany him. The little man, who had grown very fond of his nephew, was only too delighted to go with him, and so they set out together. They lived alone in the forest for several years, till the youth had come to mature manhood, when a restless spirit came over him. At last he said to his uncle, 'I am going to look for a wife for myself. I know of two beautiful women in Cloudland. I shall go and get them for wives.' He thereupon shot a large mountain eagle, and carefully skinning it, he dried and prepared the skin, leaving the feathers and wings on. When he had finished it he put it on himself and attempted to fly. As he mounted into the air his uncle cried out to him not to fly away and leave him all alone. 'Don't be afraid, little uncle,' answered he; 'I am not going away yet. I am only practising.' When he had practised enough he returned to his uncle again, who begged him not to fly off and leave him. 'Very well,' answered the young man, 'I can take you with me, but only on one condition. You must promise to keep your eyes shut tight all the time we are in the air.[1] If you open them we shall fall to the ground.' The uncle readily gave the promise. The nephew then took him in his arms and soared aloft with him. They had not, however, gone far when the uncle felt a great curiosity to see what it looked like down on the earth, and forgetting his promise opened his eyes. Immediately they descended rapidly to the ground. 'O uncle, you broke your promise, I know,' said the nephew; 'you must have opened your eyes. Now if you do that we can never get up.' The little man was very sorry, and promised not to open his eyes again. They started a second time, but they had not got very far up before the desire to open his eyes was too strong for the uncle to resist. As soon as he opened them they returned to the ground as before. The nephew, finding he could not trust his uncle, told him he must leave him behind. 'But,' said he, 'I will change you into whatever animal or bird you would like to be while I am away.' The little man thought for a moment, and then said he would prefer to be a little duck and sport in the lake. The nephew thereupon turned him into a little red-eyed duck. 'When will you return to me, nephew?' asked the uncle. 'When you see the clouds in the sky get very red you will know I am coming. That shall be my sign,' replied the nephew. Having thus disposed of his uncle he now flew off. The little duck watched him till he could see him no longer, and then began to disport himself after the manner of his kind in the water. Meanwhile the nephew flew into the clouds, and after some little time came to a small island there. Alighting on a tree, he stood for a moment to survey the prospect. At no great distance from him he perceived a house out of which a beautiful young woman was now coming. He watched her as she made her way to a lake at the foot of the tree on which he was resting. On nearing the lake the maiden cast aside the beautiful robe she was wearing, and which resembled the dress of a magpie, and stood naked, all unconscious that a man's gaze was upon her. She approached the lake and was about to plunge in for a swim when she caught sight of the reflection in the water below her of the eagle in the tree above her head. In a moment she was overcome with shame, and knew that the seeming eagle was really a man in disguise who had looked unhindered upon her nakedness. Immediately she drew her long hair about her and

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[1] The shutting of the eyes during prayers and the performance of Shamanistic tricks, incantations, and such like seem to have been regarded by the N'tlaka'pamuQ, at least, as essential to the success or efficacy of the act.

crouched down in confusion on the edge of the bank. The youth looked on, but uttered no word. Presently the maid cast her eyes upward towards him, and addressed him in these words: 'I know that you are not a bird, but a man disguised as one. You have looked upon me in my nakedness and brought shame upon me.[1] I must now become your wife. But I have a sister; you must see her too,' and with that she sprang towards her dress, drew it hastily about her, and rushed home. On arriving there she threw herself on her bed, sobbing and crying, and would make no reply to her sister when she sought to learn the cause of her trouble and grief. Finding it vain to attempt to get an answer to her queries, she took the water-bucket in her hand and went off to the lake to get some water, and to see if she could discover why her sister had returned so quickly, and what had caused her trouble. She was robed as a kingfisher is robed, and on getting near the lake she also threw off her dress and made to plunge into the water to bathe, but was likewise arrested in the act of doing so by the image of the eagle in the water beneath her. But, unlike her sister, she was not overcome with shame at being caught naked.[2] She addressed the disguised young man thus: 'Oh, now I see what is the matter with my young sister. Well, she must be your wife now; but not she only, you must also marry me. Come down from the tree and cast aside your disguise.' The young man descended from the tree, cast off his eagle-skin, and hung it upon a branch close by. Meanwhile, the woman had put her robe on again and filled her pail with water. Together they walked to the sisters' house, and he became husband to them both. He lived thus with them for some time, and each of his wives gave birth to a son. They were now five in all, and one day the young man said to his two wives, 'We are getting too many for this small place; let us return to Earth again and go back to my old grandfather, the Loon.' The wives consenting, he once more donned his eagle-skin, and taking a wife under each arm, and a child tied to each of his legs, he descended thus from the Cloud Island.

While he had been absent the little duck uncle had each day watched for signs of his nephew's return. One day he was gladdened by seeing many red clouds in the sky. 'Now,' said he to himself, 'I shall see my nephew once more.' He kept his little red eyes on the clouds, and presently saw his nephew approaching the spot where he was. In a few moments more he alighted, and presented his wives to his uncle. 'Now,' said he, 'will you come home with us?' But the little uncle felt a pain at his heart, for he had perceived that his nephew's affections were no longer his own as in the former days. He now had children and wives to love and care for. So the little man answered, 'No, nephew; I will remain here. You do not need me any longer; you have your wives and

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[1] I have already pointed out in my remarks on the social customs of the N'tlaka'-pamuQ that the girls of this tribe were very shy of being seen in a disrobed condition, being much confused and shamed if caught naked. The words put into the mouth of this girl in the Cloud Island seem to suggest that she lay under some sort of obligation to become the young stranger's wife, since he had looked upon her nakedness, whether she would or no. I could, however, gather no confirmation of this idea, but in the story of Ha'nni's wife, p. 579, we have a similar case. Here, too, the girl who is surprised while bathing goes off and becomes the wife of the chief of the Salmon who surprised her. In this case it may be that she was carried off and could not help herself.

[2] It would seem that the second sister was elderly, and had outgrown her bashfulness.

children now.' 'Very well,' replied the nephew, 'do just as you like.' So the uncle remained on the lake as a duck, and became the progenitor of all the little red-eyed ducks now in the country.

Bidding the uncle good-bye, the young man took his wives and children, and directed his way to his grandfather's village. When they arrived there was great rejoicing once more. The old Loon and his wife were still alive, and encouraged their grandson to settle down with them. This he did, and his descendants in course of time became a great and powerful tribe.

Snū'ya c'pīta'kōᴇtl, or Beaver Story.

A long time ago Beaver lived all alone in his keekwilee-house just below the village of Spuzzum. He had two sisters, the Mouse and the Bush-rat. They lived together at Swimp, and the Frog lived with them. Both sisters had several children. One day Snū'ya got out his canoe and crossed the river to Spuzzum late in the evening. He went on to Swimp and visited the house of his sisters. When Snū'ya saw the Frog, whose arms from the elbows to the wrists were adorned with bracelets, he admired her much. She came and sat down by the fire, holding herself so that her bracelets might be easily seen. Snū'ya presently tells his sisters that he would like the Frog for his wife. He sat at the fire till it had burnt itself out and all was in darkness. The others had all retired earlier. When it is dark Snū'ya crawls over to the Frog's sleeping-place and pulls her blanket. 'What do you want? Who are you?' said the Frog. Snū'ya says nothing, but pulls the Frog's foot. The Frog cries out again, 'Who are you, and what do you want?' Snū'ya now reveals himself, and the Frog says again, 'What do you want?' 'I want you to become my wife,' said he. The only answer the Frog gave was to lift her foot and kick Snū'ya in the face. He does not mind this in the least; he simply falls on his back and laughs. He pulls her by the foot a second time, and she kicks him away again. Again Snū'ya laughs and tells her he does not mind her kicking, and intends to make her his wife. The Frog now remarks that she does not desire him for her husband. 'You are not the kind of man I want,' said she. 'Do you think I like a round, big-bellied, big-headed creature like you for husband?' Snū'ya only laughs at this. This makes the Frog angry, and she begins to revile him in bitter language. Still Snū'ya does not mind. But presently, finding he can make no impression upon her, he gave up his efforts and left her, and went over to his sister the Mouse, and told her to take her children and go with them to the hill near by. 'There is a cave there,' said he; 'it will hold you all nicely.' He then goes to his other sister, the Bush-rat, and bids her do the same. The Mouse sister now wishes to know why she should go in the night. 'Would not the morning do?' said she. Snū'ya tells her that the Frog has shamed and scorned and insulted him. Bush-rat then asks what he is going to do when they are gone. 'Oh!' said he, 'I am going to have some fun all to myself, and I don't want you to be present.' This is all they can get from him. However, they both get up, roll up their blankets and mats, and leave him alone with the Frog-woman. The Frog has not spoken a word while this conversation was going on. As soon as his sisters and their families have gone Snū'ya begins to dance and whistle. When he whistles the Frog gets very angry, calling him many objectionable names, and bidding him go and leave her to sleep in peace. Snū′ya pays no attention whatever to her, but continues to whistle and dance more vigorously than ever. It was a rain-song that he was whistling called *tlazmīū̱′qtcin.*[1] ‘tlaz-pe-e-e-e-e-e-e-e′-ūq-tcin,’ ‘tlaz-pe-e-e-e-e-e-e-e′-ūq-tcin,’ tlaz-pe-e-e-e-e-e-e-e′-ūq-tcin,’ sang Snū′ya, and presently the rain began to fall gently. But as the song continued and Snū′ya danced faster and faster it fell harder and harder until it descended in sheets, no such rain ever having been seen before. In a short time the creek near the house began to rise and roll the rock about with a thunderous noise. Soon the water overflows and spreads itself everywhere. It enters the keekwilee-house, and soon Snū′ya is swimming about and beating time to his song with his tail on the water. The Frog's bed begins to get wet: she gets up and raises it higher. In a little while the water is up to it again. A second time she raises it. But now Snū′ya knocks a hole in the wall with his tail, and the flood pours in upon them. Snū′ya now swims home across the river. The day now begins to break. He gets into his canoe and paddles merrily away, still whistling the Rain Song. In the meantime the Frog is floating about on her bed-board, and is carried to the mouth of the creek, calling aloud for help. She presently perceives Snū′ya paddling by in his canoe, and calls out to him to come and save her, telling him she will take him for husband. To all her entreaties Snū′ya replies, ‘What do you want?’ and whistles away. The Frog implores him to bring his canoe over and save her. ‘Oh, come and take me into your canoe and I will be your wife,’ cried she. Snū′ya answers back, ‘Use your own stomach for a boat. I'll not trouble myself about you.’ The Frog still continues to beseech him to deliver her, calling him by all the endearing terms she can utter. The eddies whirl her about and greatly alarm her. Snū′ya now begins to mock her. ‘Oh, you could not be my wife. You surely could not marry a round-headed, big-bellied, short-legged, flat-tailed creature like me,’ said he, repeating the ill names she had so disdainfully called him by a little time before. The current soon carries her past him out into the great Fraser, down which she floats till she comes to a spot about four or five miles above Yale called Nū′ksakōum. Thus did Snū′ya revenge himself upon the disdainful Frog for refusing to accept him as her husband.

Story of Snikīā′p, Qai′non, Tzala′s, and Spatc.[2]

Once upon a time Snikīā′p, Qai′non, Tzala′s, and Spatc lived in the same locality, each in his own keekwilee-house. Snikīā′p being one day without any food in his house, bethought him that it would be a good time to pay a neighbourly visit to the house of Qai′non. On reaching Qai′non's keekwilee-house he looked down the smoke-hole and accosted him. Qai′non replied in a friendly manner, and bade his visitor come in. Snikīā′p clambered down. Said he, as he took a seat near the fire, ‘I was feeling very lonesome this morning, and thought I should like to come over and have a neighbourly chat with you.’ ‘I am truly delighted

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[1] It will be seen that I have spelt this term first with an ‘m’ and afterwards in the song with a ‘p.’ I have done this purposely. In the title my informant distinctly uttered the ‘m,’ but in repeating the word in the song he as distinctly changed it into a ‘p.’ This is an interesting instance of the interchange of these two letters in the mouth of the same person. With the N′tlaka′pamuQ ‘p’ frequently takes the place of the ‘m’ seen in the other divisions of the Salish.

[2] Snikīā′p = Coyote; Qai′non = Magpie; Tzala′s = Diver; Spatc = Black Bear.

to see you,' responded Qai'non; 'I am always glad to see a friend drop in for a chat. Snikīā'p now began to look about him, and perceived that the house was well stocked with lots of dried deer-flesh. Presently, after they had chatted awhile, Qai'non said, 'You must have some dinner before you go away.' Looking towards his stores of dried meat, he said, 'I can't offer you this dried stuff; I should like you to have some fresh meat. Just stay a moment, and let me run out to my deer-trap and see if there is anything in it. I ought to find a deer there.' And with that Qai'non hastened to go to the trap. Snikīā'p, as soon as he had gone out, climbed up the notched pole and observed with much curiosity and interest Qai'non go towards his deer-trap, which was not far from the house. He saw him pause there a moment to inspect the trap, which held no deer, and then pass on to the wood beyond. Presently a big buck sprang up in Qai'non's path. The deer took no notice of Qai'non, who now began to revile it in insulting language. At first the buck paid no attention to the remarks of Qai'non, but presently his language became so bad that he grew angry and ran at Qai'non to punish him. This was just what Qai'non wanted, and as the angry deer approached him he turned and ran towards the snare, keeping just a few feet in front of his pursuer. When he was close to the trap he opened his wings and shot through the opening in a twinkling. The deer, not perceiving the snare, blindly followed, and was caught by the noose, and thus fell a victim to Qai'non's cunning. Qai'non now took his knife and cut the deer's throat to bleed him. He then quickly skinned him, cut off a large piece of the meat, and returned to the house with it. 'Ah!' said Snikīā'p, when Qai'non came near, 'I see you hunt your game just as I do. I always catch my deer that way.' Qai'non was surprised to hear Snikīā'p say this, being under the impression that he himself was the only person who hunted in this way. He said nothing, however, but hastened to cook some of the venison. When the food was ready Snikīā'p ate very heartily, being very hungry, but could not eat all that had been prepared. Wishing very much to take some home with him, he said to Qai'non: 'I think I will borrow your mat and take home some of this cooked meat for my supper; it will save me cooking to-night.' The other was quite willing, and readily loaned him the mat. Snikīā'p wrapped up all that was left from their meal, and now took his departure, saying as he went, 'You must come and pay me a visit soon, and then you can get the mat.[1] I like to have a visit from my friends.' The day following Qai'non thought he would return Snikīā'p's visit. Approaching his house, he shouted down the smoke-hole, 'Good day, friend; I have taken you at your word, and am come to have a little chat with you.' 'Oh, come in, dear friend,' said unctuous Snikīā'p, 'I am truly delighted to see you.' But even as he spoke he felt in his heart that he would much rather his visitor had remained at home; and he wondered what he should do for a dinner, having nothing in the house. However, he put on an air of welcome, and entertained his visitor till dinner-time came. Said he then to Qai'non, 'It is time I was looking after the dinner; you must stay and eat some with me.' To this Qai'non agreed rather more readily than

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[1] The mat here referred to was that off which they had been eating their dinner. In the olden days the Indians of this district always made use of mats for table-cloths. One or more of them was spread on the ground, and the food set out upon them. They were made from reeds and swamp grasses, and were one of the commonest articles of native furniture.

Snikīā'p desired. 'I must get you some fresh meat,' he continued. 'I will run out and see if there is a deer in my trap.' Snikīā'p now went out and looked at his deer-trap, which he had constructed after the plan of Qai'non's. There was nothing in it. He had not really expected to find anything, but he knew Qai'non was observing him, so he followed the course he had seen Qai'non do. He now went into the wood, and presently, to his surprise, came upon a fine buck. The buck looked scornfully at him for a moment, but otherwise took no notice of him. Snikīā'p, remembering what Qai'non had done, began to call the buck ill names. For some time the buck ignored his presence, but presently his language became too bad, and the deer ran at him with antlers down to punish him. Snikīā'p turned tail, and ran as fast as his legs would carry him in the direction of his trap, with the buck close behind him. When he got close to the trap he made a leap to go through, as he had seen Qai'non do, but he failed in his attempt, and stuck fast in the middle, being unable to get through or go back. The infuriated buck now took his revenge, and prodded poor Snikīā'p with his sharp antlers in his rear. Snikīā'p howled with agony, and called upon Qai'non to relieve and help him. Qai'non now came forward, killed the deer, and relieved Snikīā'p from the snare. 'You should not hunt in this way,' said he to poor crestfallen Snikīā'p; 'you do not understand the trick. I would advise you to stick to your own mode of hunting, and not copy anybody else's.' Qai'non now cooked some of the deer for them, and after the meal bade his friend good day, and returned to his own house. It took Snikīā'p some time to recover from the wounds inflicted upon him by the angry deer; but by the time he had consumed the remains of the deer's carcase he was able to get about again. Having met with no luck in his hunting, and being very hungry, he said to himself one day, 'I think I will go and see Tzala's to-day; maybe I can get a dinner from him. He set off on his visit, and presently came to Tzala's' house. 'Good day, neighbour Tzala's; how are you feeling to-day?' said he, as he looked down the smoke-hole. 'Is that you, friend Snikīā'p?' said Tzala's very cordially. 'Come down and have a chat.' Snikīā'p descended. Says he, 'I was feeling lonely this morning, and thought I would come over and see how you were getting on, and have a friendly chat with you.' 'I am very glad you came,' amiably responded Tzala's, and they chatted away together till dinner-time. Tzala's now said, 'You must have some dinner before you go; but I can't let you eat this *dried* fish,'[1] and he pointed to the stores of dry fish that hung in abundance from the rafters of his house. 'I'll just run out for a minute, and see if I can't find some fresh fish in my traps.' Tzala's, thus saying, went down to the river, which was at the time covered with a thick sheet of ice. Every here and there, however, small openings appeared in the ice. Pausing for a moment on the bank of the river over one of these, Tzala's took a long breath, dived downwards, and shot through the hole. He reappeared in a short time with a long string of fine fish. Snikīā'p had observed the action, and, as Tzala's returned, remarked, 'I see you catch your fish as I do. I always dive for them that way myself.' 'Oh, indeed,' said Tzala's the Diver; 'I was not aware of that. I thought I was the only one who fished in that way.' Tzala's said no more, but

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[1] The rules of Indian hospitality demanded that a guest should be given the best food procurable.

speedily prepared the fish. Snikīā'p ate very heartily, but some of the fish were left over. These he coveted for himself. Said he presently, 'If you will lend me the mat, I think I will take a bit of this fish home for my supper with me; it will save me cooking to-night.' Tzala's made no objection, and Snikīā'p bundled the whole up in the mat, and then bade his friend good-bye. 'You must come and see me shortly,' said he as he left; 'I like my friends to pay me a visit sometimes.' Tzala's promised to make an early call.

Next day Tzala's determined to redeem his promise and pay Snikīā'p a visit and bring home his mat. When he arrived at Snikīā'p's house Snikīā'p was a little surprised to see him appear so soon, and was not too well pleased; but he made pretence to be overjoyed at his visit, and did his best to entertain his visitor till dinner-time came. Seeing that Tzala's was intending to stay to dinner, he thought he must do something to prepare it. So he presently observed, 'You will stay and have some dinner with me. I was just going down to the river to look at my traps when you came. I'll just run down now and see what is in them.' So saying he ran down to the river's edge. Tzala's watched him go, and looked on with some curiosity. When Snikīā'p got to the river he stood a moment on the bank as he had seen Tzala's the Diver do, then took a deep breath and plunged headforemost into the nearest vent-hole. But he had miscalculated once more, the hole was not big enough to let his body through. The force of his plunge had carried his head and shoulders through, but then he had stuck fast and could now neither get up nor down. He was thus in serious danger of drowning, and wriggled and twisted his body frantically to free himself. Had not Tzala's been looking on and seen the dilemma into which he had got himself, and hastened down and released him, he would assuredly have been drowned. When the good-natured Diver had got him out of the hole and had bound up the cuts he had received in his struggles, he expostulated with him for attempting to copy him in his methods of fishing. 'It's all very well for me to dive down through the ice—it's my trade; but you should not attempt any such thing. You will surely get into trouble some day if you interfere with other people's business.' So saying he plunged into the river and presently returned with a string of fine fish. These he then cooked, and together they made a hearty meal. After dinner he took his mat and returned to his own house. The fish that were left over lasted Snikīā'p for some little time, after which he was again without food for days, and was very hungry. This time he bethought him he would pay Spatc the Bear a visit. Reaching Spatc's house he accosted him as he had the others, and was invited in by the Bear, who presently, when dinner-time came, brought out some berries in a dish and put them down before the fire. He then washed his fore-paws, sat down close to the fire, and held them over the dish close to the flame. In a little while the Bear's claws began to drip with liquid fat, which he caught in the dish containing the berries. When he had thus secured what he thought a sufficient quantity of fat, he set the dish between himself and Snikīā'p, and together they made a hearty meal. They did not eat it all, however, and Snikīā'p said he would take what was left home with him if Spatc would lend him the dish. To this the Bear agreed, and also promised to pay Snikīā'p a visit at his house very shortly. Now, while Spatc had been drawing the fat from his paws, Snikīā'p looked on for a moment and then observed that he was in the habit of getting his grease in the same way.

Spatc looked as if he did not believe him, but said nothing. Snikīā'p presently took his leave, carrying the remains of their dinner home with him in the Bear's dish. The very next day Spatc took it into his head to return Snikīā'p's visit and get back his dish. So just before dinner-time he dropped in on Snikīā'p. The latter made a great show of welcoming him, and presently, when dinner-time came, got up to get the dinner. Having no berries, he put the empty dish before the fire as he had seen Spatc do, then washed his paws, and, seating himself before the fire, held them towards the flames. In a very little while the heat began to try him and his paws began to smart; but he would not let Spatc see it, and continued to hold them before the fire. Presently the pain made him groan and writhe. 'What is the matter?' said Spatc, who had been closely observing him. Answered Snikīā'p, 'The grease does not run freely this morning, and I feel the heat a little.' 'You do not put them close enough to the fire,' replied Spatc. Snikīā'p put his paws still closer to the fire, and kept them there till the pain made him howl with agony. Spatc, in the meantime, smiled grimly, and when Snikīā'p would have given up he grasped his paws in his own and held them before the fire till poor Snikīā'p's flesh was burnt and his muscles drawn and twisted by the great heat, saying as he did so, 'Let me hold your paws for you, dear friend.' When he thought Snikīā'p had been sufficiently punished for his humbugging and insincerity he let him go, and picking up his dish went off home, leaving Snikīā'p in a sad and disabled condition. It was some time before his paws healed up, and even then they were not as before. The cords and muscles had been so severely scorched that they remained contracted, and he could never again stretch out his paws as before.

Thus was Snikīā'p the impostor punished by Spatc, and thus it is that the Coyote's paws are contracted and bent to this very day.

Story of Ha'nnī's Wife and the Revenge of her Son.

A long time ago there lived at Tl'k·umtcīn (Lytton) a chief who had an only daughter who was very beautiful. The girl led a very secluded life, never being permitted to mix with the other girls or leave the house except at night. The maid gets very tired of this dreary kind of life, and one day begs her mother to allow her to go out and bathe in the river. The mother at length consents to her going. She chooses a secluded spot on the river's bank, disrobes there, and enters the water and swims about. As she was thus engaged the young men of the Salmon tribe came up the river. They came with the intention of seeking her in marriage, so renowned had she become on account of her beauty. Four of her salmon suitors came up in their canoe. Three of these were named respectively Kōīē'ya (spring salmon), Swāas ('Sockeye' salmon), and Ha'nnī (humpback salmon). They happened to land just where the girl was bathing. At first she did not see them, but presently, when they had landed and she was about to come out of the water, she caught sight of them. Being naked, she feels abashed and ashamed, and sits down in the water to hide her person, and asks them to give her her clothes. The salmon reply that they have come to take her away. They give her the clothes and take her away with them to the coast without further ceremony. They cast lots whose wife of them she shall be, and Ha'nnī the Humpback salmon gets her. She becomes his wife, and a son is born to them. In the meantime the parents and friends of the girl make diligent search and inquiries for her everywhere, but can hear nothing of her. They suppose she has been drowned. The following year the Humpback Salmon husband, accompanied by all the other fish, canoed up the river to the girl's old home at Lytton. As they neared the place two little river fish, the tcoktcī' and the ni'nᴇktcin, hastened on before and told the parents that their daughter was returning with the Coast fish. Everybody is delighted to hear the news, and the people paint their faces white and red to show their joy. The news of her arrival soon spreads far and wide, and the people of Nicola heard of it among the rest. Now at this place there were many notable men. Four of these, named respectively Kōi'ᴇkin (Wolverine), N'Qoeni'ken (Badger ?), Qua'kqōc (Marten), and Tcītc'q (Weasel), determined to go down to Lytton and carry the girl off. They arrived during the night. When they got there a great gambling bout was going on in the keekwilee-house of the father of the girl. All the Fish people were there, as well as the chief's own friends. A big fire had been built to light up the house, that everybody might watch the game. The large crowd of people and the big fire made the house very warm. The daughter begins to feel the heat very trying. Presently she can stand it no longer, and asks to be allowed to go out and get some fresh air. She is permitted to pass, and climbs the notched pole that led through the smoke-hole. The four Nicola men are just outside, and have observed all that took place. They see the girl climbing the pole below them, and when her head appears at the opening Tcitcq the Weasel makes a jump, and passes through her mouth into her stomach. The girl is unconscious of what has taken place, she only suddenly feels sick. When her head is out of the smoke-hole Qua'kqōc the Marten leaps into her mouth and passes into her stomach. The girl at this feels as if she were half dead, and hastens to get outside. But when she is partly out NQoeni'ken the Badger makes a leap, and passes also into her stomach. She is fainting now as she steps out from the hole; and when Kōi'lᴇkin the Wolverine follows his fellows and jumps into her stomach she falls down dead. A little later, when the others come out, they find her lying dead on the ground. Everybody is in great distress, and the greatest medicine-man of the district is called in to see if he can restore her to life again. He performs a great dance, but all to no purpose. The young woman remains dead. Other medicine-men now try their skill, but with no better success. They desist from their efforts to restore her, and next day they bury her. The party now breaks up, everybody being very sad. The Salmon and Coast fish return home again. The night following, the Nicola chiefs, who had caused her death in the way related, now restore her to life, and return with her to their own country. Here the young woman lives with them. In course of time a rumour of her presence among the Nicola tribe reaches her own people. Word is sent all round to all the camps and to all the Fish people of the coast. A meeting is convened at which war is declared by the Fish tribe against the Nicola people, who are all members of the Animal tribe. All the Coast fish, with Hō'atl the Sturgeon at their head, swarm up the Fraser to Nicola. In such numbers did they come that the upper river was too narrow and confined to hold them all. A fierce battle now takes place between the Fish of the Coast and the Animals of Nicola. The Animals came in from all parts to help their friends at Nicola, and after a bloody conflict the Fish are beaten, and great numbers of them are killed. Those that escaped from the fight are followed by the victorious Animals, and not one of them, except the mighty armoured Sturgeon, escapes to get back to the coast again. Even the great

Sturgeon is often hard pressed, and obliged to use strategy to get away from his pursuers. It is to his efforts to thus escape that the winds and turns and angles in the Fraser are due. He caused them to appear when his pursuers were getting too near and embarrassing him.

When the Sturgeon chief gets back to the coast, the son of the captured woman is much grieved to hear of the disaster which has befallen his tribe, and he determines to avenge the slaughter of his friends when older. He thereupon undergoes a course of discipline and exercise to fit himself to become a powerful medicine man. In course of time he acquires great power. He now determined to take his revenge upon the Nicola men. He goes up the river, and in time gets to Nicola. When he arrives he goes to where his mother is. She does not recognise him in the tall and handsome man before her. The people are much surprised at the visit of the stranger, but treat him hospitably. They inquire from what direction he comes. He answers: 'From below.' The Grizzly, the Black-bear, the Badger, the Wolverine, the Weasel, the Wolf, and the Coyote suggest that they shall hold a great dance and test their medicine powers against that of the stranger. He agrees, and that same night a great medicine dance is held. They first let the fire out, and then they began the contest, one by one. The Black-bear opens the dance, but he is a failure. The others follow in due order, but none of them is able to do anything very wonderful till Snikīā'p the Coyote comes forward. Snikīā'p has power over the north wind, and can summon it at his will. When he begins to dance the wind begins to rise. As he proceeds and his dancing quickens, the wind increases in force and volume, till presently the very ladder is shaking and the snow is falling fast. This dance is considered a great success by his companions. When he stops, the wind and snows stop too. It is now the stranger's turn. Before he begins he goes to his mother and tells her she must go outside. She leaves the keekwilee-house. As soon as she is gone he begins his dance, singing as he dances a fire song: 'ō'ī, ō'ī, ō'ī, ō'ī,' &c. (stem of term 'fire,' as seen in the word *ō'iyip*= to burn). Sparks now began to fly about, and presently sheets of flame appear, and in a short time the house is on fire, and every one is much frightened. The stranger stops and utters the word Ahō'sa, and the fire disappears. Snikīā'p now dances a second time, and again the cold north wind and the snow appear. Ha'nnī's son exhibits his power again in like manner, and is followed a third time by Snikīā'p. The young man now finds that he has the strongest medicine, and prepares to carry out his scheme of revenge. He commences to dance a third time. This time he sings his fire song louder, and dances more rapidly. Soon the flames spread everywhere. They burn the house and the people, and when everything is well on fire he gives a great jump, and leaps out through the smoke-hole. Everybody is destroyed by the fire, and the slaughter of his tribe is thus avenged. He now returns to the coast, taking his mother back with him.

The N'tlaka'pamuQ Indians account for the presence of the fish in the rivers up country by saying that when the Nicola Animals killed the Coast Fish the spawn of many of the latter was left in the streams, which later developed into fish. One of the effects, though, of the great licking the Fish got is seen, they believe, in the form of the descendants of some of them. For instance, the flat-headed river-cod is said to have inherited his flat head from his ancestor, who was killed by a great blow, which knocked his head flat.

General Remarks.

A consideration of the foregoing folk-tales brings out many points of interest. It will be seen, for instance, that the number 4 is an oft-recurring number. It is undoubtedly the sacred mystic number of the Salish stock, as we find it holding an equally predominant place in the myths and stories of the Bella Coola tribe on the coast, between whom and the N'tlaka'pamuQ there has been no intercourse from time immemorial. I am unable at present to say how far it is common to the mythology of the other tribal divisions of this stock; but finding it in these two widely divergent branches separated by impassable physical barriers, we may fairly conclude that it is common to the whole. Our knowledge of the mythology of the other great divisions of the Salish is not yet very extensive if we except that of the Bella Coola recently published by Dr. Boas; and it will be interesting and profitable to gather collections similar to these from all the other divisions. Whether all the tribes of the Salish have such a store of folk-tales, or are as imaginative as the N'tlaka'pamuQ, I am unable to say. That they possess more, or have more active and lively imaginations, I much doubt, for it seems scarcely possible to find a people more highly imaginative than the folklore of the N'tlaka'pamuQ shows them to be, or rather to have been. There is not a single peculiar feature of the landscape which has not its own story attached to it. There is no conspicuous object of any kind within their borders but has some myth connected with it. The boulders on the hill-sides, the benches of the rivers, the falls, the cañons and the turns of the Frazer, the mud slides, the bare precipitous cliffs, the sand bars, the bubbling spring and the running brook, the very utensils they use, all have a history of their own in the lore of this tribe. Every single peculiarity in bird, or beast, or fish is fully and, to them, satisfactorily accounted for in their stories. The flat head of the river cod, the top-knot of the blue jay, the bent claws and dingy brown colour of the coyote, the flippers of the seal, the red head of the woodpecker, and a host of other characteristics, all have their explanation in story.

Some of the tales here recorded are extremely valuable to us in the glimpses they afford of the past and, for the most part, forgotten life, customs, thoughts, and beliefs of this people. The intense repugnance in which they held incestuous intercourse, the deep shame and disgrace that followed a lapse from virtue in the unmarried of both sexes, and the serious and damaging reflections it cast upon the parents, are portrayed in the somewhat pathetic story of the sister who was wronged by her own brother. The pains she took, and the lonely exile she bore to shield her father's name from dishonour, and finally her own and her guilty brother's self-destruction, all make this abundantly clear. Whether this story has any foundation in fact, or whether it was told merely to inculcate virtue and a hatred of incest, is quite immaterial. That it showed and embodied the feelings of the people on this head is perfectly clear, and that is the point which is of interest to us. The praise and enjoinment of virtue, self-discipline, and abstinence in young men is no less clearly brought out, while the respect and consideration paid by the young to the elders of the family and tribe is an equally conspicuous virtue. In no other way could we learn these things. The folk-tales alone can now recall the vanished past for us. Hence their high value in ethnological inquiry, and the importance of bringing them together and recording them while there is yet opportunity. The pictures which these tales reveal to us of the ancient life and condition of these village communities is that of a rude and simple, but virtuous people, living at peace among themselves under the mild patriarchal sway of their local chiefs, who were assisted in their government by the elders of the tribe. We find them skilful and resourceful in the adaptation of means to ends, exhibiting at times remarkable ingenuity—as witness their skill in basketry; hardy and successful hunters, preferring peace to war, but ready and prepared to defend their homes and property when called upon to do so. The picture makes their lives stand out in strong contrast to those of their congeners on the coast, whose totemic and clan system, secret societies, ceremonial dances, and other peculiar institutions find no counterpart here at all. If we admit the principle that the simpler the life and institutions of a people are, the nearer they are to their primitive original condition, we learn from a consideration of these stories that the manners and customs and life of the coast Salish have been much modified since the separation of the stock into its present divisions. This, it may be pointed out, incidentally confirms what Dr. Boas and other investigators have called attention to in their writings.

It may be of interest to add here that a body of mythological matter, collected by Mr. James Tait, of Spence's Bridge, B.C., from the upper N'tlaka'pamuQ, has recently been published by the American Folklore Society. I have not yet seen this, but I have no doubt a comparison of the two will bring out many points of interest.

Marriage Customs of the Yale Tribe.

The following account of the marriage customs of the Yale tribe of the Salish stock of B.C. was given to the writer by chief Mischelle, of Lytton, whose father was a Yale Indian. These customs have been much modified of late years. Some of the Indians are now married, after the manner of the whites, by the priest or minister, some few retain the old customs, and others unite the church service with the customs of their forefathers, and thus go through what is practically a double marriage.

Formerly, when a young man wished to marry a girl he went to the house of her father at daybreak and squatted down just inside the door with his blanket so wrapped about him that only his face was visible. When the father rose he perceived the young man there, but passed by him without taking any notice of his presence. All the other members of the household did the same. They prepared the morning meal, sat down to it, and still continued to ignore the young man's presence, who, as soon as the meal was finished, quietly left the house without speaking. The members of the girl's family make no comment upon the occurrence. The following morning the young man enters the house and squats down again by the door. After breakfast he departs still without speaking. After his departure on this second occasion the father of the girl calls the family and relatives together and discusses with them the eligibility of the suitor. If acceptable to the family, when he presents himself next morning he is invited to breakfast, and knows thereby that his suit is accepted. After the meal is over, without in any way referring to the object of his visits, he leaves the house, and in the course of a day or two sends a message to the girl's father saying that he intends paying him a formal visit. The girl's people make preparation to receive him and the friends who accompany him. Accordingly at the time appointed, in company with his friends, who all, as well as himself, bring gifts and food to the girl's father, he makes his formal call, and presents the gifts of himself and friends.

When these have been received they sit down to a feast to which all the friends and relatives of both parties have been invited. After the feast is over the bridegroom takes his bride and departs with her to his own house. When two or three weeks have intervened, the wife's relations send word that they are coming to pay the young couple a visit of ceremony. The young wife forthwith prepares a feast for them, and all the young man's friends and relatives turn up again, together with those of the wife. Presents of value equal to those given by the bridegroom and his friends are now presented to him by the wife's father and friends, after which all sit down to the feast prepared for the occasion. When this is over, the marriage is regarded as consummated, and the two are man and wife in the eyes of the whole community.

But, on the other hand, should the suitor not be agreeable to the girl's parents, the eldest male member of the girl's family is appointed to acquaint the youth on his third visit that his advances are not acceptable to the family, and that he had better discontinue his visits. On the third morning, therefore, when the young man presents himself and squats down in the customary place, the old man chosen for the office of messenger goes over and informs him that the decision of the family is against him, and that he had better seek a wife elsewhere. If the young man's affections have not been very deeply engaged, he will accept his dismissal and trouble them no more; but if, on the contrary, he has set his heart on getting this particular girl for his wife, he will now go to the forest and cut down a quantity of firewood. He chooses for this the best alder-wood he can find, as this is more highly esteemed than other kinds among the Indians on account of its emitting no sparks when burning. This he will take to the house of the girl's father next morning at daybreak, and start a fire for the inmates. If the girl's parents are serious in their rejection of him as their daughter's husband, they will take both fire and wood and throw them out of the house. The youth is in no wise daunted by this, and repeats his action on the following morning, when they again reject his services, and cast out the wood and fire as before. But during that day, seeing his determination to get the girl for his wife, her people call another family council, at which the father points out to those assembled the young man's perseverance and earnestness, and asks for their advice under the circumstances. They all answer that he must do what he thinks right and fitting. If the objection to the young man's suit has come perchance from the mother of the girl—as it frequently does if she thinks the youth will not make a good food supplier for her daughter—the father asks her what she now thinks about the matter. She will probably reply that if they refuse any longer to accede to the young man's wishes they will give him pain, so she withdraws her opposition. The girl is then for the first time in the ceremony consulted in the matter, but as her desires are mostly what her parents wish, she rarely dissents from the arrangement. The matter thus being satisfactorily settled, the next morning, when the persevering youth presents himself with his wood and builds a fire, some of the elder members of the family come and sit round and warm their hands over it. By this action the youth knows that his suit is at last accepted, and that his perseverance is not to go unrewarded. He presently joins them at the morning meal, and the conclusion of the affair from that moment follows the course already described where the suitor was at the outset accepted.

The Anthropology and Natural History of Torres Straits. Report of the Committee, consisting of Sir WILLIAM TURNER (*Chairman*), Professor A. C. HADDON (*Secretary*), Sir MICHAEL FOSTER, Dr. J. SCOTT KELTIE, Professor L. C. MIALL, and Professor MARSHALL WARD.

A brief account of the work of the expedition has been published in the Journal of the Royal Geographical Society (September, 1899, p. 302), and a more detailed one, giving a number of anthropometrical results, was published in *Nature* (August 31, 1899, p. 413). These may be taken as the official Report of the Expedition.

The following abstracts of papers are samples of some of the work accomplished.

All the results of the Expedition will be duly published by the University of Cambridge in a series of memoirs.

APPENDIX.

I. *Notes on the Yaraikanna Tribe, Cape York, North Queensland.*
By Dr. A. C. HADDON, *F.R.S.*

The Yaraikanna are fairly typical Australians in appearance; six men were measured, average height 1·625 m. (5 ft. 4 in.), cephalic index 74·7 (extremes, 72·4–77·7). A lad is initiated by his *mawara*, apparently the men of the clan into which the boy must subsequently marry; he is anointed with 'bush-medicine' in the hollow of the thighs, groins, hollow by the clavicles, temples, and back of knees to make him grow—the bull-roarer is swung. In the *Yampa* ceremony the initiates (*langa*) sit behind a screen in front of which is a tall pole, up which a man climbs and catches the food thrown to him by the relatives of the *langa*. Then the bull-roarer is swung and shown to the *langa*; lastly, a front tooth of the *langa* is knocked out, with each blow the name of a 'land' belonging to the boy's mother or of her father is mentioned, and the land, the name of which is mentioned when the tooth flies out, is the territory of the lad. Water is next given to the boy, who rinses out his mouth and gently empties his mouth into a palm-leaf water vessel; the clot by its resemblance to some animal or vegetable form determines the *ari* of the lad. The *ari* appears to be analogous to the *manitu* or *okki* (or 'individual totem' of Frazer) of the North American Indians. After the ceremony the boy is acknowledged to be a man. Other *ari* may be given at any time by men who dream of an animal or plant, which is the *ari* of the first person they meet on awakening. The *Okara* ceremony was alluded to, and various customs, among which may be noted, children must take the 'land' or 'country' of their mother, a wife must be taken from another country, all who belong to the same place are brothers and sisters.

II. *Contributions to Comparative Psychology from Torres Straits and New Guinea.*

1.—*General Account and Observations on Vision, &c. By* W. H. R. RIVERS.

Previous work on the psychology of savage peoples has been limited to deductions from their behaviour, customs, and beliefs. The special object of the psychological work of the Cambridge Anthropological expedition was to employ exact experimental methods in the investigation of the mental character of the natives of Torres Straits and New Guinea. By means of these methods it is only possible to investigate directly the more elementary mental processes, but in the course of such work one meets indirectly with many facts which illustrate the higher and more complex developments of mind.

Observations were made in Murray Island by Messrs. McDougall, Myers, and myself on about 150 individuals. The subjects investigated included visual acuity, sensitiveness to light, colour vision, including colour-blindness, binocular vision, and visual space perception; acuity and range of hearing, appreciation of differences of tone and rhythm; tactile acuity and localisation, sensibility to pain, estimation of weight; smell and taste; simple reaction times to auditory and visual stimuli, and choice reaction times; estimation of intervals of time; memory; strength of grasp and accuracy of aim; reading, writing, and drawing; the influence of various mental states on blood-pressure; and the influence of fatigue and practice on mental work.

In Kiwai and Mabuiag fewer observations could be made, owing to the fact that most of the apparatus had been taken on to Borneo, but observations were made by Mr. Seligmann and myself on more than 100 individuals, many of whom were not, however, natives of these islands. The subjects investigated were chiefly visual acuity and colour vision; auditory acuity; smell and touch; writing and drawing.

It is not possible now to do more than give a rough sketch of our results. Most of the methods used had been in some degree modified to meet the unusual conditions, while some were new, and the consequence is that, with one or two exceptions, we have very few data with which to compare our results. The exact bearing of most of our observations will only become apparent when comparative data on European and other races have been collected.

Our observations were in most cases made with very little difficulty, and, with some exceptions, we could feel sure that the natives were doing their best in all we asked them to do. This opinion is based not only on observation of their behaviour and expression while the tests were being carried out, but on the consistency of the results. The small deviations of individual observations from the average (mean variation) showed that the observations were made with due care and attention.

The introspective side of psychological experimentation was almost completely absent. We were unable to supplement the objective measurements and observations by an account of what was actually passing in the minds of the natives while making these observations. Attempts were made in this direction without much success.

One general result was to show very considerable variability. It was obvious that in general character and temperament the natives varied greatly from one another, and very considerable individual differences also came out in our experimental observations. How great the variations were as compared with those in a more complex community can only be determined after a large number of comparative data have been accumulated.

Another general result which should be of great interest to anthropologists is that the natives did not appear to be especially susceptible to suggestion, but exhibited very considerable independence of opinion. Leading questions were found not to be so dangerous as was expected. It is hoped that when our results are worked out, it will be possible to express in some definite manner the suggestibility of these people as compared with Europeans.

Of the special investigations undertaken by myself, that on visual acuity will be the subject of a paper in another Section.

The colour vision of the natives was investigated in several ways. A hundred and fifty natives of Torres Straits and Kiwai were tested by means of the usual wool test for colour-blindness without finding one case. About eighty members of other races, including Australians, Polynesians, Melanesians, Tamils, and half-castes, were also tested without finding one case, except among natives of Lifu. No less than three out of eight natives of this island were found to suffer from well-marked red-green blindness of the ordinary type. Unfortunately the number of Lifu natives who could be examined was too small to allow any definite conclusions to be drawn, but the possibility is suggested that colour-blindness may be a racial peculiarity, a fact which, if established, would be of great ethnological importance.

The names used for colours by the natives of Murray Island, Mabuiag, and Kiwai were very fully investigated, and the derivation of such names in most cases established. The colour vocabularies of these islands showed the special feature which appears to characterise many primitive languages. There were definite names for red, less definite for yellow, and still less so for green, while a definite name for blue was either absent or borrowed from English.

The three languages mentioned, and some Australian languages, seemed to show different stages in the evolution of a colour vocabulary. Several Australian natives (from Seven Rivers and the Fitzroy River) appeared to be almost limited to words for red, white, and black. In Kiwai there was no word for blue, for which colour the same word was used as for black, while the name applied to green appeared to be inconstant and indefinite. In Murray Island the native word for blue was the same as that used for black, but the English word had been adopted and modified into *bŭlu-bŭlu*. The language of Mabuiag was more advanced; there was a word for blue (*maludgamulnga*, sea-colour), but it was often also used for green.

Corresponding to this defect of colour terminology, there appeared to be an actual defect of vision for colours of short wave-length. In testing with coloured wools, no mistake was ever made with reds, but blues and greens were constantly confused, as were blue and violet. The same deficiency in seeing blue seemed also to be shown in experiments on the threshold of sensitiveness for red, yellow, and blue, carried out with Lovibond's tintometer. Experiments on the distance at which small patches of different colours could be recognised also showed great inferiority in seeing blue as compared with red, but the few comparative observations so far made do not enable one to say that there is any striking difference between Europeans and Papuans in this respect.

Observations were also made on the colour vision of the peripheral retina, on after-images, and on colour contrast.

Observations were made by means of Hening's fall experiment which showed the existence of binocular vision in all except one man with an orbital tumour.

Quantitative observations were made on some visual illusions.

Numerous observations were made on writing and drawing, the former chiefly in the case of children. The most striking result here was the ease and correctness with which mirror writing was performed. In many cases native children, when asked to write with the left hand, spontaneously wrote mirror writing, and all were able to write in this fashion readily. In some cases children, when asked to write with the left hand, wrote upside down.

Experiments were made on the estimation of time. The method adopted was to give signals marking off a given interval; another signal was then given as the commencement of a second interval, which the native had to finish by a similar signal when he judged it to be equal to the given interval. This somewhat difficult procedure met with unexpected success, and intervals of 10 seconds, 20 seconds, and one minute were estimated with fairly consistent results.

Nearly all the investigations gave some indication of the liability to fatigue and the capability for improvement by practice, but these were also the subject of a special investigation carried out by modifications of Kraepelin's methods.

2.—*Observations on Hearing, Smell, Taste, Reaction Time, &c.* *By* C. S. Myers.

The conditions for testing acuity of hearing were very unfavourable on Murray Island, owing to the noise of the sea and the rustle of the cocoanut palms. The general results of many experiments lead me to conclude that few Murray Islanders surpass a hyper-acute European in auditory acuity, while the majority cannot hear as far. For the determination of the upper limit of the perception of tone I used Hawksley's improved form of Galton's Whistle. Of the fifty-one Murray Islanders who were investigated, all save one readily appreciated the difference between the pure high note and the noise of the blast that is inseparable from it. Experiments were also made to determine the minimum perception of tone-differences. Twelve islanders were tested for their sense of rhythm; this was found to be remarkably accurate for 120 beats of the metronome to the minute, and somewhat less so for 60 beats. Most of the subjects had a tendency to vary in the direction of increasing the rate of the taps.

Olfactometry is very difficult to prosecute for various reasons. Until I have made further comparative observations on Europeans, I can draw no certain conclusions as to the relative smell-acuity of the former and the Murray Islanders; but so far as my experiments go, they seem to indicate no marked superiority in the development of this sense among the islanders. Doubtless hyper-acuity is more common among them, but there seems no reason to believe that they are able to perceive such traces of odour as would be imperceptible to the most sensitive European noses.

Experiments were made to determine the appreciation and recognition of the common tastes—sweet, salt, bitter, and acid. Sugar and salt were readily recognised, acid was compared to unripe fruit; the bitter is the most uncertain—evidently there is no distinctive name for it in the Murray Island vocabulary.

Binet's diagram used for testing visual memory was employed on twenty-eight people with interesting results.

Numerous time reaction experiments were made, more on simple auditory reaction than on simple visual reactions; a few visual choice reactions were also made. The time of the simple reaction is not sensibly longer, but probably in many cases even shorter, than would be that given by a corresponding class of Europeans. The experiments clearly showed the great difference of temperament among the individuals investigated. There was at one extreme the slow, steady-going man who reacted with almost uniform speed on each occasion; at the other extreme was the nervous, high-strung individual who was frequently reacting prematurely, and whose mean variation in consequence was relatively great. Yet the mean variation, save in the choice-times, was extraordinarily low for such unpractised people.

3.—*Observations on the Sense of Touch and of Pain, on the Estimation of Weight, Variations of Blood-Pressure, &c.* *By* W. McDougall.

The power of discrimination of two points by the sense of touch was investigated in a series of fifty adult males. On half the number of subjects the observations were made on the skin of the thumb, of the second toe, and of the nape of the neck, and on the skin of forearm on all the subjects. There was a general correspondence of delicacy of discrimination in the different parts of the skin tested in any one subject. A few of the subjects showed a very much greater delicacy of discrimination than the others, while the latter showed a fairly uniform delicacy which is considerably greater than that shown by the short series of white men who have been tested by the same method.

Observations on the sensitivity to pain produced by simple pressure on the skin were made by means of Cattell's algometer. With this instrument it seems to be possible to register accurately the point at which, with increasing pressure, a painful element is first perceived. The sensitivity to pain as thus determined seemed to be, roughly, inversely proportional to the delicacy of touch discrimination in the series of individuals, and in the whole series the sensitivity seemed to be distinctly less than in the short series of white men observed.

Similar series of observations were made on thirty children. It should be understood that the degree of pain produced was in all cases so slight as not to spoil the pleasure and interest of subjects in the proceedings.

The accuracy of localisation of touch sensations was also measured in a number of the same subjects, and temperature spots were mapped out in a few.

In the same subjects a series of observations on the delicacy of discrimination of differences of weight was made, and other series were made with the purpose of determining the degree of suggestibility of the people—the effect of size as appreciated by sight and grasp on the judgment of weight. It was interesting to find that although the abstract idea of weight seemed entirely new to the minds of these people, and no term in their language answered to it exactly, yet their power of discrimination of difference is at least as good as our own.

In the same series of people the blood-pressure was observed by means of Hill and Barnard's sphygmo-manometer during rest, muscular work, mental work and excitement, and slightly painful skin-pressure, and marked variations recorded under these conditions. No series of observations on white men under similar conditions have yet been made for comparison.

III. *The Linguistic Results of the Cambridge Expedition to Torres Straits and New Guinea.* *By* SIDNEY H. RAY.

The geographical position of the Torres Straits Islands renders an accurate knowledge of the construction of the languages important, especially for determining the relation of the Australian languages to those of New Guinea and the Malay Archipelago, and also, perhaps, to languages further west in Southern India and the Andaman Islands. Several missionaries have worked among the Eastern and Western tribes of the Straits, and the existing gospel translations are reputed to have been made by them, but no one has preserved any record of, or can throw any light upon the construction of the languages. The translations were analysed in a former work by Dr. Haddon and myself,[1] but the result was somewhat unsatisfactory. As we had dealt exhaustively with the vocabularies, my attention during my stay in the islands was mainly concentrated upon the grammars of the two languages.

The construction of the Eastern (Murray and Darnley Islands) language was found to be very complex, modifications of sense being expressed by an elaborate system of prefixes and suffixes.

The grammar bears no resemblance to the Melanesian, and but little to the Australian. The speech used in school and church is a debased form of the original; as my native informant described it, 'they cut it short.' As most of the young people know English, it is very probable that the pure language will die out with the older folk.

The language of the Western tribe was studied at the central island of Mabuiag, but the closely allied dialects spoken on Warrior Island, Saibai, and Prince of Wales Island, were also investigated. The grammar of this language is decidedly of Australian type, though there is no marked connection in structure or vocabulary with languages of the neighbouring mainland. Of these latter, the dialect of the Yaraikanna tribe in the neighbourhood of Cape York was also investigated.

In New Guinea, at Port Moresby, the Motu language is well known, and I used it as the means of obtaining from Koitapu natives some illustrations of their strange language. The results show that there are people living in the Motu

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[1] 'A Study of the Languages of Torres Straits.' By S. H. Ray and A. C. Haddon, *Proc. Roy. Irish Acad.* (3) 1893, ii. p. 463; iv. 1897, p. 119.

villages, whose languages are totally distinct from that of the Motu both in structure and vocabulary. A language (Koiari) similar to the Koitapu was found to prevail in the district inland from Port Moresby.

At Port Moresby I also obtained from some Cloudy Bay natives specimens of their language, which, like those of Koitapu and Koiari, approaches the Australian type, but has nothing in common with the Melanesian.

At Bulaa (Hula), Hood Peninsula, the structure of the dialects of Bulaa, Keapara (Kerepunu), and Galoma were the subject of conversations with Kima, the intelligent chief of Hula. These dialects are related to the Motu, and, like it, are in grammar and vocabulary very closely akin to the languages of the Melanesian Islands.

At Saguana in Kiwai Island in the Fly River Delta, I took advantage of a fortnight's stay to make a first investigation into Kiwai and Mowata grammar. The language is very difficult, with exceedingly complex forms. It shows some traces of connection with the speech of the Eastern Islanders of the Torres Straits.

IV. *Seclusion of Girls at Mabuiag, Torres Straits.*
By C. G. SELIGMANN.

When the signs of puberty appear, a circle of bushes is made in a dark corner of the girl's parents' house. The girl, now called *Kerngi gasaman*, is fully decked with cross shoulder-belts of young cocoanut leaf, with leglets just below the knee, with anklets, with petticoat, with chaplet round head, with armlets of cocoanut with cut dracænas in them; with shell ornaments hung on front and back of chest, and with nautilus shell ornaments in her ears. She squats in the centre of the bushes, which are piled so high round her that only her head is visible. This lasts for three months, the bushes being changed nightly, at which time the girl is allowed to slip out of the hut. She is attended by one or two old women, the girl's maternal aunts, who are especially appointed to look after her. These women are called *Mowai* by the girl; one of them cooks food for the girl at a special fire in the bush. The girl may not feed herself or handle her food, it being put into her mouth by her attendant women. No man—not even the girl's father—may come into the house; if he saw his daughter during this time he would certainly have bad luck with his fishing, and probably smash his canoe the first time he went out. The girl may not eat in the breeding season turtle or turtle eggs; no vegetable food is forbidden. The sun may not shine on her; 'he can't see daytime, he stop inside dark,' said my informant. At the end of three months a girl is carried to the fresh-water creek by her *Mowai*, she hanging on to their shoulders so that not even her feet touch the ground, the women of the tribe forming a ring round the girl and *Mowai*, thus escorting her to the creek. Her ornaments are removed, and the *Mowai* with their burden stagger into the creek, where the girl is immersed, all the women joining in splashing water over the three. On coming out of the water, one of the *Mowai* makes a heap of grass for her charge to squat on, while the other runs to the reef and catches a small crab. She tears off its claws, and with these she runs back to the creek, where a fire has meanwhile been made, at which the claws are roasted. The girl is then fed on these by the *Mowai*. She is then freshly decorated, and the whole party marches back to the village in one rank, the girl being in the centre, with the *Mowai* at her side, each of them holding one of the girl's wrists. The husbands of the *Mowai*, called by the girl *Waduam*, receive her, and lead her into the house of one of them, where all eat food, the girl being now allowed to feed herself in the usual manner. The rest of the community have meanwhile prepared and eaten a feast, and a dance is held, in which the girl takes a prominent part, her two *Waduam* dancing, one on each side of her. When the dance is finished the *Mowai* lead the girl into their house and strip her of her ornaments. They then lead her back to her parents' house.

V. *Notes on the Club Houses and Dubus of British New Guinea.*
By C. G. SELIGMANN.

One or more houses larger and more highly decorated than the rest, called in the Gulf and Mekeo districts *elamo* and *marea* respectively, are to be seen in every village of these parts of British New Guinea. No women may enter these, they are the club houses of the men, the home of the unmarried youths, and strangers are quartered there. Each family or family group, called *itsubu* in the Mekeo district, is responsible for the upkeep of one of these. Among the Toaripi much stress is laid on the convenience and advantage of an *elamo* in keeping the young men from the women's quarters, and their legend of the origin of the *elamo* relates how one of their ancestors, called Meuliave, was visited by Avara Laru, who rules the N.W. squalls, who bade him build a house for the unmarried youths into which no woman might come. Infringement of these rules is still met by Avara Laru destroying the *elamo*. Wooden effigies of birds and fishes are hung outside *elamos*, but these are not reverenced—the beast they represent is eaten when opportunities offer, and the family group is not called by their name. East of Delena *elamos* or *mareas* are not found, but their place is taken by the *dubu*, a platform, often two-storied, with elaborately carved corner posts and cross-pieces stretched longitudinally across the tops of these, which are hollowed to receive them. One man called *Dubu Tauna*, from each principal family of a family group (*iduhu*), looks after and is responsible for the *dubu*. The office is hereditary, not necessarily in the direct line. Women may not approach the *dubu* except on the Hood Peninsula, where once a year the girls who have become marriageable assemble on the *dubu*. The products of the garden and chase are sometimes hung on the *dubu*, which may rarely be painted red and white. Semon[1] notes that he has seen skulls hung on one, but does not state where. Before fighting, warriors fully decked and armed resort to the *dubu* and there mutter the names of their ancestors. After killing a man the successful warrior would, on his return to the village, go straight to the *dubu*, and on it eat his first meal. But little could be determined as to the meaning of the carving, the origin of the *dubus* themselves being unknown to the natives. At Qualimarupu there is a carefully excavated hollow in one of the corner posts, said to represent a bowl. The pattern, as a rule, is made up of a number of four-sided pyramids carved on the wood, and the tops of the corner posts are carved so as to resemble jaws, between which the cross-pieces rest. Perhaps these represent the jaws of a crocodile, the pyramids being conventionalised scales. This form of decoration is, however, found among inland people whose acquaintance with crocodiles must have been but slight.

VI. *Notes on Savage Music.* *By* C. S. MYERS.

As our modern orchestra admits the noises of drums and cymbals, and our harmony allows chords which in a more classical period were inadmissible, we, in our inquiry into past and primitive music, will not refuse to consider certain sounds as musical even though they be noisy. Sympathy should be our sole test of music. In savage life the songs of a tribe are its chief heritage. Certain songs recorded on the phonograph in Murray Island, Torres Straits, are now obsolete, and will probably die out with the old men. Neither there nor in Borneo could any trace of the notes of birds be found in the music. Of the two fundamentally distinct elements in music, rhythm and melody, the one has its basis in bodily movement, the other in the emotional recitative. In Murray Island the drum is beaten to accentuate the words of the old songs, the music being singularly lacking in rhythm; among the North American Indians, on the other hand, rhythm is well developed. The extraordinary complexity of rhythm in certain Malay music was graphically recorded.

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[1] *Im australischen Busch*, p. 353.

The Murray Islanders have a wonderfully developed idea of rhythm, as is proved by their being able regularly to continue accurately recorded beats of prescribed rapidity for a considerable period. Many suggestions have been made as to which of the intervals came most naturally to the human voice. The Murray Islanders have no polyphonic music, but in a chorus accompanying the songs of the Kenyah and allied races in Borneo a long-drawn note a fifth below the key-note runs drone-like through the song. A similar interval has been noted in one of the rare examples of polyphonic music found in North America.

Writers have been led to conclude that various peoples employed far smaller intervals than our own, misled apparently by viewing the numerous intervals as if they formed a scale instead of a series of notes from which various scales were derived. In this way travellers have been induced to look for quarter-tone music in uncivilised parts of the world; but the author has no doubt that those quarter-tones, which have been written down as occurring between any two whole (or semi-) tones, merely express a gradual descent in the voice from one of these tones to the other. The insensitiveness of the ear of the Murray Islanders to minute differences of interval was estimated by means of tuning-forks. The common incorrect intonation in savage music was alluded to.

Photographs of Anthropological Interest.—Report of the Committee, consisting of Mr. C. H. READ (*Chairman*), Mr. J. L. MYRES (*Secretary*), Dr. J. G. GARSON, Mr. H. LING ROTH, Mr. H. BALFOUR, Mr. E. S. HARTLAND, *and* Professor FLINDERS PETRIE, *appointed for the Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.*

THIS Committee was appointed by the British Association for the Advancement of Science in September 1898, to provide for the 'Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.'

A similar Committee on Geological Photographs was appointed in 1889, and has organised the valuable collection preserved in the Museum of Practical Geology. The Royal Geographical Society has gradually collected a large number of geographical photographs, many of which are also of anthropological interest. More recently the Hellenic Society has announced a large special collection for the use of students of the topography, civilisation, and art of Greece. And the Anthropological Institute possesses a considerable collection of photographs, which have been lately mounted and classified; and has permitted the registration of these in the list of the new Anthropological Photographs Committee.

The considerations which led to the appointment of this Committee are briefly as follows:—

(1) A very large number of Anthropological phenomena can only be studied in the field, or by means of accurate reproductions; but the latter are in many cases difficult to procure, except where typical examples have been regularly published; and even then it is frequently of advantage to be able to acquire separate copies of single plates or illustrations, for purposes of comparison, without breaking up a collection or a volume.

(2) On the other hand, most travellers, collectors, and museum officials find it necessary to make many photographic negatives in the course of their own work, for which they themselves have no further use, but which

they would gladly make accessible to other students, if any scheme existed by which this could be done without trouble to themselves. Such negatives also accumulate, and take up valuable space; and are very liable to damage through neglect.

(3) Further, though many professional photographers in remote parts of the world have made admirable use of their opportunities of recording native types, customs, and handiwork, there has hitherto existed no single record of what has been done in this direction; with the result that valuable collections have remained practically inaccessible to those in whose interest they have been made. In the case of the Hellenic Society, already cited, the inclusion, in the reference collection, of selected prints from the negatives of professional photographers abroad has been found to be of great advantage to teachers and students, who consult it with the view of choosing the best representations to add to their own series.

What appears therefore to be required is, in the first place, a register of the photographic negatives which can be made generally available, illustrated by a permanent print from each, preserved at an accessible centre; together with an arrangement by which properly qualified students may be enabled to have duplicate prints made from them for their own use, at a reasonable price. In any such scheme it is understood that the copyright, for purposes of publication, remains with the owner of the negative, and that all duplicate prints distributed under this arrangement are subject to that qualification.

In establishing such a Register and Collection of Anthropological Photographs, the Committee invites the co-operation of all owners of suitable photographic negatives, who are requested to submit for registration one unmounted print from each negative (which will be mounted by the Committee and preserved either at the office of the British Association, or in some central and accessible place); together with a full description of the photograph. The latter should state:

(1) The subject of the photograph, and the place where the original subject is (or was) to be found, the date when the photograph was taken, and name of the person who took the photograph.

(2) The name and address of the owner of the negative.

(3) The whereabouts of the negative itself: *i.e.* whether it is retained by the owner at his own address, or deposited with a professional photographer at an address named, or with the Committee.

(4) The terms on which prints, enlargements, and lantern slides will be supplied when ordered through the Committee.

The Committee has made arrangements for the storage and insurance of any negatives which may be deposited on loan, and for the production of prints and lantern slides from them to order; and a number of negatives have already been so deposited.

The Secretary of the Committee will be glad to supply forms for the registration of negatives, and any further information which may be required. It is hoped that it may be possible to publish a first list of photographs in the next report.

The Lake Village at Glastonbury.—Fourth Report of the Committee, consisting of Dr. R. MUNRO (*Chairman*), Mr. A. BULLEID (*Secretary*), Professor W. BOYD DAWKINS, General PITT-RIVERS, Sir JOHN EVANS, *and* Mr. A. J. EVANS. (*Drawn up by the Secretary.*)

WE regret that from unavoidable reasons the excavations of the Marsh Village near Glastonbury could not be reopened this summer, but the investigations will be continued another year, and the examination of the site proceeded with until completed. Notwithstanding the discontinuance of the excavations this year, an important amount of work has been accomplished since our last report was presented at the Bristol Meeting last autumn.

The excavated ground mentioned in the following report was situated at the centre and west side of the village, and includes fifteen dwelling mounds and the ground around them. The more important dwellings were the following :—

P.P.—A large mound situated near the west border of the village composed of four horizontal layers of clay one foot thick. Near the centre of the mound there were ten superimposed hearths. The timber foundation was strongest at the south and south-west sides of the mound, and overlying the entire surface of the timber was a layer of rushes one foot thick, compressed to such an extent that it both cut and looked like wood when making a section. Amongst the timber and vegetable débris in the foundation of this mound were dug up a finely turned wheel-spoke, and many fragments of pottery and bones, some very complete and well preserved hurdle work, evidently part of a dwelling wall fallen flat; near this there were also a number of pieces of cut wood, the base of a wooden tub, a wood mallet, and a wheel cut from the solid fifteen inches in diameter.

Mound E E consisted of three floors of clay, the total thickness of which was 2 feet 9 inches; the dwelling that was contemporary with the middle floor was evidently destroyed by fire. This mound was noteworthy for the number of baked clay sling pellets, and for a human skull, the latter object being discovered amongst the timber under the centre of the dwelling.

Mound C C was in size an unimportant one, but was interesting in many ways. It consisted of four layers of clay of irregular outline; it contained as many as ten hearths; the timber foundation was slight, except under the lowest hearth, where it formed a square platform from five to six feet wide. In the upper, second, and lowermost floors, basin-shaped depressions were found with the sides and base of baked clay; they were evidently circular holes cut in the clay floors, the sides carefully smoothed and baked. Two of the depressions were within one foot of their respective hearths. On and around this mound were dug up great quantities of pottery, some loom weights of baked clay, five bone weaving combs, three bone needles, one bronze fibula, and several perforated bones and stone spindle whorls.

The remaining dwellings did not yield anything of special note. The numbers of smaller objects found during the latter part of last season are as follows :—Thirty pieces and implements of cut bone, ten pieces of bronze, portions of two glass beads, fifteen pieces of cut horn, including seven weaving combs. There were also objects of iron, lead, tin, and Kimmeridge shale, four quern stones, fifteen spindle whorls, and the usual quantity of pottery in fragments, bones, and baked clay. Since the last report was read, Dr. J. H. Gladstone has very kindly made an exhaustive examination and analysis of the metals, and in his three valuable reports he says :—

Report A.

I have examined the specimens you kindly sent me from the Lake Village both by the microscope and chemical analysis. The following are the results arrived at :—

No. 1 Bronze.—This consisted of thin strips of metal, evidently coated with oxide. The smaller piece was analysed just as it was, and gave

Copper	60·8 per cent.
Tin	23·5 ditto

There was a little iron, but no lead or silver was found, nor any sulphur. The deficiency on analysis must have been almost wholly oxygen. As the tin is in such unusual proportion, I scraped the surface of both sides of the larger strip, and obtained a very thin plate which showed metallic lustre. This, pretty nearly freed from the crust of oxide, was analysed as before, and then gave

Copper	80·7 per cent.
Tin	15·7 ditto

There was a small quantity of iron. The scrapings from the surface proved to be almost entirely oxide of tin, but contained small quantities of copper and iron. It was evident that in the slow decomposition of this bronze, the copper had mostly disappeared while the tin remained in the crust as the insoluble oxide. It is also evident that the original bronze did not contain 23 per cent. of tin, which would be a very unusual amount, but even 15 per cent. is a rich bronze, such as might be expected where tin ore abounded. The absence of lead is significant, as that metal was generally one of the components of Roman bronze of the period.

No. 2.—The lump of rust-coloured substance which surrounded the bronze was found to be peaty matter infiltrated with iron oxide. There was no tin, but a little copper, which doubtless had dissolved from the adjoining metal. The second specimen was of very much the same character.

No. 3.—This black powder is not antimony, but finely pulverised galena (sulphide of lead). I find it leaves a black mark if rubbed on the skin ; and from the articles with which it was associated I presume it was used for the same purpose as stibium.

No. 4.—This white metal is pure tin, containing no silver, lead, or copper in perceptible quantity. It had a slight crust of black oxide of tin. The black powder, which you sent me in the same box, when examined microscopically, was found to be minute fragments of quartz encrusted with tinstone. This suggests that the fine sand containing stream tin was carefully collected, and smelted in the village. It is interesting to note that metallic tin was used for a finger ring in Egypt, found at Gurob, which dates back about 1450 B.C. On analysing this it was found that some particles of the unreduced black oxide were dispersed through the metal.

Report B.

I have made a careful analysis of the metallic rod from the Glastonbury village, both microscopically and chemically. For the purpose of gaining an insight into the interior of the main portion, I have bored a hole halfway through at about the middle of the rod, and a smaller one at about a quarter of an inch from one of the bronze terminals. They both revealed a central core of metallic tin covered by a very hard, but somewhat brittle, crust; in the first case, about one-eighth of an inch thick, and in the second about one-twelfth. This inner core gave on analysis 98·5 per cent. of tin. It may therefore be considered a very pure specimen of that metal.

The crust of the products of oxidation exhibited under the microscope great varieties of the oxides of tin, varying from semicrystalline pale yellow pieces, to amber, reddish brown, and nearly black groups of minute crystals. A portion analysed gave 85 per cent. of the oxide of tin, small quantities of other mineral matter, about 5 per cent. of gold, and some 4 per cent. of combined water. All appearances indicate that this crust has resulted from the slow oxidation of the tin rod in a marshy soil. As no gold could be found in the interior tin, it is probable that the rod was originally gilded in part or whole, and that the gold found in the crust was due to this. One of the striking features of this crust is the number of irregular longitudinal cracks, in some of which there is metal which appears to have been squeezed up from below. This is doubtless due to the gradual oxidation of the tin under the crust that was first formed. As the oxide of tin occupies a much larger bulk than the metal from which it is made, there must have been a great pressure from within, and this has burst the outer crust just as the growth of many tree stems causes the bark to split. Another feature is that the external crust is pitted with a large number of little crater-like depressions, commonly of about one-twelfth of an inch in diameter, but some very minute, and others attaining to the size of a quarter of an inch. This does not appear to be due to any external cause, but rather to the tendency of the oxide of tin to arrange itself in this form.

The terminal pieces have been made of bronze; but at least two different qualities have been employed. They are also much corroded and rent by fissures. A piece of the alloy pretty well separated from the disintegrated crust gave on analysis

Tin	13·5 per cent.
Copper	78·2 ,,
Oxygen, &c. . . .	8·3 ,,

It was, therefore, a bronze of no unusual composition, though with rather more than the average amount of tin. Into each of these terminals there seems to have been inserted a piece of bronze very much richer in tin, and which has been almost entirely oxidated. The tin has become cassiterite; the copper is changed into the black oxide. It seems impossible from these decomposed bronzes to say with any accuracy what has been their original constitution. In the case of one piece taken from the wedge, analysis shows at least twice as much tin as copper, besides a good proportion of iron oxide, and a little alumina and lime, and much organic matter and water. These latter constituents were doubtless derived from the marsh in which the rod had been lying for so many centuries.

The specific gravity of the whole object is 6·78. This agrees fairly with what may be calculated from the relative amounts of tin and tin oxide, with the bronze terminals, showing that it is solid throughout. The slight double bend in the bar is probably due to the inequality of the support during these ages. Even very rigid substances will suffer such changes in long periods of time.

There remains the question as to the purpose for which it was made. Originally, it probably appeared as a round bar of white metal, ornamented with gold, capped at each end by a bronze terminal. This suggests the idea of some official mace or sceptre, sufficiently strong and heavy to serve as a weapon if so required.

Report C.

I have examined all the metallic objects which you sent me recently. First I thought it best to take the specific gravity of each, as that could not injure the specimens in any way, while it might give good indications as to the metals of which they are composed. The accompanying paper gives their specific gravity, arranged from the highest to the lowest. You will see that the objects fall into two groups; four of them having a specific gravity approaching that of lead (11·4) and the others that of tin (7·3). In all cases the actual specific gravity is too low, but as the objects are all more or less oxidated, mixed perhaps with some earthy matter, we may expect such to be the case. The density of L 21 was not taken, as it was manifestly an unwrought piece of melted tin, probably oxidated by exposure to the air while still hot.

To commence with the larger group, that of tin L 12, the largest object, is proved by its density, as well as its general appearance, to be a solid ball of metallic tin, only very slightly oxidated; while, on the other hand, the three last in the table are possibly oxidated all through, as the specific gravity of tin oxide itself is about 6·7.

As to the four which are classified as lead, the first two would appear to be not far removed from pure metal, with a slight crust of suboxide (specific gravity 9·7) and of carbonate (6·5); but L 15 and L 25 are a good deal lighter, though they do not seem to be much oxidised. They both have brown patches on a yellowish white crust, and under the microscope there are indications of the ridges, cracks, and small shiny spheres which are seen in the crust of undoubted specimens of tin from Glastonbury. I thought it worth while, therefore, to cut off a small piece from the end of the coiled ring L 25. The result of the analysis, after removing the white incrustation as much as possible, showed 95·5 per cent. of lead; besides this there was some other substance which had all the appearance of insoluble tin oxide. Supposing it to be really tin, it is so small in quantity, that it probably arises from some accidental mixture of tinstone with the ore from which the metal was reduced, and can hardly be looked upon as having been purposely added. They, therefore, rather support than contravene the opinion that the art of making pewter was not practised in Britain before the time of the Romans.

Metal Objects from Glastonbury.

Label	Weight in Grains	Density	Metal
L 19	36·78	10·98	Lead
W 116	18·72	10·74	"
L 15	10·66	9·98	"
L 25	9·42	9·91	"
L 12	127·21	7·26	Tin
L 20	20·33	7·18	"
W 54	47·33	7·17	"
L 26	2·92	7·09	"
L 23	21·57	7·00	"
L 14	23·35	6·89	"
L 11	51·97	6·80	"
W 111	26·64	6·65	"
Br 35	15·93	6·57	"
W 95	23·81	6·27	"

Mr. C. W. Andrews, of the British Museum, has examined the later discoveries of bird bones, and in July last he published an interesting paper in 'The Ibis,' giving a list of birds in addition to those already mentioned by Professor Boyd Dawkins. Mr. Andrews thinks from the large number of specimens of Pelecanus crispus (Bruch) there can be little doubt that the pelican inhabited the West of Britain in considerable numbers, and that it not improbably bred there and was used for food by the people of the lake dwellings.

The other species of birds which Mr. Andrews has found in the collection are :—

Corvus corone (L.), Carrion Crow.
Astur palumbarius (L.), Goshawk.
Haliaëtus albicilla (L.), White-tailed Sea Eagle.
Milvus ictinus (Sav.), Kite.
Strix flammea (L.), Barn Owl.
Phalacrocorax carbo (L.), Cormorant.
Ardea cinerea (L.), Common Heron.
Botaurus stellaris (L.), Common Bittern.
Ducks (*Anatidæ*) :—

Cygnus musicus.
Anser sp. indet.
Anas boscas.
? Clangula glaucion.
Querquedula crecca.
? Dafila acuta.
? Spatula clypeata.
? Mareca penelope.
Fuligula cristata.
" *marila.*
Mergus serrator.

Puffinus sp. indet.
Crex, Corn Crake.
Fulica atra (L.).
Tachybaptes fluviatilis (Tunst.), Little Grebe.

Histology of the Suprarenal Capsules.—Report of the Committee, consisting of Professor E. A. Schäfer (*Chairman*), Mr. Swale Vincent (*Secretary*), and Mr. Victor Horsley.

The investigation has been carried on in birds and mammals, and comparisons instituted between the organ in these animals and that previously studied in the lower vertebrates. The results have been embodied in a paper published in the 'Internat. Monatsschr. f. Anat. u. Physiol.' 1898.

Electrical Changes accompanying the discharge of the Respiratory Centre. Report of the Committee, consisting of Dr. A. WALLER *(Chairman)*, Professor E. WAYMOUTH REID *(Secretary)*, Professor F. GOTCH, *and* Mr. J. S. MACDONALD. *(Drawn up by* Mr. J. S. MACDONALD.)

Further Examination of Changes in Phrenic Nerve and their comparison with Simultaneous State of Blood Pressure.

THE further prosecution of research has taken the form of an inquiry *into the nature of part (if any) played by alterations of blood pressure in the causation of electrical phenomena observed in the phrenic nerve.*

In a nerve well supplied with blood-vessels, and with a circulation preserved in such good condition as that noted in experiments, errors might be introduced by such alterations in several ways.

(A) By alteration of volume of blood and lymph in nerve, and so of conducting media external to electrically disturbed tissue.[1]

By such means a change, produced in the relative proportion of current derived through galvanometer circuit, might in records give rise to an apparent change of total current.

(B) By action of changes of blood pressure upon the walls of vessels or upon the flow of blood through them, setting up electromotive changes of entirely different origin from intrinsic changes in nervous tissue.

(C) By direct effect of alterations of circulation upon the nervous tissue itself, especially in nerve partially dried and cooled from exposure, giving rise to intrinsic alterations in current of injury by altering conditions of moisture, temperature, presence of waste products, &c., affecting its development.

There were considerations which made it improbable that such causes were at work in the production of current changes observed in phrenic nerves. Amongst these may be mentioned—

(1) The constancy of base line in tracings.

(2) The character of the rhythmical oscillations, the first part of each of which bore evidence of being a true negative variation ; the second part, as observed both in galvanometer and electrometer, being due to return of instrument to rest at a rate determined by instrumental elasticity.

(3) The observation that phenomena in phrenic ceased when blood pressure was still considerable, and the heart continued its beat.

It was, indeed, anticipated that the relation between circumstances was really in a reverse order. That the phenomena, being genuine indications of large discharges from respiratory centre, would probably, in their most extreme form, be accompanied by discharges of vasomotor centres leading to alterations of blood pressure ; and not that such indirectly caused changes of blood pressure would declare themselves so obviously by indirect effects upon injury current of phrenic nerves.

It was, however, deemed advisable to satisfy any criticism upon presence of errors of this nature by as careful as possible an estimation of

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[1] Source of current of injury.

their value. To do this it did not seem necessary, or even advisable, to confine the research to direct experiments upon the phrenic nerve, as it was presumed that errors (such as were sought for) would affect the apparent changes in any nerve under similar conditions of experiment to a degree dependent upon the vascularity of the nerve and the maintenance of its blood supply.

Experimental means were obtained for the simultaneous record upon same travelling surface of the movements both of a galvanometer and of a blood-pressure manometer. In this way two curves were obtained, one of electrical changes in tissue experimented upon and one of blood pressure in general circulation, admitting of immediate contrast.

The nerves chosen for experiment were :—

(*a*) The central end of divided vagus.
(*b*) The peripheral end of divided vagus.
(*c*) The recurrent laryngeal.

In all these cases phenomena were found characteristic of each individual nerve and irrespective of state of blood pressure, which will be elsewhere described.

But in addition indications were obtained and records taken of a relation sometimes existing between change of blood pressure and change of demarcation current in nerve, a fall of pressure being accompanied by a fall of current, and a succeeding rise of pressure by an increase in current.

In such cases the parallelism of curves when obtained is of a crude description, the galvanometer record following the main trend of the blood-pressure record, but not responding to the finer variations. It is also thought that such parallel curves are best obtained at the end of an experiment, when the nerve has presumably suffered from exposure.

A somewhat similar comparison [1] has been made previously by other observers in the case of spinal nerves, in which the demarcation current was noticed as dependent upon the condition of animal.

A very remarkable variation from such observations was, however, several times obtained from the peripheral end of divided vagus, in which the relation between the curves was inverted ; a rise of blood pressure being accompanied by a negative variation in demarcation current, a fall with an increase. There is also a marked difference in the nature of correspondence between the two curves from that previously related, in this case much more exact, finer changes being responded to and with a constant latency.

The possible presence of a double relation of demarcation current in the peripheral end of vagus to changes of blood pressure, one in the opposite direction to the other, was naturally the cause of a multiplicity of experiments made upon this stretch of nerve. It might be remarked that whilst the first type of change is analogous to that so far found in other nerves, this second is peculiar to the nerve in question ; and although admitting of a simple explanation by the behaviour of electromotive changes in the walls of blood-vessels contained in it, is not (for reasons to be elsewhere advanced) thought to be so caused.

In continuation of general research an attempt was made to differentiate between the secondary results of an altered circulation in nerve and

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[1] Gotch and Horsley, Croonian Lectures, 1891.

the direct effects produced by changes in the blood-vessels contained in it.

For this purpose direct experiments of a similar kind were carried out upon large blood-vessels. An artery was ligatured and divided, the central end (towards the heart) dissected from its surroundings, raised in air, and connected with galvanometer in same manner as nerves had been connected. The stretching was found of importance, and the femoral artery first chosen was abandoned for the carotid, as free from branches and, therefore, from local injuries during dissection.

In such a preparation current changes are found proportional to changes of blood pressure of a gross kind and with a marked latency. The relation between two is of same kind as that found in the peripheral end of vagus nerve, a rise of pressure causing a fall of current. Such current changes are not due to alterations in resistance of tissue to any current found there, as their nature remains unaffected by the compensation or over-balancing of the demarcation current, retaining always the same direction whatever the direction of current traversing tissue may be.

As to the real source of such changes no positive statement can be made. The most probable cause would seem to be an alteration in tonus of muscular coat secondary to the change of pressure within vessel. This is supported by the result of one experiment, in which an otherwise uninjured carotid artery was separated from surrounding tissues by a thin sheet of indiarubber and a portion of its length connected with the galvanometer. The galvanometric curve bore at first no relation to the blood-pressure curve, but a relation was imperfectly introduced by injury to artery at electrode distal from heart. In other experiments attempts were also made to introduce electrodes into blood stream, but experiments were lost owing to coagulation of blood and the effects of pressure upon electrodes themselves. It is, however, felt that without further evidence an attempt to fix source of origin is futile.

It was thought that the general research might be assisted by a study of such changes as might be obtained under similar conditions from largest combination of nerve and artery to be obtained in body. Experiments were performed, in which the vagus and carotid, having been divided and ligatured at same place, were lifted up without being separated from one another. The piece of tissue so formed was stretched to its normal length, and its distal end connected to galvanometer in usual way.

From this preparation it was found possible to obtain, with unfailing regularity, a galvanometer curve having the most marked correspondence to simultaneous blood-pressure curve, a rise of pressure being accompanied by a negative variation of current.

It is to be noticed that the demarcation current obtained from this tissue was exceedingly small, and that the variations in it were of a magnitude bearing an extremely large ratio to it; in fact the most successful comparisons were made in preparations in which the original current was practically nil. It is also of note that the quantity of change obtained from this preparation in response to a change of blood pressure is greater than that obtainable from carotid artery alone, and much greater than that obtainable from vagus nerve alone.

In the total result it seems possible that a contribution is due to artery, a portion to nerve, and that in this case the components have same direction; for ligature of nerve near to trunk and as far as possible from electrodes produced a diminution in the steepness of curve, and it is believed an alteration of its character.

The value of this latter observation is enhanced by the manner in which other changes unrelated to changes of blood pressure, but known from further research to occur in nerve during conditions of experiment, are swamped by the superposition of artery, it being presumed that value of derived circuit through galvanometer is rendered comparatively negligible by its relatively large resistance.

In cases of all previous part of research it may be said that the physiological continuity of tissue examined is essential.

Summing up, it may be said that all the experiments upon which statements have been based were carried out under the conditions of original experiments upon phrenic nerves; that is, that the experimental method used for obtaining the alterations of blood pressure[1] consisted of curarisation, artificial respiration, and intervals of its suspension.

This, though not a good method for the unravelling of secondary problems which have presented themselves, allows one to translate all the occurrences which have been found in other nerves and tissues to a probable occurrence during any one of phrenic experiments. The main results may be tabulated as follows:—

(1) Current changes have been found in divided nerves directly proportional to changes of pressure, the relation between the two being however, as to time and quantity of a gross kind.

(2) Current changes have been found in peripheral end of divided vagus nerve *inversely* proportional to changes of blood pressure, in which relation is much more exact.

(3) The latter class of changes has not been obtained from any other nerve examined;

(4) but is constantly to be obtained from the divided carotid artery, though here less exact;

(5) and with great exactness and magnitude from vagus carotid preparation.

(6) That this latter result is diminished by ligature of vagus below point examined.

Having thus obtained information of events met with in other tissues, nerves, and blood-vessels, situated in near neighbourhood and obtaining their blood supply from very similar sources, experiments were resumed upon phrenic itself.

Simultaneous curves of electrical changes in phrenic and of general blood pressure show no correspondence of a kind to explain the characteristic phenomena obtained in phrenic nerve alone of all the nerves examined, and the large alterations of blood pressure which occur in every experiment cannot be even definitely said to constantly affect the base line of phrenic tracing.

To make the result more conclusive, simultaneous records were taken both of current changes in phrenic and in vagus carotid preparation, which latter is known to repeat all the incidents of a blood-pressure curve.

The tracings obtained show the typical appearances of either curve, of quite diverse types, showing no relation of the kind sought for. Oscilla-

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[1] Chloroform anæsthesia was used.

tions in one curve are unaccompanied by oscillations in the other, with an exception of no moment from point of view of question at issue.

It is worth stating that, as two galvanometers of same pattern but of different internal resistance were used in the latter class of experiment, care was taken to change the instrument connected to either tissue during the course of experiment. This, however, may be looked at as of considerable advantage, and serves to make result obtained more conclusive.

The final statement may be therefore made with positive conviction :—'That the phenomena obtained in phrenic nerves are independent of, in the sense of being in no way due to, local changes of blood pressure or of circulation ; neither in so far as such conditions affect the nerve nor the blood-vessels contained in it.'

This does not affirm the absence of circumstances analogous to those obtained elsewhere, but places them, when present, in a position of very minor importance.

The Comparative Histology of the Cerebral Cortex.—Report of the Committee, consisting of Professor GOTCH (*Chairman*), Dr. G. MANN (*Secretary*), *and* Dr. F. W. MOTT.

WORK upon this subject has been carried on or initiated during the year by Dr. G. Mann in the Physiological Laboratory, Oxford ; details are given in the subjoined report.

The brains (including the retinæ) of five specimens of Macaque monkey have been utilised for this inquiry. The material was fixed for histological purposes in one of the following fixatives : (*a*) picro-corrosive formaldehyde ; (*b*) Zenker's solution ; (*c*) Weigert's solution of sodium bichromate, chrome alum, and formol ; (*d*) Weigert's solution of chrome alum, glacial acetic acid, acetate of copper, and formol. All solutions were injected into the animal as soon after death as practicable under normal pressure. The Weigert methods did not yield good results, although slices of the cerebral tissue, 5 mm. thick, were left for five days in the solutions at body temperature. On embedding in paraffin and cutting sections, the blocks were found to be over-hardened on the surface, whilst the interior was insufficiently fixed. One of the specimens fixed in picro-corrosive was unsatisfactory, as the tissue showed extensive waxy degeneration. A second specimen fixed in the same way appears to give most satisfactory results as far as the examination of the sections has at present extended. Serial sections have been made of the olfactory bulb, the olfactory lobe, the hippocampal region, the occipital lobe and the retinæ, the motor regions of the trunk and hind limb muscles ; sections of the motor regions of the upper limbs, head, &c., have not yet been made. As regards the examination of the olfactory bulb and the fascia dentata, it is of interest that the granules present in these regions, if stained by the toluidine-blue and eosin method, show Nissl's substance, and thus appear to be true nerve-cells.

The examination of the retinæ has brought out several points of interest. Sections in the horizontal plane, through the optic disc, and the macula lutea, show that the structure of the retinæ in the Macaque apparently differs from that of human retinæ as described by Schäfer and Golding-Bird. The macula lies 2·75 mm. from the centre of the optic disc ; the outer rim of the cup measures $\frac{1}{2}$ mm., the inner more depressed part of the cup $\frac{1}{4}$ mm. The dipping inwards of the external limiting membrane causes a circumferential cup around the inner one. The inner and outer ganglionic layers, as well as the inner fibrous layer, are reduced to very small proportions, there being in a section 10 μ thick only 15 nuclei of the outer ganglionic layer scattered along the margin of the macula. The thickness of the layer of the nuclei of the rods and cones (outer nuclear) is greater when measured from within outwards in the part opposite the macula than in any other region of the retina (55 μ); this is largely due to the loose arrangement of the cone nuclei. The most interesting point is the peculiar arrangement of the rods and cones. Opposite the macula the cones are erect, i.e. their inner, middle, and outer segments are all in a straight line; outside the macula, however, the outer segments of both rods and cones all point towards the centre of the macula, the angle which these segments make with the middle ones depending upon the distance of the elements from the yellow spot. The different segments of the cones are of the same length, whether the part examined is within or outside the macula; there is thus no evidence of the shortening of the inner and middle cone segments which is present in the macula region of the human retina.

The transverse dimension of a cone increases steadily in proportion to the distance of the region examined from the macula. The large extent of the increase on the temporal side is shown in the following table:—

Distance from Centre of Optic Disc.	Transverse Dimension of Cones in Micromillims (μ).	
½ millimetre	4·25	Nasal side
1 "	4	
1½ "	4·25	
2 millimetres	4·5	
Macula	1·25	Macula
3 "	2·5	
3½ "	4·5	Temporal side
4½ "	5·5	
5½ "	6·5	
6½ "	7·5	
7½ "	8·75	
8½ "	9	
9 "	10	

Both the inner and outer ganglionic layers reach their maximal development on the temporal side of the retina, the greatest thickness, measured from within out, of the inner ganglionic layer being 50 μ on the temporal and 14 to 16 μ on the nasal side, that of the outer layer 55 μ on the temporal and 38 μ on the nasal side. On the other hand, the layer of the nuclei of the rods and cones is nearly equal in thickness on these two sides of the retina.

There is in the monkey a further sharp division of the outer fibrillar (molecular) layer into a part consisting of the internal processes of the nuclear layer of the rods and cones, and a part consisting of the external processes of the outer ganglionic (inner nuclear) layer; the fibrils in the former case run horizontally near their terminations, in the latter at right angles to this distribution.

The Physiological Effects of Peptone and its Precursors when introduced into the Circulation.—Third Interim Report of a Committee, consisting of Professor E. A. SCHÄFER, *F.R.S.* (*Chairman*), Professor C. S. SHERRINGTON, *F.R.S.*, Professor R. W. BOYCE, *and* Professor W. H. THOMPSON (*Secretary*). (*Drawn up by the Secretary.*)

IN pursuing this research during the past year, work has in the first instance been directed towards the completion of the different portions of the enquiry already in hand. In several of the sections this has been achieved, and the results have been published *in extenso* in the 'Journal of Physiology' for the current year.

The following is a brief *résumé* of the chief conclusions arrived at, as given in the above articles.

The substances employed were—Purified amphopeptone, antipeptone, deuteroproteose, protoproteose, heteroproteose, and, in certain cases, Witte's 'peptone.'

SECTION I. *Influence on Blood Coagulation.*

(*a*) With purified amphopeptone only a *retarding* effect was observed. The doses employed varied from 0·005 grammes to 0·2 grammes per kilo of body weight.

(*b*) With antipeptone only a *hastening* effect was yielded by doses up to 0·3 grammes per kilo.

(*c*) With each of the primary and secondary proteoses *both phases* of coagulation effect were observed. In all, coagulation was *hastened* in eight experiments, *retarded* in seventeen experiments.

SECTION II. *Influence on Blood Pressure.*

(*a*) All of the substances employed, with the exception of antipeptone, possess undoubted vaso-dilating properties.

(*b*) The effect in question belongs to these substances in different degrees, the products taking their places in increasing order of potency, as follows : amphopeptone, deuteroproteose, heteroproteose, protoproteose.

(*c*) Antipeptone possesses practically no immediate lowering influence on the tonus of blood-vessels, or at most an effect so transient that it is doubtful if it should not be attributed to adhering impurity.

SECTION III. *Influence on Vaso-Mobility.*

(*a*) The vaso-dilating influence shown by the bodies under examination, in agreement with that caused by Witte's 'peptone,' is brought about by a peripheral effect on the vessel walls, causing a reduction or temporary suppression of vaso-mobility.

(*b*) Amphopeptone and deuteroproteose, while differing little from each other, manifest far less effect in this respect than do the primary proteoses. The latter exert this influence to a profound degree.

(*c*) Of the primary bodies, protoproteose is probably the more potent, though not to a wide extent. Heteroproteose, indeed, almost equals in influence its fellow body.

(*d*) The effect of Witte's 'peptone' must therefore be mainly ascribed to its protoproteose constituents. This body ordinarily forms a much larger ingredient of the substance in question than does heteroproteose.

(*e*) Antipeptone possesses no power of depressing vaso-mobility consistently with its lack of influence in lowering blood-pressure.

SECTION IV. *Local Vascular Influences.*

In this section, in addition to completing the observations on the limb, kidney, and spleen districts, the research was extended during the year so as to include the vessels of two other regions, namely, those of the intestine and liver. The following is a brief summary of the results as a whole.

1. *Intestinal Vessels.*

(*a*) Direct observation and record verify the inference that dilatation of the intestinal vessels accompanies and must to a certain extent account for the fall of blood-pressure produced by injection of Witte's 'peptone' and similar products into the vascular system.

(*b*) It also establishes beyond doubt that the dilatation of intestinal vessels is produced by peripheral depression, or even temporary abolition of vaso-mobility, in the area in question.

(*c*) That the order of potency in regard to effect on intestinal vessels corresponds with that above given for the splanchnic area in general; the primary proteoses exerting much the most profound influence, that of deuteroproteose and purified peptone being comparatively small.

2. *Renal Vessels.*

(*a*) The blood-vessels of the kidney do not share in the dilatation brought about by these substances. On the contrary, the vessels of this organ are much less distended under their influence than under ordinary circumstances.

(*b*) Vaso-mobility in the renal area is much less profoundly influenced than in the intestinal district.

(*c*) Bearing in mind the statement made in the foregoing paragraph, the primary proteoses are also the most effective on renal vessels. Indeed, they may be said to be the only members of the group which appreciably reduce renal vaso-mobility.

3. *Splenic Vessels.*

(*a*) The vessels of this district share to a moderate extent in the dilatation which follows an injection of 'peptone' or of one of the proteoses.

(*b*) Vaso-mobility is also diminished in the splenic district, but to a less degree than in the intestinal. In this respect the vessels of the spleen take a position intermediate between those of the kidney and the intestine.

(*c*) Proto- and heteroproteose are here also the most effective of the substances examined. Deuteroproteose and purified peptone have comparatively little influence.

4. *Liver Vessels.*

(*a*) The vessels of this district suffer an enormous dilatation under the influence of 'peptone' and proteoses, corresponding to the period of general fall of blood-pressure.

(*b*) This dilatation is primarily due to an increased onflow of blood from the vessels of the portal system, and not to mere stoppage from supposed weakening of the heart.

(*c*) Under conditions of great fall of blood-pressure resulting from vascular dilatation in the splanchnic region, the chief accumulation of blood seems to take place in the liver, exceeding even that in the vessels of the intestine.

(*d*) The vessels of this district, owing to their easy dilatability, probably play the part of a safety receptacle to the heart, thereby guarding it against over-influx of blood under conditions of great dilatation in the splanchnic vascular territory.

(*e*) The substances examined produce a great depression of vasomobility in the liver district, the vessels of this organ thus showing a high degree of susceptibility to the influence of the bodies here employed.

(*f*) The different substances show the same order of potency in their influence on the liver district as is manifested by them elsewhere.

5. *Limb Vessels.*

(*a*) Some influence is undoubtedly exerted on limb vessels by the products here dealt with, but this influence is very slight, less even than in the case of renal vessels.

(*b*) Little or no dilatation is experienced by these vessels during the period of fall of general blood-pressure.

(*c*) Here, also, the influence of the primary proteoses is greater than that of the other bodies examined. Indeed, the former may be said to be the only members of the group which possess any influence on limb vessels.

From the foregoing local vascular manifestations, the following conclusions of a more general nature may be deduced :

1. That the blood-vessels of different vascular districts show different degrees of susceptibility to 'peptone' influence, and play unequal parts in producing the general results which follow an injection of peptone or proteoses.
2. The vessels of the splenic, intestinal, and hepatic districts constitute a group eminently sensitive to 'peptone' influence, while those of the kidney and limbs are eminently insensitive in this respect.
3. Amongst the vessels of the first group, those of the splenic district are least susceptible, those of the liver most so, while those of the intestine occupy an intermediate position.

SECTION V. *Effects on Urinary Secretion.*

Work in this section was also brought to a temporary completion, and furnished interesting and important deductions. An article dealing with these will shortly be published. The results attained invite further investigation, which it is intended to take in hand during the coming year.

Part of the work of completion just alluded to involved the performance of a series of control experiments to determine the influence which the anæsthetic employed might exert on the secretion of urine. These showed that the peptone effects were in no wise modified by the influence of the anæsthetic.

SECTION VI. *Effects of Antipeptone-constituents.*

It has recently been shown that antipeptone is composed of a number of different bodies, the chief amongst these being Arginin, Histidin, and Lysin. It was therefore deemed advisable to extend the research into an examination of the physiological effects produced by these substances when introduced into the circulation. This was carried into effect with the kind permission of Professor A. Kossel, in the Physiological Institute of Marburg University. A preliminary communication dealing with the results, so far as obtained, will, it is hoped, be made to Section I. at the forthcoming Meeting.

The Influence of Drugs upon the Vascular Nervous System.—Report of the Committee, consisting of Professor F. GOTCH (*Chairman*), Professor HALLIBURTON (*Secretary*), *and* Dr. F. W. MOTT.

THE physiological action of choline and neurine has been investigated by Dr. F. W. Mott, M.D., F.R.S., and Professor Halliburton; the results of their experiments are embodied in the subjoined third report.

In the two reports which precede this, we have shown that cerebro-spinal fluid from cases of general paralysis of the insane contains choline, and that the fall of arterial blood-pressure that takes place when the fluid is injected into animals is due to this substance. This base is absent from normal cerebro-spinal fluid, and is doubtless, in the pathological fluid, derived from the disintegration of lecithin in the cerebral tissue. The proof that the base is choline rests partly on its chemical identification in the fluid, and partly on the identical action which the fluid has with weak solutions (0·2 per cent.) of choline or choline hydrochloride.

The closely related and much more toxic base, neurine, is absent.

In the case of choline, the fall of blood-pressure is partly cardiac and partly produced by vascular dilatation, especially in the intestinal area. Contrary to expectation the spleen does not participate in this dilatation, but is constricted; this constriction is followed by an increase of the normal splenic waves. It seems probable that the material in extracts of brain which Schäfer and Moore found to produce the same effect is choline. Neurine produces a much more intense constriction of the spleen, but no exaggeration of the splenic waves follows. The action of the base on the intestinal blood vessels is due to its action on the neuro-muscular mechanism of the blood vessels themselves. This was demonstrated by locally bathing the mesenteric vessels with solutions of choline; and by the fact that choline still continues to produce the usual fall of arterial pressure, (1) after the spinal cord has been divided high up, (2) after the splanchnic nerves have been cut, and (3) after the animal has been poisoned with nicotine; the last method excludes any action of peripheral ganglia.

Neurine produces a fall of blood-pressure, chiefly due to its action on the heart; this is followed by a rise of pressure, due to constriction of peripheral vessels. Using the same methods as in the investigation of choline, this is not an action on the central nervous system. The constriction of the vessels is, however, probably due to the action of the base on the peripheral ganglia, for after nicotine poisoning it does not occur.

The animals used have been dogs, cats, and rabbits. These were always anæsthetised with ether, chloroform, or A. C. E. mixture; in some cases they also had a subcutaneous injection of morphine. If, however, a small amount of atropine is mixed with the morphine, the effect of choline is always a rise of blood pressure; the lever of the intestinal oncometer also rises.

The Micro-chemistry of Cells.—Interim Report of the Committee, consisting of Professor E. A. SCHÄFER (*Chairman*), Professor E. RAY LANKESTER, Professor W. D. HALLIBURTON, Mr. G. C. BOURNE, *and* Professor A. B. MACALLUM (*Secretary*).

THE Committee beg to present an interim report.

The investigation was directed along the following lines :

(1) The detection and localisation of iodine in animal cells and organs. In regard to the detection of this element considerable difficulty was experienced in finding a suitable reaction ; for starch, the usual test for iodine, being a colloid when in solution, cannot penetrate iodine-holding colloid tissue-material. Another difficulty consisted in the firmness with which organic compounds of iodine hold the element in 'masked' combination. Both difficulties were overcome by the discovery that solutions of hydrochloric acid and mercuric chloride, under certain conditions, not only set the iodine free in an inorganic form but yield it also as red mercuric iodide. By this method it has been found that the iodine compound of the thyroid gland is confined to its colloid masses, the gland cells being free from traces even of the element. The 'colloid' masses of the pituitary body gave no evidence of the presence of iodine, nor was any trace of it found in the other organs. Experiments in this line are being made on the tissues of certain invertebrates.

(2) The micro-chemical localisation of sulphur of inorganic and organic combinations in animal cells. The reaction employed is that obtained when a mixture of solutions of lead acetate and potassic hydrate with glycerine, in such proportions as to yield a clear solution, is allowed to act on tissue material which has been hardened for a long time in alcohol. Inorganic sulphur combinations yield the result at once, while the lightly bound organic sulphur gives the brown colour of lead sulphide on the application of heat. The reaction has been found useful in determining some points of importance, as for example the proteid character of a number of structures in the protozoa and protophyta, and the presence of sulphur in the chromosomes of the nucleus in the dividing cell, a fact which indicates that these bodies, contrary to the view of some cytologists, are not constituted of pure nucleic acid but rather of a nucleo-proteid.

(3) Observations on the distribution of organic phosphorus, in the case of compounds digestible in artificial gastric juice. These demonstrated that the soluble compounds are much more abundant than the insoluble ones (*i.e.* nucleins or chromatins) in the cells of the liver, thyroid, suprarenals, and pituitary gland. In the latter organ the soluble compounds are specially abundant, and they appear to constitute also a considerable portion of the colloid material of this organ.

(4) The action of different mineral reagents on cellular structures hardened in alcohol, under high pressures (8–12 atmospheres), and at temperatures between 100° C. and 200° C. This line of work has been followed for less than two months, and consequently the results are incomplete, but they are of interest when taken in connection with the results of artificial digestion. It is proposed to compare these results with those obtained by treating in a similar way the cell juices extracted from fresh cells by hydraulic pressure.

(5) The elaboration of atom-group reactions of proteids for micro-chemical purposes. Those which have proved to be the most useful are the oxyphenyl (tyrosin) reaction, the CN (biuret) reaction, and that resulting from the action of slowly concentrating sulphuric and hydrochloric acids, discovered by Elliott, and apparently due to the indol atom-group. It has been found that the Reichl reactions, which are supposed to indicate the presence of either indol or skatol in proteids, are without value in micro-chemical application, and the same may be said of Krasser's reaction with alloxan, which is held to postulate the occurrence of $CH_2 \cdot CH(NH_2) \cdot COOH$ in the proteid molecule. The atom-group reactions are being employed to study the characters of the nuclear compounds in different cells.

Owing to the extent of the investigation undertaken, more time is required, and the Committee ask to be reappointed.

Fertilisation in the Phæophyceæ.—Report of the Committee, consisting of Prof. J. B. FARMER (*Chairman*), Prof. R. W. PHILLIPS (*Secretary*), Prof. F. O. BOWER, *and* Prof. HARVEY GIBSON. (*Drawn up by the Secretary.*)

THE grant made last year for the furtherance of the study of the processes of fertilisation among Phæophyceæ was 20*l.*, and your Committee decided to devote again the whole amount as an aid to Mr. J. Lloyd Williams in his researches.

The following are some of the questions to which Mr. Williams has been giving his attention during the past year :—

1. *Dictyota dichotoma.* The cytology of the sexual cells of the fertilised egg, and of the parthenogenetic stages of the unfertilised egg, has been fully worked out, and the results are now ready for publication.
2. *Halidrys siliquosa* and *Himanthalia lorea.* The life-history and cytology of these plants have been further investigated. Mr. Williams proposes to submit a paper on the former plant for the consideration of the Section at Dover.
3. *Laminaria saccharina* and *Alaria esculenta.* Mr. Williams has submitted the zoospores of these species to experiment, and has made some interesting observations on their germination.
4. *Fucaceæ.* A joint paper by Professor Farmer and Mr. Williams on the natural history of several species of Fucaceae is in course of preparation.
5. *Fucus hybrids.* Mr. Williams has communicated to the 'Annals of Botany' (vol xiii., No. 49) a short note giving the results of observations on this subject.

The Committee consider that these investigations are likely to yield more interesting results when they are carried still further, and they would urge the renewal of the grant for another year.

Assimilation in Plants.—Interim Report of the Committee, consisting of Mr. FRANCIS DARWIN (*Chairman*), Professor J. R. GREEN (*Secretary*), *and* Professor MARSHALL WARD, *appointed to conduct an Experimental Investigation of Assimilation in Plants.*

THE Committee beg to report that they have expended two-thirds of the 20*l.* placed at their disposal, and they request that they may be reappointed with a view to the expenditure of the balance.

The grant has been mainly devoted to aiding Mr. Blackman in the construction of an expensive apparatus for the investigation of assimilation, which is now complete; and it is proposed to allot to him the remainder of the sum for the continuation of his researches. These have been in progress for some time; they deal with the sources of the carbon dioxide of leaf assimilation; with the respiration of the stem as distinguished from the leaf; with the magnitude of the absorption of carbon dioxide from the soil; and with kindred problems, of which a preliminary account was given by Mr. Blackman at the Bristol meeting. The many ways in which these various factors interact on one another make it desirable not to publish the detailed investigations of one before those of the others are completed. It is expected, however, that the results will be ready for publication in the course of the coming year.

TRANSACTIONS OF THE SECTIONS.

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SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

PRESIDENT OF THE SECTION.—Professor J. H. POYNTING, D.Sc., F.R.S.

THURSDAY, SEPTEMBER 14.

The President delivered the following Address:—

THE members of this Section will, I am sure, desire me to give expression to the gratification that we all feel in the realisation of the scheme first proposed from this chair by Dr. Lodge, the scheme for the establishment of a National Physical Laboratory. It would be useless here to attempt to point out the importance of the step taken in the definite foundation of the Laboratory, for we all recognise that it was absolutely necessary for the due progress of physical research in this country. It is matter for congratulation that the initial guidance of the work of the Laboratory has been placed in such able hands.

While the investigation of Nature is ever increasing our knowledge, and while each new discovery is a positive addition never again to be lost, the range of the investigation and the nature of the knowledge gained form the theme of endless discussion. And in this discussion, so different are the views of different schools of thought, that it might appear hopeless to look for general agreement, or to attempt to mark progress.

Nevertheless, I believe that in some directions there has been real progress, and that physicists, at least, are tending towards a general agreement as to the nature of the laws in which they embody their discoveries, of the explanations which they seek to give, and of the hypotheses they make in their search for explanations.

I propose to ask you to consider the terms of this agreement, and the form in which, as it appears to me, they should be drawn up.

The range of the physicist's study consists in the visible motions and other sensible changes of matter. The experiences with which he deals are the impressions on his senses, and his aim is to describe in the shortest possible way how his various senses have been, will be, or would be affected.

His method consists in finding out all likenesses, in classing together all similar events, and so giving an account as concise as possible of the motions and changes observed. His success in the search for likenesses and his striving after conciseness of description lead him to imagine such a constitution of things that likenesses exist even where they elude his observation, and he is thus enabled to simplify his classification on the assumption that the constitution thus imagined is a reality. He is enabled to predict on the assumption that the likenesses of the future will be the likenesses of the past.

His account of Nature, then, is, as it is often termed, a descriptive account.

Were there no similarities in events, our account of them could not rise above a mere directory, with each individual event entered up separately with its address. But the similarities observed enable us to class large numbers of events together, to give general descriptions, and indeed to make, instead of a directory, a readable book of science, with laws as the headings of the chapters.

These laws are, I believe, in all cases brief descriptions of observed similarities. By way of illustration let us take two or three examples.

The law of gravitation states that to each portion of matter we can assign a constant—its mass—such that there is an acceleration towards it of other matter proportional to that mass divided by the square of its distance away. Or all bodies resemble each other in having this acceleration towards each other.

Hooke's law for the case of a stretched wire states that each successive equal small load produces an equal stretch, or states that the behaviour of the wire is similar for all equal small pulls.

Joule's law for the heat appearing when a current flows in a wire states that the rate of heat development is proportional to the square of the current multiplied by the resistance, or states that all the different cases resemble each other in having $H \div C^2Rt$ constant.

And, generally, when a law is expressed by an equation, that equation is a statement that two different sets of measurements are made, represented by the terms on the two sides of the equation, and that all the different cases resemble each other in that the two sets have the constant relation expressed by the equation. Accurate prediction is based on the assumption that when we have made the measurements on the one side of the equation we can tell the result of the measurements implied on the other side.

If this is a true account of the nature of physical laws, they have, we must confess, greatly fallen off in dignity. No long time ago they were quite commonly described as the Fixed Laws of Nature, and were supposed sufficient in themselves to govern the universe. Now we can only assign to them the humble rank of mere descriptions, often tentative, often erroneous, of similarities which we believe we have observed.

The old conception of laws as self-sufficing governors of Nature was, no doubt, a survival of a much older conception of the scope of physical science, a mode of regarding physical phenomena which had itself passed away.

I imagine that originally man looked on himself and the result of his action in the motions and changes which he produced in matter, as the one type in terms of which he should seek to describe all motions and changes. Knowing that his purpose and will were followed by motions and changes in the matter about him, he thought of similar purpose and will behind all the motions and changes which he observed, however they occurred; and he believed, too, that it was necessary to think thus in giving any consistent account of his observations. Taking this anthropomorphic—or, shall we say, psychical—view, the laws he formulated were not merely descriptions of similarities of behaviour, but they were also expressions of fixed purpose and the resulting constancy of action. They were commands given to matter which it must obey.

The psychical method, the introduction of purpose and will, is still appropriate when we are concerned with living beings. Indeed, it is the only method which we attempt to follow when we are describing the motions of our fellow-creatures. No one seeks to describe the motions and actions of himself and of his fellow-men, and to classify them without any reference to the similarity of purpose when the actions are similar. But as the study of Nature progressed, it was found to be quite futile to bring in the ideas of purpose and will when merely describing and classifying the motions and changes of non-living matter. Purpose and will could be entirely left out of sight, and yet the observed motions and changes could be described, and predictions could be made as to future motions and changes. Limiting the aim of physical science to such description and prediction, it gradually became clear that the method was adequate for the purpose, and over the range of non-living matter, at least, the psychical yielded to the physical. Laws ceased to be commands analogous to legal enactments, and became mere descriptions. But during the passage from one position to the other, by a confusion of thought which may appear strange to us now that we have finished the journey, though no doubt it was inevitable, the purpose and will of which the laws had been the expression were put into the laws themselves; they were personified and made to will and act.

Even now these early stages in the history of thought can be traced by survivals in our language, survivals due to the ascription of moral qualities to matter. Thus gases are still sometimes said to obey or to disobey Boyle's Law as if it were an enactment for their guidance, and as if it set forth an ideal, the perfect gas, for their imitation. We still hear language which seems to imply that real gases are wanting in perfection, in that they fail to observe the exact letter of the law. I suppose on this view we should have to say that hydrogen is nearest to perfection; but then we should have to regard it as righteous overmuch, a sort of Pharisee among gases which overshoots the mark in its endeavour to obey the law. Oxygen and nitrogen we may regard as good enough in the affairs of everyday life. But carbon dioxide and chlorine and the like are poor sinners which yield to temptation and liquefy whenever circumstances press at all hardly on them.

There is a similar ascription of moral qualities when we judge bodies according to their fulfilment of the purpose for which we use them, when we describe them as good or bad radiators, good or bad insulators, as if it were a duty on their part to radiate well, or insulate well, and as if there were failures on the part of Nature to come up to the proper standard.

These are of course mere trivialities, but the reaction of language on thought is so subtle and far-reaching that, risking the accusation of pedantry, I would urge the abolition of all such picturesque terms. In our quantitative estimates let us be content with 'high' or 'low,' 'great' or 'small,' and let us remember that there is no such thing as a failure to obey a physical law. A broken law is merely a false description.

Concurrently with the change in our conception of physical law has come a change in our conception of physical explanation. We have not to go very far back to find such a statement as this—that we have explained anything when we know the cause of it, or when we have found out the reason why—a statement which is only appropriate on the psychical view. Without entering into any discussion of the meaning of cause, we can at least assert that that meaning will only have true content when it is concerned with purpose and will. On the purely physical or descriptive view, the idea of cause is quite out of place. In description we are solely concerned with the 'how' of things, and their 'why' we purposely leave out of account. We explain an event not when we know 'why' it happened, but when we show 'how' it is like something else happening elsewhere or otherwhen—when, in fact, we can include it as a case described by some law already set forth. In explanation, we do not account *for* the event, but we improve our account *of* it by likening it to what we already knew.

For instance, Newton explained the falling of a stone when he showed that its acceleration towards the earth was similar to and could be expressed by the same law as the acceleration of the moon towards the earth.

He explained the air disturbance we call 'sound' when he showed that the motions and forces in the pressure waves were like motions and forces already studied.

Franklin explained lightning when and so far as he showed that it was similar in its behaviour to other electric discharges.

Here I do not fear any accusation of pedantry in joining those who urge that we should adapt our language to the modern view. It would be a very real gain, a great assistance to clear thinking, if we could entirely abolish the word 'cause' in physical description, cease to say 'why' things happen unless we wish to signify an antecedent purpose, and be content to own that our laws are but expressions of 'how' they occur.

The aim of explanation, then, is to reduce the number of laws as far as possible, by showing that laws, at first separated, may be merged in one; to reduce the number of chapters in the book of science by showing that some are truly mere sub-sections of chapters already written.

To take an old but never-worn-out metaphor, the physicist is examining the garment of Nature, learning of how many, or rather of how few, different kinds of thread it is woven, finding how each separate thread enters into the pattern, and seeking from the pattern woven in the past to know the pattern yet to come.

How many different kinds of thread does Nature use?

So far, we have recognised some eight or nine, the number of different forms of energy which we are still obliged to count as distinct. But this distinction we cannot believe to be real. The relations between the different forms of energy, and the fixed rate of exchange when one form gives place to another, encourage us to suppose that if we could only sharpen our senses, or change our point of view, we could effect a still further reduction. We stand in front of Nature's loom as we watch the weaving of the garment; while we follow a particular thread in the pattern it suddenly disappears, and a thread of another colour takes its place. Is this a new thread, or is it merely the old thread turned round and presenting a new face to us? We can do little more than guess. We cannot get to the other side of the pattern, and our minutest watching will not tell us all the working of the loom.

Leaving the metaphor, were we true physicists, and physicists alone, we should, I suppose, be content to describe merely what we observe in the changes of energy. We should say, for instance, that so much kinetic energy ceases, and that so much heat appears, or that so much light comes to a surface, and that so much chemical energy takes its place. But we have to take ourselves as we are, and reckon with the fact that though our material is physical, we ourselves are psychical. And, as a mere matter of fact, we are not content with such discontinuous descriptions. We dislike the discontinuity and we think of an underlying identity. We think of the heat as being that which a moment before was energy of visible motion, we think of the light as changing its form alone and becoming itself the chemical energy. Then to our passive dislike of discontinuity we join our active desire to form a mental picture of what may be going on, a picture like something which we already know. Coming on these discontinuities our ordinary method of explanation fails, for they are not obviously like those series of events in which we can trace every step. We then imagine a constitution of matter and modifications of it corresponding to the different kinds of energy, such that the discontinuities vanish, and such that we can picture one form of energy passing into another and yet keeping the same in kind throughout. We are no longer content to describe what we actually see or feel, but we describe what we imagine we should see or feel if our senses were on quite another scale of magnitude and sensibility. We cease to be physicists of the real and become physicists of the ideal.

To form such mental pictures we naturally choose the sense which makes such pictures most definite, the sense of sight, and think of a constitution of matter which shall enable us to explain all the various changes in terms of visible motions and accelerations. We imagine a mechanical constitution of the universe.

We are encouraged in this attempt by the fact that the relations in this mechanical conception can be so exactly stated, that the equations of motion are so very definite. We have, too, examples of mechanical systems, of which we can give accounts far exceeding in accuracy the accounts of other physical systems. Compare, for instance, the accuracy with which we can describe and foretell the path of a planet with our ignorance of the movements of the atmosphere as dependent on the heat of the sun. The planet keeps to the astronomer's time-table, but the wind still bloweth almost where it listeth.

The only foundation which has yet been imagined for this mechanical explanation—if we may use 'explanation' to denote the likening of our imaginings to that which we actually observe—is the atomic and molecular hypothesis of matter. This hypothesis arose so early in the history of science that we are almost tempted to suppose that it is a necessity of thought, and that it has a warrant of some higher order than any other hypothesis which could be imagined. But I suspect that if we could trace its early development we should find that it arose in an attempt to explain the phenomena of expansion and contraction, evaporation and solution. Were matter a continuum we should have to admit all these as simple facts, inexplicable in that they are like nothing else. But imagine matter to consist of a crowd of separate particles with interspaces. Contraction and expansion are then merely a drawing in and a widening out of the crowd. Solution is merely the mingling of two crowds, and evaporation merely a dispersal from the outskirts. The most evident properties of matter are then similar to what may be observed in any public meeting.

For ages the molecular hypothesis hardly went further than this. The first step onward was the ascription of vibratory motion to the atoms to explain heat. Then definite qualities were ascribed, definite mutual forces were called into play to explain elasticity and other properties or qualities of matter. But I imagine its first really great achievement was its success in explaining the law of combining proportions, and next to that we should put its success in explaining many of the properties of gases.

While light was regarded as corpuscular—in fact molecular—and while direct action at a distance presented no difficulty, the molecular hypothesis served as the one foundation for the mechanical representation of phenomena. But when it was shown that infinitely the best account of the phenomena of light could be given on the supposition that it consisted of waves, something was needed, as Lord Salisbury has said, to wave, both in the interstellar and in the intermolecular spaces. So the hypothesis of an ether was developed, a necessary complement of that form of the molecular hypothesis in which matter consists of discrete particles with matter-free intervening spaces.

Then Faraday's discovery of the influence of the dielectric medium in electric actions led to the general abandonment of the idea of action at a distance, and the ether was called in to aid matter in the explanation of electric and magnetic phenomena. The discovery that the velocity of electro-magnetic waves is the same as that of light waves is at least circumstantial evidence that the same medium transmits both.

I suppose we all hope that some time we shall succeed in attributing to this medium such further qualities that it will be able to enlarge its scope and take in the work of gravitation.

The mechanical hypothesis has not always taken this dualistic form of material atoms and molecules, floating in a quite distinct ether. I think we may regard Boscovich's theory of point-centres surrounded by infinitely extending atmospheres of force as really an attempt to get rid of the dualism, and Faraday's theory of point-centres with radiating lines of force is only Boscovich's theory in another form. But Lord Kelvin's vortex-atom theory gives us a simplification more easily thought of. Here all space is filled with continuous fluid—shall we say a fluid ether?—and the atoms are mere loci of a particular type of motion of this frictionless fluid. The sole differences in the atoms are differences of position and motion. Where there are whirls, we call the fluid matter; where there are no whirls, we call it ether. All energy is energy of motion. Our visible kinetic energy, $MV^2/2$, is energy in and round the central whirls; our visible energy of position, our potential energy, is energy of motion in the outlying regions.

A similar simplification is given by Dr. Larmor's hypothesis, in which, again, all space is filled with continuous substance all of one kind, but this time solid rather than fluid. The atoms are loci of strain instead of whirls, and the ether is that which is strained.

So, as we watch the weaving of the garment of Nature, we resolve it in imagination into threads of ether spangled over with beads of matter. We look still closer, and the beads of matter vanish; they are mere knots and loops in the threads of ether.

The question now faces us—How are we to regard these hypotheses as to the constitution of matter and the connecting ether? How are we to look upon the explanations they afford? Are we to put atoms and ether on an equal footing with the phenomena observed by our senses, as truths to be investigated for their own sake? Or are they mere tools in the search for truth, liable to be worn out or superseded?

That matter is grained in structure is hardly more than the expression of the fact that in very thin layers it ceases to behave as in thicker layers. But when we pass on from this general statement and give definite form to the granules or assume definite qualities to the intergranular cement we are dealing with pure hypotheses.

It is hardly possible to think that we shall ever see an atom or handle the ether. We make no attempt whatever to render them evident to the senses. We connect observed conditions and changes in gross visible matter by invisible molecular and ethereal machinery. The changes at each end of the machinery of which we seek to give an account are in gross matter, and this gross matter is our only instrument of detection, and we never receive direct sense impressions of the imagined atoms or the intervening ether. To a strictly descriptive physicist their only use and interest would lie in their service in prediction of the changes which are to take place in gross matter.

It appears quite possible that various types of machinery might be devised to produce the known effects. The type we have adopted is undergoing constant minor changes, as new discoveries suggest new arrangements of the parts. Is it utterly beyond possibility that the type itself should change?

The special molecular and ethereal machinery which we have designed, and which we now generally use, has been designed because our most highly developed sense is our sense of sight. Were we otherwise, had we a sense more delicate than sight, one affording us material for more definite mental presentation, we might quite possibly have constructed very different hypotheses. Though, as we are, we cannot conceive any higher type than that founded on the sense of sight, we can imagine a lower type, and by way of illustration of the point let us take the sense of which my predecessor spoke last year—the sense of smell. In us it is very undeveloped. But let us imagine a being in whom it is highly cultivated, say, a very intellectual and very hypothetical dog. Let us suppose that he tries to frame an hypothesis as to light. Having found that his sense of smell is excited by surface exhalations, will he not naturally make and be content with a corpuscular theory of light? When he has discovered the facts of dispersion, will he not think of the different colours as different kinds of smell—insensible, perhaps, to him, but sensible to a still more highly gifted, still more hypothetical dog?

Of course, with our superior intellect and sensibility, we can see where his hypothesis would break down; but unless we are to assume that we have reached finality in sense development, the illustration, grotesque as it may be, will serve to show that our hypotheses are in terms of ourselves rather than in terms of Nature itself, they are ejective rather than objective, and so they are to be regarded as instruments, tools, apparatus only to aid us in the search for truth.

To use an old analogy—and here we can hardly go except upon analogy—while the building of Nature is growing spontaneously from within, the model of it, which we seek to construct in our descriptive science, can only be constructed by means of scaffolding from without, a scaffolding of hypotheses. While in the real building all is continuous, in our model there are detached parts which must be connected with the rest by temporary ladders and passages, or which must be supported till we can see how to fill in the understructure. To give the hypotheses equal validity with facts is to confuse the temporary scaffolding with the building itself.

But even if we take this view of the temporary nature of our molecular and ethereal imaginings, it does not lessen their value, their necessity to us.

It is merely a true description of ourselves to say that we must believe in the continuity of physical processes, and that we must attempt to form mental pictures of those processes the details of which elude our observation. For such pictures we must frame hypotheses, and we have to use the best material at command in framing them. At present there is only one fundamental hypothesis—the molecular and ethereal hypothesis—in some such form as is generally accepted.

Even if we take the position that the form of the hypothesis may change as our knowledge extends, that we may be able to devise new machinery—nay, even that we may be able to design some quite new type to bring about the same ends—that does not appear to me to lessen the present value of the hypothesis. We can recognise to the full how well it enables us to group together large masses of facts which, without it, would be scattered apart, how it serves to give working explanations, and continually enables investigators to think out new questions for research. We can recognise that it is the symbolical form in which much actual knowledge is cast. We might almost as well quarrel with the use of the letters of the alphabet, inasmuch as they are not the sounds themselves, but mere arbitrary symbols of the sounds.

In this country there is no need for any defence of the use of the molecular hypothesis. But abroad the movement from the position in which hypothesis is confounded with observed truth has carried many through the position of equilibrium equally far on the other side, and a party has been formed which totally abstains from molecules as a protest against immoderate indulgence in their use. Time will show whether these protesters can do without any hypothesis, whether they can build without scaffolding or ladders. I fear that it is only an attempt to build from balloons.

But the protest will have value if it will put us on our guard against using molecules and the ether everywhere and everywhen. There is, I think, some danger that we may get so accustomed to picturing everything in terms of these hypotheses that we may come to suppose that we have no firm basis for the facts of observation until we have given a molecular account of them, that a molecular basis is a firmer foundation than direct experience.

Let me illustrate this kind of danger. The phenomena of capillarity can, for the most part, be explained on the assumption of a liquid surface tension. But if the subject is treated merely from this point of view it stands alone—it is a portion of the building of science hanging in the air. The molecular hypothesis then comes in to give some explanation of the surface tension, gives, as it were, a supporting understructure connecting capillarity with other classes of phenomena. But here, I think, the hypothesis should stop, and such phenomena as can be explained by the surface tension should be so explained without reference to molecules. They should not be brought in again till the surface-tension explanation fails. It is necessary to bear in mind what part is scaffolding, and what is the building itself, already firm and complete.

Or, as another illustration, take the Second Law of Thermodynamics. I suspect that it is sometimes supposed that a molecular theory from which the Second Law could be deduced would be a better basis for it than the direct experience on which it was founded by Clausius and Kelvin, or that the mere imagining of a Maxwell's sorting demon has already disproved the universality of the law; whereas he is a mere hypothesis grafted on a hypothesis, and nothing corresponding to his action has yet been found.

There is more serious danger of confusion of hypothesis with fact in the use of the ether: more risk of failure to see what is accomplished by its aid. In giving an account of light, for instance, the right course, it appears to me, is to describe the phenomena and lay down the laws under which they are grouped, leaving it an open question what it is that waves, until the phenomena oblige us to introduce something more than matter, until we see what properties we must assign to the ether, properties not possessed by matter, in order that it may be competent to afford the explanations we seek. We should then realise more clearly that it is the constitution of matter which we have imagined, the hypothesis of discrete particles, which obliges us to assume an intervening medium to carry on the disturbance from particle to particle. But the vortex-atom hypothesis and Dr. Larmor's strain-atom hypothesis both seem to indicate that we are moving in the direction of the abolition of the distinction between matter and ether, that we shall come to regard the luminiferous medium, not as an attenuated substance here and there encumbered with detached blocks—the molecules of matter—but as something which in certain places exhibits modifications which we term matter. Or starting rather from matter, we may come to think of matter as no longer consisting of separated granules, but as a continuum with properties grouped round the centres, which we regard as atoms or molecules.

Perhaps I may illustrate the danger in the use of the conception of the ether by considering the common way of describing the electro-magnetic waves, which are all about us here, as ether waves. Now in all cases with which we are acquainted, these waves start from matter; their energy before starting was, as far as we can guess, energy of the matter between the different parts of the source, and they manifest themselves in the receiver as energy of matter. As they travel through the air, I believe that it is quite possible that the electric energy can be expressed in terms of the molecules of air in their path, that they are effecting atomic separations as they go. If so, then the air is quite as much concerned in their propagation as the ether between its molecules. In any case, to term them ether waves is to prejudge the question before we have sufficient evidence.

Unless we bear in mind the hypothetical character of our mechanical conception of things, we may run some risk of another danger—the danger of supposing that we have something more real in mechanical than in other measurements. For instance, there is some risk that the work measure of specific heat should be regarded as more fundamental than the heat measure, in that heat is truly a 'mode of motion.' On the molecular hypothesis, heat is no doubt a mixture of kinetic energy and potential energy of the molecules and their constituents, and may even be entirely kinetic energy; and we may conceivably in the future make the hypothesis so definite that, when we heat a gramme of water 1°, we can assign such a fraction of an erg to each atom. But look how much pure hypothesis is here. The real superiority of the work measure of specific heat lies in the fact that it is independent of any particular substance, and there is nothing whatever hypothetical about it.[1]

Another illustration of the illegitimate use of our hypothesis, as it appears to me, is in the attempt to find in the ether a fixed datum for the measurement of material velocities and accelerations, a something in which we can draw our co-ordinate axes so that they will never turn or bend. But this is as if, discontented with the movement of the earth's pole, we should seek to find our zero lines of latitude and longitude in the Atlantic Ocean. Leaving out of sight the possibility of ethereal currents which we cannot detect, and the motions due to every ray of light which traverses space, we could only fix positions and directions in the ether by buoying them with matter. We know nothing of the ether, except by its effects on matter, and, after all, it would be the material buoys which would fix the positions and not the ether in which they float.

The discussion of the physical method, with its descriptive laws and explanations, and its hypothetical extension of description, leads us on to the consideration of the limitation of its range. The method was developed in the study of matter which we describe as non-living, and with non-living matter the method has sufficed for the particular purposes of the physicist. Of course only a little corner of the universe has been explored, but in the study of non-living matter we have come to no impassable gulfs, no chasms across which we cannot throw bridges of hypothesis. Does the method equally suffice when it is applied to living matter? Can we give a purely physical account of such matter, likening its motions and changes to other motions and changes already observed, and so explaining them?

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[1] This risk of imagining one particular kind of measure more real than another, more in accordance with the truth of things, may be further illustrated by the common idea that mass-acceleration is the only way to measure a force. We stand apart from our mechanical system and watch the motions and the accelerations of the various parts, and we find that mass-accelerations have a certain significance in our system. If we keep ourselves outside the system and only use our sense of sight, then mass-acceleration is the only way of describing that behaviour of one body in the presence of others which we term force on it. But if we go about in the system and pull and push bodies, we find that there is another conception of force, in which another sense than sight is concerned—another mode of measurement much more ancient and still far more extensively used—the measurement by weight supported. Each method has its own range; each is fundamental in that range. It is one of the great practical problems in physics to make the pendulum give us the exact ratio of the units in the two systems.

Can we group them in laws which will enable us to predict future conditions and positions? The ancient question never answered, but never ceasing to press for an answer.

Having faith in our descriptive method, let us use it to describe our real attitude on the question. Do we, or do we not, as a matter of fact, make any attempt to apply the physical method to describe and explain those motions of matter which on the psychical view we term voluntary?

Any commonplace example, and the more commonplace the more is it to the point, will at once tell us our practice, whatever may be our theory. For instance, a steamer is going across the Channel. We can give a fairly good physical account of the motion of the steamer. We can describe how the energy stored in the coal passes out through the boiler into the machinery, and how it is ultimately absorbed by the sea. And the machinery once started, we can give an account of the actions and reactions between its various parts and the water, and if only the crew will not interfere, we can predict with some approach to correctness how the vessel will run. All these processes can be likened to processes already studied—perhaps on another scale—in our laboratories, and from the similarities prediction is possible. But now think of a passenger on board who has received an invitation to take the journey. It is simply a matter of fact that we make no attempt at a complete physical account and explanation of those actions which he takes to accomplish his purpose. We trace no lines of induction in the ether connecting him with his friends across the Channel, we seek no law of force under which he moves. In practice the strictest physicist abandons the physical view, and replaces it by the psychical. He admits the study of purpose as well as the study of motion.

He has to admit that here his physical method of prediction fails. In physical observations one set of measurements may lead to the prediction of the results of another set of measurements. The equations expressing the laws imply different observations with some definite relation between their results, and if we know one set of observations and that definite relation we can predict the result of the other set. But if we take the psychical view of actions, we can only measure the actions. We have no independent means of studying and measuring the motions which preceded the actions, we can only estimate their value by the consequent actions. If we formed equations, they would be mere identities with the same terms on either side.

The consistent and persistent physicist, finding the door closed against him, finding that he has hardly a sphere of influence left to him in the psychical region, seeks to apply his methods in another way by assuming that if he knew all about the molecular positions and motions in the living matter, then the ordinary physical laws could be applied and the physical conditions at any future time could be predicted. He would say, I suppose, with regard to the Channel passenger, that it is absurd to begin with the most complicated mechanism, and seek to give a physical account of that. He would urge that we should take some lower form of life where the structure and motions are simpler, and apply the physical methods to that.

Well, then, let us look for the physical explanation of any motion which we are entitled from its likeness to our own action to call a voluntary motion. Must we not own that even the very beginning of such explanation is as yet non-existent? It appears to me that the assumption that our methods do apply, and that purely physical explanation will suffice to predict all motions and changes, voluntary and involuntary, is at present simply a gigantic extrapolation, which we should unhesitatingly reject if it were merely a case of ordinary physical investigation. The physicist when thus extending his range is ceasing to be a physicist, ceasing to be content with his descriptive methods in his intense desire to show that he is a physicist throughout.

Of course we may describe the motions and changes of any type of matter after the event, and in a purely physical manner. And as Professor Ward has suggested, in a most important contribution to this subject which he has made in his recently published Gifford Lectures,[1] where ordinary physical explanations fail to give an

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[1] 'Naturalism and Agnosticism,' *The Gifford Lectures*, 1896–98, vol. ii. p. 71.

account of the motions, we might imagine some structure in the ether, and such stresses between the ether and matter that our physical explanations should still hold. But, as Professor Ward says, such ethereal constructions would present no warrant for their reality or consistency. Indeed they would be mere images in the surface of things to account for what goes on in front of the surface, and would have no more reality than the images of objects in a glass.

If we have full confidence in the descriptive method, as applied to living and non-living matter, it appears to me that up to the present it teaches us that while in non-living matter we can always find similarities, that, while each event is like other events, actual or imagined, in a living being there are always dissimilarities. Taking the psychical view—the only view which we really do at present take—in the living being there is always some individuality, something different from any other living being, and full prediction in the physical sense, and by physical methods, is impossible. If this be true, the loom of Nature is weaving a pattern with no mere geometrical design. The threads of life, coming in we know not where, now twining together, now dividing, are weaving patterns of their own, ever increasing in intricacy, ever gaining in beauty.

The following Papers and Report were read:—

1. *On the Spectroscopical Examination of Contrast Phenomena.* *By* George J. Burch, *M.A.*

The author has shown that by exposing the eye to bright sunlight in the focus of a burning glass, behind a screen composed of ordinary ruby glass in conjunction with a gelatine film stained with magenta, a condition of temporary red-blindness may be induced, during which red flowers, such as scarlet geraniums, appear black, and red roses blue, although the observer is still perfectly able to distinguish colours composed of green, blue, and violet. Similarly blindness to green, to blue, or to violet may be produced by fatiguing the retina with monochromatic light of sufficient intensity and of suitable colour. Experiments of the same character by Aitken, Hunt, Hess, and others, have since been brought to the author's notice. His own, which were made quite independently many years ago, differ from theirs in degree rather than in kind, the light used by these observers having apparently been not sufficiently intense to produce the full effect.

These phenomena, in the author's opinion, are unfavourable to the theory of Hering, but support that of Young and Helmholtz, with a slight modification. They indicate the existence of a separate sensation of blue as well as of violet, a possibility which Young was prepared to admit, though he could find no proof of it.

On Young's hypothesis all complementary colours and all contrast effects may be represented as coming under the same category as absorption spectra, in that they are due to the subtraction of something from the normal sensations which should result from the physical conditions of the experiment. According to Hering's theory, complementary colours cannot be regarded as due to the mere absence, or diminution, or suppression of certain elements of a complex sensation.

So far as regards the effect of continuous light, the phenomena of artificial colour-blindness seem conclusive against the view of Hering. The author described apparatus by which the methods of spectroscopic analysis may be applied to the investigation of the phenomena of complementary colours and of successive contrast by intermittent light.

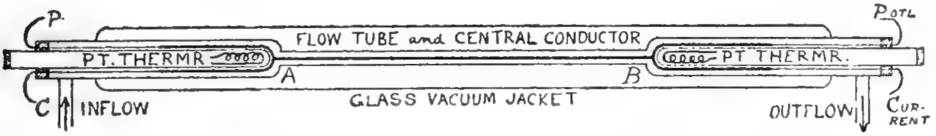
2. *Preliminary Note on the Variation of the Specific Heat of Water.* *By* H. L. Callendar, *M.A., F.R.S., Quain Professor of Physics at University College, London, and* H. T. Barnes, *M.A.Sc., Demonstrator of Physics, McGill College, Montreal.*

At the meeting of the British Association at Toronto in 1897 the authors communicated a note describing their new method of determining the specific heat of a liquid in terms of the international electrical units, and gave a few results which had been obtained in the cases of water and mercury. The whole apparatus was also exhibited in action to several members of Section A, on the occasion of their visit to McGill College. One of the main objects of the work was the determination of the mode of variation of the specific heat of water over the range 0° to 100° C., for which the method was peculiarly suited.

The progress of the investigation has been somewhat delayed by the removal of Professor Callendar to London in May 1898. Since that time the work has been in the sole charge of Mr. Barnes, who has now succeeded in obtaining satisfactory results over the greater part of the range to be covered.

The general principle of the method, and the construction of the apparatus, will be readily understood by reference to the diagram of the Steady-Flow Electric Calorimeter given in fig. 1. A steady current of water flowing through a fine tube, AB, is heated by a steady electric current through a central conductor of platinum. The steady difference of temperature between the inflowing and outflowing water is observed by means of a differential pair of platinum thermometers at either end. The bulbs of these thermometers are surrounded by thick copper tubes, which by their conductivity serve at once to equalise the temperature, and to prevent the generation of heat by the current in the immediate neighbourhood of the bulbs of the thermometers. The leads CC serve for the introduction of the current, and the leads PP, which are carefully insulated, for the measurement of the difference of potential on the central conductor. The flow tube is constructed of glass, and is sealed at either end, at some distance beyond the bulbs of the thermometers, into a glass vacuum jacket, the function of which is to diminish as much as possible the external loss of heat. The whole is enclosed in an external copper jacket (not shown in the figure), containing water in rapid circulation at a constant temperature maintained by means of a very delicate electric regulator.

FIG. 1.—Diagram of Steady-Flow Electric Calorimeter.



Neglecting small corrections, the general equation of the method may be stated n the following form:—

$$ECt = JMd\theta + H.$$

The difference of potential E on the central conductor is measured in terms of the Clark cell by means of a very accurately calibrated potentiometer, which serves also to measure the current C by the observation of the difference of potential on a standard resistance R included in the circuit.

The Clark cells chiefly employed in this work were of the hermetically sealed type described by the authors in the 'Proc. Roy. Soc.' October 1897. They were kept immersed in a regulated water bath at 15° C., and have maintained their relative differences constant to one or two parts in 100,000 for the last two years.

The standard resistance R consists of four bare platinum silver wires in parallel wound on mica frames and immersed in oil at a constant temperature. The coils were annealed at a red heat after winding on the mica, and are not appreciably heated by the passage of the currents employed in the work.

The time of flow t of the mass of water, M, was generally about fifteen to twenty minutes, and was recorded automatically on an electric chronograph reading to ·01 second, on which the seconds were marked by a standard clock.

The letter J stands for the number of joules in one calorie at a temperature which is the mean of the range, $d\theta$, through which the water is heated.

The mass of water, M, was generally a quantity of the order of 500 grammes.

After passing through a cooler, it was collected and weighed in a tared flask in such a manner as to obviate all possible loss by evaporation.

The range of temperature, $d\theta$, was generally from 8° to 10° in the series of experiments on the variation of J, but other ranges were tried for the purpose of testing the theory of the method and the application of small corrections. The thermometers were read to the ten-thousandth part of a degree, and the difference was probably in all cases accurate to ·001° C. This order of accuracy could not possibly have been attained with mercury thermometers under the conditions of the experiment.

The external loss of heat, H, was very small and regular, owing to the perfection and constancy of the vacuum attainable in the sealed glass jacket. It was determined and eliminated by adjusting the electric current so as to secure the same rise of temperature, $d\theta$, for widely different values of the water-flow.

The great advantage of the steady-flow method as compared with the more common method in which a constant mass of water at a uniform temperature is heated in a calorimeter, the temperature of which is changing continuously, is that in the steady-flow method there is practically no change of temperature in any part of the apparatus during the experiment. There is no correction required for the thermal capacity of the calorimeter; the external heat loss is more regular and certain, and there is no question of lag of the thermometers. Another incidental advantage of great importance is that the steadiness of the conditions permits the attainment of the highest degree of accuracy in the instrumental readings.

In work of this nature it is recognised as being of the utmost importance to be able to detect and eliminate constant errors by varying the conditions of the experiment through as wide a range as possible. In addition to varying the electric current, the water-flow, and the range of temperature, it was possible, with comparatively little trouble, to alter the form and resistance of the central conductor, and to change the glass calorimeter for one with a different degree of vacuum, or a different bore for the flow tube. In all six different calorimeters were employed, and the agreement of the results on reduction afforded a very satisfactory test of the accuracy of the method.

The general results of the investigation, so far as it has been possible to work them out for publication at present, may be gathered from an inspection of fig. 2, which includes the results of previous observers plotted on the same scale. The curve marked Regnault, 1840, represents the well-known formula of Regnault which has been adopted as the basis of much calorimetric work. This formula was confessedly approximate, and was deduced from experiments on mixing water at high temperatures with water at 15° C. The method could not be expected to give any information with regard to the variation of the specific heat at ordinary temperatures. The experiments of Jamin and Amaury (J. & A.), 1870, by the method of electric heating, gave a very rapid increase of the specific heat at low temperatures, but the science of electrical measurement, and the difficulties of the electrical method, were not at that date sufficiently appreciated to render the results of any value.

The discovery of the diminution of the specific heat of water with rise of temperature from 0° to 30° C. was made by Rowland in his investigation of the mechanical equivalent of heat by the method of Joule. His original results, reduced to the scale of his own air thermometer, are shown by the dotted curve marked Ro. The corresponding values of the specific heat in absolute measure are shown by the scale of joules in the right-hand margin. His results have recently been reduced to the Paris scale by the comparison of his thermometers with a Tonnelot thermometer standardised at the International Bureau, and with a platinum thermometer standardised by Griffiths.[1] The results so reduced are indicated by the full curve Rp. The effect of this reduction is to lower the temperature at which the specific heat is 4·200 joules from 10° to 7° C., to diminish the temperature coefficient, and to lower the point of minimum specific heat to about 29° C.

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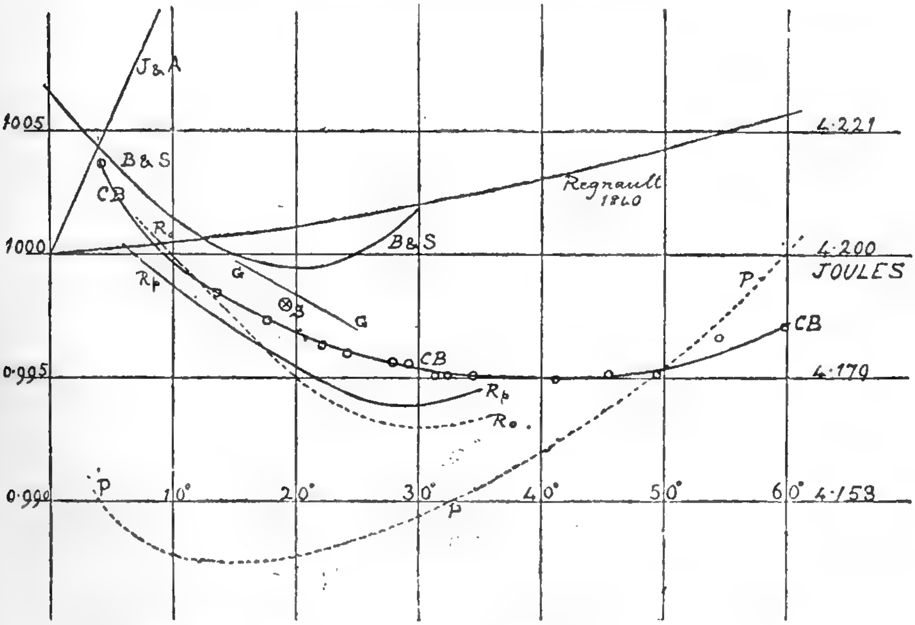
[1] Waidner and Mallory, *Phil. Mag.* June 1899.

The experiments of Bartoli and Stracciati (1891) were made by the method of mixtures, and are expressed in terms of a thermal unit at 15° C. The corresponding curve, marked B. & S., bears a general resemblance to that of Rowland, but shows a minimum at 20° C. The errors and limitations of this method are well known, and it is difficult to suppose it capable of an order of accuracy higher than one part in a thousand, or to resist the impression that this excessive lowering of the minimum point is due to some constant error inherent in the method, which cannot be eradicated by mere repetition of similar experiments.

The experiments of Griffiths (G) over the range 15° to 25° were made by observing the rate of rise of temperature of a mass of water in a calorimeter heated by an electric current. His work threw a flood of light on the difficulties of electrical calorimetry as usually practised, and explained the failure of previous observers to secure satisfactory results by this method. Over the range of his experiments he found approximately the same rate of diminution of the specific heat as that given by the experiments of Rowland when reduced to the same scale of temperature.

The curve marked CB in the figure, extending from 4° to 60°, represents the results so far obtained in the present investigation. The points indicated by small circles represent samples of single observations with different calorimeters, and are inserted to give an idea of the order of agreement attainable by this method. The order of accuracy diminishes as the temperature rises, owing to the greater difficulty of satisfactorily regulating the temperature of the water-jacket at the higher points. It is hoped, however, by a slight modification of the heating and regulating apparatus, to secure good results at temperatures as high as 90° C. with the water-jacket, and to obtain an observation at 100° C. with a steam-jacket.

FIG. 2.—Variation of Specific Heat of Water.



J. & A. Jamin and Amaury, 1870.
B. & S. Bartoli and Stracciati, 1891.
Ro. Rowland, 1880 ; *Rp.* reduced to Paris scale.
G. Griffiths, 1893.
S. Schuster and Gannon.
C.B. Callendar and Barnes.
Assuming Clark Cell = 1·4342 volts at 15° C.

According to the authors' experiments, the curve representing the variation of the specific heat is much flatter than that given by Rowland, and has a minimum at 40° C. instead of 29° C. The experiments of Rowland did not extend sufficiently beyond the minimum point to afford a really satisfactory determination. The value of the specific heat could not be determined by his method with the same degree of precision at the extremities of the range as in the middle, and all the probable errors of the method would be greatly increased as the temperature of the calorimeter was raised so far above its surroundings. In particular, the corrections and changes of zero of the mercury thermometers, and the rate of external loss of heat, would be excessive at the higher points. In the authors' method, on the contrary, there are no thermometric difficulties of this nature, owing to the direct employment of platinum thermometers, and the external heat loss increases very little as the temperature is raised, because the external water-jacket is always at the same temperature as the inflowing water current, so that the mean excess of temperature is always nearly the same.

Another indication that the temperature of minimum specific heat should be not far below the middle of the range is afforded by the experiments of Regnault, and more recently by those of Reynolds and Moorby, on the mean specific heat of water between 0° and 100° C. Their results by entirely different methods agree in showing that the mean specific heat over the whole range does not greatly exceed the value at 20° C.

There is apparently revealed for the first time by the authors' experiments a very rapid increase in the specific heat as the freezing point is approached. The point at 4° C. on the curve CB represents the mean specific heat over the range 0° to 8°. The rapid increase of the curvature as this point is reached is probably due to an exceptionally high value in the immediate neighbourhood of 0° C. The probability of this result was foreseen by Rowland on theoretical grounds, but his original curve, which is accurately a straight line from 5° to 20°, does not show the effect. The authors propose to investigate this point more closely by taking smaller ranges of temperature, such as 0°–2°, and 0°–4° C., from which the actual form of the curve may be deduced.

With reference to the possibility of obtaining an independent verification of the accuracy of the electrical units, and, in particular, of the absolute value of the E.M.F. of the Clark cell, it is interesting to compare the absolute values of the specific heat deduced by the electrical methods with that of Rowland by the mechanical method. For this purpose the authors' results, and those of Griffiths (G.), and of Schuster and Gannon (S.), have been reduced to joules on the assumption that the absolute value of the E.M.F. of the Clark cell at 15° C. is 1·4342 volts, as found by Glazebrook and Skinner, assuming Lord Rayleigh's value of the electrochemical equivalent of silver, and taking the international ohm as correct. It has been pointed out that the results of Griffiths would be brought into harmony with those of Rowland by supposing that the true E.M.F. of the Clark cells employed was about 2 millivolts lower, or one part in 700. The authors' results, however, lie about midway between those of Rowland and Griffiths, and would require a correction of only 1 millivolt if the whole of the difference were to be debited to the Clark cell. It is not at all likely that the E.M.F. of the cells employed by the authors can have exceeded the B.O.T. standard by so much as 1 millivolt, or that their resistance standards can have been incorrect by so much as one part in 700. It is most likely that both the Clark cells and the resistance standards employed by the authors agreed with those employed by Griffiths to within one or two parts in 10,000, and that the difference of the results is mainly to be attributed to the radical difference in the methods of calorimetry.

These and similar questions relating to the absolute values of the standards employed do not affect the accuracy of the relative results as regards the variation of the specific heat of water with temperature. The relative results are regarded by the authors as being probably as accurate as their present apparatus is capable of affording. By far the most important consideration affecting the form of the curve in this respect is the particular thermometric scale to which the results are reduced. If, for instance, the results were expressed, as originally obtained, in terms of the platinum scale of temperature, which differs from the absolute scale by only 0°·38 C. at 50° C., where the divergence is a maximum, the curve would be that represented by the dotted line PPP in the figure. The curve CB is deduced from this by the usual parabolic difference formula, which gives results in practical agreement with the Paris scale.

Since the discussion of the thermal unit introduced by Griffiths[1] at the British Association Meeting of 1895, and partly in consequence of the general interest excited by that discussion, so many new facts have been brought to light, and so much experience has been gained of the practical effect of the proposals then made, that it appears desirable to discuss more fully the bearing of the present work on the general question of the relation between the various thermal units.

Dieterici ('Wied. Ann.' 33, p. 417, 1888) made a determination of the mean specific heat in terms of the electrical units by means of a Bunsen ice-calorimeter. His result (when reduced on the assumption that the electrochemical equivalent of silver is 0·0011180 grm. per amp. sec., and that the ohm is the resistance at 0° C. of a column of mercury 1 sq. mm. in section and 106·30 cm. in length) gives 4·233 joules as the value of the mean specific heat of water in absolute measure between the limits 0° and 100° C.[2]

Winkelmann ('Handbook of Physics,' vol. ii. part ii. p. 338) endeavoured to connect this result with those of Rowland at low temperatures by assuming a parabolic formula for the mode of variation, and taking the minimum value at 30·6° C. to be 0·9898 of the value at 0° C. These assumptions give for the specific heat s_t at any temperature t° C., the formula—

$$s_t = 1 - 0{\cdot}0006684\, t + 0{\cdot}00001092\, t^2 \quad . \quad . \quad . \quad . \ \text{(W)}$$

and for the mean specific heat between 0° and t°, which may be written $s\,{}^t_0$,

$$s\,{}^t_0 = 1 - 0{\cdot}0003342\, t + 0{\cdot}00000364\, t^2.$$

According to this formula, the ratio of the mean specific heat between 0° and 100° to the specific heat at 20° C. would be 1·0120. According to the formula of Regnault, the same ratio would be 1·0038. If we take Rowland's corrected value at 20° C. as 4·181 joules, the mean value between 0° and 100° would be 4·197 joules according to Regnault, but 4·233 joules according to Winkelmann. The latter gives a remarkable coincidence with Dieterici, in consequence of which the formula (W) has been frequently quoted and employed in physical investigations. It must be remarked, however, that Rowland's curve is not even approximately parabolic, and that the range covered by his observations is hardly sufficient to justify this method of treatment. It must also be observed that the values given by Winkelmann's formula for the specific heat in the neighbourhood of 100°, and still more at higher temperatures, are so large that they cannot conceivably be reconciled with the experiments of Regnault and other good observers.

Griffiths ('Phil. Trans.' vii. 1895, pp. 318–323) came to the conclusion from a comparison of his experiments on the latent heat of evaporation of water at 30° and 40° C. with those of Dieterici at 0° C. expressed in terms of the mean specific heat, and with those of Regnault on the total heat of steam at 100° C., that the mean specific heat must be very nearly identical with the specific heat at 15° C., although Regnault's direct experiments made the ratio from 0·5 per cent. to 1 per cent. larger. At his suggestion Professor Joly performed the inverse experiment of determining the mean specific heat between 12° and 100° with his steam calorimeter in terms of the latent heat of steam at 100° taken as 536·63 times the thermal unit at 15° C. The result of this experiment was to make the mean specific heat appear nearly 0·5 per cent. *smaller* than the specific heat at 15° C. If we suppose that the inversion of the experiment would tend to reverse the error of the original determination of the latent heat, the result would appear to be strongly in support of Griffiths's contention.

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[1] Griffiths's 'The Thermal Unit.' *Phil. Mag.* Nov. 1895.

[2] Assuming that the mean caloric melts a quantity of ice sufficient to cause 15·44 milligrams of mercury to enter the calorimeter. Bunsen gives 15·41 mgm., and Velten 15·47 mgm. See also Dieterici, *Wied. Ann.* 1896, lvii. p. 333, where a curve somewhat similar to Winkelmann's is given.

Peabody, in the preface to his well-known 'Tables of the Properties of Saturated Steam' (1896), as the result of a careful discussion of Rowland's and Regnault's experiments, adopts Rowland's values from 0° to 40°, and expresses his results in terms of the mean specific heat between 15° and 20°. He finds that Regnault's experiments may be sufficiently represented in terms of this unit by assuming the specific heat to be constant and equal to 1·008 between the limits 45° and 155°, and constant and equal to 1·046 between the limits 155° and 200° C. This assumption would make the mean specific heat between 0° and 100° have the value 1·0044 in terms of the specific heat at 17°·5, or the value 1·0056 in terms of the specific heat at 20°, assuming Rowland's coefficient of diminution. The general effect of these changes is to make the tables agree fairly well throughout with Regnault's experiments, but the method can only be justified on the ground of expediency, and can hardly be regarded as a satisfactory reconciliation of conflicting evidence on account of the assumed discontinuities in the specific heat.

Shaw ('B. A. Report,' 1896, p. 162) gives a similar reduction of Regnault's experiments by means of Rowland's original table, but tabulates only the total heat in joules at each point between 100° and 180° C. His reduction shows a similar flattening of the curve between 100° and 150°, as compared with Regnault's formula. This may be a physical fact, but might also be explained by supposing that the earlier experiments at 108° to 120° were about 0·4 per cent. too high. Shaw's reduction, expressed in terms of a thermal unit at 20° C., is given for comparison in the table on p. 631.

Quite recently a direct determination of the mean specific heat in terms of mechanical units has been made by Reynolds and Moorby ('Phil. Trans.' A. 1897) on a large scale with Reynolds's break and a steam-engine. Their result expressed in absolute units is 4·1832 joules, and is entitled to very great weight on account of the minute accuracy of the measurements, and the full discussion of possible sources of error. It exceeds the value found by Rowland at 20° C. by only one part in two thousand, but is no less than 1·20 per cent. smaller than the mean value found by Dieterici—a discrepancy far too large to be explained by any uncertainty in the values of the electrical units.

Unless the mean value found by Reynolds and Moorby is summarily rejected, it is clear that the minima of specific heat at 20° and 30° indicated by the work of Bartoli and Stracciati and of Rowland respectively, must be due to some constant source of error inherent in their methods, and that all formulæ hitherto proposed for the mode of variation of the specific heat between 0° and 100° must be abandoned.

It is possible, however, to deduce a more satisfactory comparison of the results of Rowland with those of Reynolds and Moorby by means of the present series of experiments, on account of their greater range, and the close agreement of the individual observations. Neglecting for the present the rapid change of the specific heat in the immediate neighbourhood of 0° C., it may be observed that all the authors' observations between 10° and 60° (with the exception of one at 55°) are represented within one part in 5,000 (*i.e.* within the limits of agreement of the observations with different calorimeters at any one point) in terms of the minimum value s_{40}40° at C., by the simple formula—

$$s_t = s_{40}\,(1 + 0{\cdot}0000045\,(t-40)^2) \quad . \quad . \quad . \quad . \quad . \quad (\mathrm{CB})$$

which gives for the mean specific heat between 0° and t° the formula—

$$s^t_0 = s_{40}\,(1{\cdot}0072 - 0{\cdot}00018\,t + 0{\cdot}00000150\,t^2).$$

If this formula could be assumed to hold beyond these limits over the whole range 0° to 100°, the ratio of the mean specific heat between 0° and 100° to the specific heat at 20° would be 1·0024. Assuming Rowland's 4·181 joules at 20°, this ratio would give the value 4·191 joules for the mean specific heat, a result which is still in excess of Reynolds and Moorby's 4·183 joules, but is not so hopelessly beyond the range of possible errors of experiment as that given by

Winkelmann's formula. It may also be worth remarking that a direct experiment of Rowland's gave the ratio $s^{100}_{28}/s^{28}_{18} = 1{\cdot}0024$, for which the above formula would give the value 1·0033.

TABLE OF SPECIFIC HEAT OF WATER.

$t°$ C	Joules	s_t	s_o^t	h (CB)	Rowland (reduced)
Range 0° to 60°. Callendar and Barnes. Formula, $s_t = 0{\cdot}9982 + 0{\cdot}0000045\,(t-40)^2$.					
0°	4·203	1·0054	—	—	—
5°	4·196	1·0037	1·0045	5·023	5·023
10°	4·190	1·0022	1·0037	10·037	10·044
15°	4·185	1·0010	1·0030	15·045	15·054
20°	4·181	1·0000	1·0024	20·048	20·057
25°	4·178	0·9992	1·0018	25·045	25·053
30°	4·176	0·9987	1·0013	30·039	30·043
35°	4·174	0·9983	1·0009	35·032	35·039
40°	4·174	0·9982	1·0006	40·024	Peabody
45°	4·174	0·9983	1·0003	45·016	45·000
50°	4·176	0·9987	1·0001	50·008	50·040
55°	4·178	0·9992	1·0000	55·002	55·080
60°	4·181	1·0000	1·0000	60·000	60·120
Range 60° to 220° C. Regnault (corrected). Formula, $s_t = 0{\cdot}9944 + 0{\cdot}00004\,t + 0{\cdot}0000009\,t^2$.					
60°	4·181	1·0000	1·0000	60·000	60·12
65°	4·184	1·0008	1·0000	65·002	65·16
70°	4·188	1·0016	1·0001	70·008	70·20
75°	4·191	1·0024	1·0002	75·018	75·24
80°	4·195	1·0033	1·0004	80·032	80·28
85°	4·199	1·0043	1·0006	85·051	85·32
90°	4·203	1·0053	1·0008	90·075	90·36
95°	4·207	1·0063	1·0011	95·105	95·40
100°	4·212	1·0074	1·0014	100·138	100·44
					Shaw
110°	4·222	1·0097	1·0020	110·22	110·67
120°	4·232	1·0121	1·0028	120·33	120·73
130°	4·243	1·0148	1·0036	130·47	130·80
140°	4·255	1·0176	1·0045	140·63	140·88
150°	4·267	1·0206	1·0055	150·82	151·01
160°	4·281	1·0238	1·0066	161·05	161·20
170°	4·295	1·0272	1·0077	171·31	171·61
180°	4·310	1·0308	1·0089	181·60	182·14
190°	4·326	1·0345	1·0102	191·94	—
200°	4·342	1·0384	1·0115	202·31	—
210°	4·359	1·0425	1·0130	212·72	—
220°	4·377	1·0467	1·0145	223·18	—

It would appear, however, from the authors' preliminary observations at higher points, that the curve of variation of specific heat is not quite symmetrical, but somewhat flatter between 60° and 100°. The rate of change of the specific heat at 100° as given by the formula (CB), if extrapolated, is more than twice as great as that given by Regnault, and at 200° about four times as great. The experiments of Regnault apply particularly to this portion of the range, for which they remain the standard, and have been universally adopted. Until more accurate experiments are forthcoming, it would be extremely desirable to retain his formula for the higher points, with such modification only as is necessary to make it fit with the observations at lower temperatures. It happens that the rate of variation of the specific heat given by Regnault's formula agrees with that given by the formula (CB) between 55° and 60°. The two formulæ can therefore be very accurately fitted at this point by the simple expedient of subtracting a constant quantity from the values given by Regnault's formula at temperatures above 60° C. This apparently arbitrary method would not be suggested if it were not that it leads to results which are intrinsically most probable, and which require the simplest modification of existing tables.

If the formula (CB) is adopted for the range 0° to 60°, over which it has been accurately verified, and the formula of Regnault (corrected as above explained) from 60° to 100°, the ratio of the mean specific heat between 0° and 100° to the specific heat at 20° is 1·0014. Taking Rowland's value as 4·181 joules at 20°, this ratio would give 4·1868 for the mean specific heat, which exceeds the value found by Reynolds and Moorby by less than one part in a thousand—a discrepancy so small as to be within the limits of possible error even in the case of these two extremely accurate determinations. Since it is a work of great labour and difficulty to redetermine the specific heat at temperatures above 100°, and since it is extremely unlikely that more accurate results over this part of the range will be forthcoming in the near future, it has appeared desirable to adopt this basis for the construction of the annexed table of the variation of the specific heat of water over the whole range 0° to 220° C. The general effect of the table is to diminish the extent of the variation hitherto assumed, but it is believed that the results here tabulated are within the limits of possible error of all the best experiments. The order of agreement may be inferred from a comparison of the values of h, the total heat of the liquid, given in the last two columns. The agreement with Rowland is within 1 in 3,000 between 10° and 40°, and with Regnault within 1 in 1,000 at 160° C. The variations of Regnault's individual observations exceed 5 parts in 1,000.

The values of the total heat h are found by integrating the specific heat from 0 to t, according to the formula. The formula does not represent the rapid change of s near the freezing-point, but accurate account may be taken of this, when desired, at any point above 10°, by adding the constant quantity 0·020 to the value of h as given in the table by the formula. This correction, however, is seldom of importance.

3. *On the Expansion of Porcelain with Rise of Temperature.* *By* T. G. Bedford.—See Reports, p. 245.

4. *Interim Report on Methods of Determining Magnetic Force at Sea.* See Reports, p. 64.

FRIDAY, SEPTEMBER 15.

The following Reports and Papers were read:—

1. *Report on Electrolysis and Electro-Chemistry.*—See Reports, p. 160.

2. *On the Energy per Cubic Centimetre in a Turbulent Liquid when Transmitting Laminar Waves.* *By* Professor G. F. FitzGerald, *F.R.S., Trinity College, Dublin.*

In the 'Phil. Mag.' vol. xxiv. p. 342, October 1887, Lord Kelvin has given equations for the transmission of laminar waves through a turbulent liquid. He expresses doubt as to the possibility of any turbulency being possible to which his investigation would apply, owing to the rapid diffusion of the motion, and he illustrates his paper by reference to a liquid in which separate vortex rings are arranged in a regular cubical order which would, as he says, be almost certainly subject to the diffusion of motion which would vitiate his investigation. A few years afterwards, however, Lord Kelvin published in the 'Proc. of the R. I. Academy,' 1889, vol. i. p. 340, a paper in which he described an arrangement of long, thin, empty, vortex filaments, which he considered would be stable, and not subject to the diffusion and mixing which would vitiate the application of his wave theorem to the first turbulent medium he suggested. I have this year, in the 'R. D. S. Proceedings' (p. 51), published a paper calling attention to the way in which laminar waves might be propagated by this latter medium, and have suggested a way in which electrons might exist therein. The paper is only suggestive, and cannot claim to prove much. I now desire to call attention to the expressions that Lord Kelvin has given for the structure changes that take place when the waves he describes are being propagated through the medium, and to show how to calculate a quantity which must be proportional to the energy per c.c. of this wave-motion. I must refer to the paper itself for an explanation of the notation, as it would make this note very long to give it here.

The equations from which Lord Kelvin deduces the possibility of the propagation of laminar motion through a turbulent liquid are two:

$$(1)\ \frac{d(fy,\,t)}{dt} = -xzav\,\frac{d(\mathrm{uv})}{dy},$$

$$(2)\ \frac{d}{dt}\,xzav(\mathrm{uv}) = -\frac{2}{9}\,\mathrm{R}^2 . \frac{d}{dy} f(y,\,t).$$

In this, R^2 is the mean square of the velocity of the original turbulency of the liquid.

The comparison of this with Maxwell's equations is obvious, and $f(y, t)$ may be either magnetic or electric action, and $xzav(\mathrm{uv})$ will then be either electric or magnetic. It shortens matters to call $\frac{2}{9}\,\mathrm{R}^2 \equiv \mathrm{V}^2$, $f(y,\,t) \equiv \mathrm{P}$, and $xzav(\mathrm{uv}) \equiv \gamma$; so that the equations are

$$\frac{d\mathrm{P}}{dt} = -\frac{d\gamma}{dy},$$

$$\text{and } \frac{d\gamma}{dt} = -\mathrm{V}^2\,\frac{d\mathrm{P}}{dy}.$$

If now we take the quantity

$$\mathrm{P}^2 + \frac{\gamma^2}{\mathrm{V}^2} = 2\Sigma$$

and integrate it throughout space, and then determine its variations with time, we find

$$\frac{d}{dt}\iiint 2\Sigma\, dxdydz = \iiint \left(\mathrm{P}\,\frac{d\mathrm{P}}{dt} + \gamma/\mathrm{V}^2\,\frac{d\gamma}{dt}\right) dxdydz$$

$$= \iiint \left(\mathrm{P}\,\frac{d\mathrm{P}}{dt} - \gamma\,\frac{d\mathrm{P}}{dy}\right) dxdydz.$$

Integrating the second term under the integral by parts, and omitting the superficial terms which may be at infinity, or wherever energy enters the space under consideration, we get

$$\frac{d}{dt}\iiint 2\Sigma dxdydz = \iiint \mathrm{P}\left(\frac{d\mathrm{P}}{dt} + \frac{d\gamma}{dy}\right) dxdydz = 0.$$

Hence we see that Σ, which is of the right dimensions, must be proportional to the energy per c.c. of the medium. This is the same as in Maxwell's theory, so that there seems very little more besides interpretation of symbols to make a turbulent liquid a satisfactory explanation of the structure of the ether

I am myself satisfied, though I think Lord Kelvin is not, that the turbulency of a sufficiently fine-grained purely and irregularly turbulent liquid would ultimately become so slow in its diffusion from place to place that Lord Kelvin's investigation would apply to it.

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3. *On the Permanence of certain Gases in the Atmospheres of Planets.*

By G. H. Bryan, *Sc.D., F.R.S.*

In a paper read before the Nottingham Meeting of the Association, the author discussed the application of the kinetic theory of gases to explain the absence of an atmosphere from the moon's surface. In the present investigation similar methods are applied to the atmospheres of planets, account being taken of the axial rotations of the planets. A test of the permanence or otherwise of different gases in the atmospheres of different celestial bodies at different temperatures has been obtained, and a superior limit has been found for the rate at which any planet would lose any gas by the molecules flying off from its atmosphere. To interpret this limit in the simplest possible form, the author has calculated the number of years which would have to elapse in various cases before the quantity of gas lost would be equivalent to that contained in a layer one centimetre thick, covering the surface of the earth. For simplicity absolute temperatures of 200°, 300°, 400°, 500°, and 600° have been chosen—*i.e.* Centigrade temperatures of $-73°$, 27°, 127°, and so forth.

In the case of terrestrial hydrogen the loss in question would occupy 84,000,000,000 years at temperature $-73°$, 600,000 years at $-23°$, and 222 years at 27° C.

For helium on the earth's surface, the corresponding numbers are $3{\cdot}5 \times 10^{36}$ years at $-73°$, 3×10^{19}, or 30 trillion years at 27°, 84,000,000,000 years at 127° 600,000 years at 227°, and 222 years at 327°. This assumes the molecular weight of helium to be 2.

For vapour of water on Mars, the figures are $1{\cdot}2 \times 10^{33}$ years at $-73°$, $1{\cdot}9 \times 10^{16}$, or 19 thousand billion years at 27°, 2,400,000,000 years at 127°, 43,000 years at 227°, and 106 years at 327°.

The removal of a layer of *air* 1 centimetre in thickness from the surface of the earth would only mean a lowering in the average barometric pressure of $\frac{1}{13600}$ of a millimetre, roughly. Suppose then that the afore-mentioned gases were present in the respective atmospheres in sufficient quantity to produce pressures comparable with one atmosphere, and assume that a fall of one millimetre in the average height of the barometer is the least secular change that could be detected; the above-mentioned intervals of time would have to be multiplied by 13,600 roughly, in order to give the numbers of years in which the escape of the respective gases could be detected by a barometer.

The only possible conclusions from these results are—

(1) That helium could exist practically permanently in our atmosphere at ordinary temperatures.

(2) That watery vapour could exist practically permanently in the atmosphere of Mars at ordinary temperatures.

(3) That if helium once existed in appreciable quantities in the earth's atmosphere, it must have escaped when the earth was far hotter than at present.

(4) That a similar conclusion holds good on the supposition that Mars once possessed, but has now lost, vapour of water as a constituent of its atmosphere, the temperature-limit at which the loss ceased to be appreciable being, however, lower than for terrestrial helium.

(5) That hydrogen, on the other hand, may escape from the earth's atmosphere, even at ordinary temperatures, to such an extent as may perhaps appreciably affect its permanence.

It should be observed that Dr. Johnstone Stoney's investigations on the present subject are based on the assumption that helium cannot remain in our atmosphere, and he has assumed a temperature of −66° in his calculations. The present results throw doubt on one or both of these two assumptions.

4. *On some Novel Thermo-Electric Phenomena.*
By W. F. Barrett, *F.R.S.*

For some time past the author, in conjunction with Mr. W. Brown, B.Sc., has been investigating the physical properties of various new alloys of iron, which had been prepared by Mr. R. A. Hadfield of Sheffield. In the course of this investigation a particular nickel steel, to which five per cent. of manganese had been added, was found to possess some remarkable physical properties. The analysis of this alloy, kindly made by Mr. Hadfield, was as follows:—

Iron . .	68·8 per cent.	Manganese . .	5·0 per cent.
Nickel . .	25·0 „	Carbon . .	1·2 „

The specific electrical resistance of this alloy was found to be 97·5 microhms per c.c. at 15° C., and its temperature coefficient comparatively small, viz. 0·08 per cent. per degree C. The thermo-electric behaviour of this nickel-manganese steel, when coupled with iron, the author discovered to be most anomalous. Upon heating the couple a rapid rise of E.M.F. took place till a certain temperature was reached, and then the E.M.F. appeared to remain practically constant in spite of increasing temperature up to a white heat, the cooler junctions of the couple being kept at 0° C. Careful pyrometric measurements were made as the couple was gradually heated, with the result that between 300° and 1100° C. the E.M.F. only varied 4 per cent. above or below that at 300° C. The mean E.M.F. in this wide range of temperature from a low black to a white heat was 4,000 microvolts, and the thermo-electric curve, representing the relation between the temperature and E.M.F. of the couple, was therefore nearly a straight line after 320°. Not quite a straight line, as the mean E.M.F. was intersected at four points, viz. at 310°, 540°, 810°, and 1030° C. Had the cooler junction been kept at 310°, instead of at 0°, there would have been three successive small inversions of E.M.F. at the points named above, that is to say three neutral points.

The effect of low temperatures (−80° C.) was tried, and also coupling this alloy with some other metals, but no anomalous behaviour was observed.

When the neutral points of a copper-iron couple were carefully determined, the author noticed that the temperature of the neutral point was not the same during heating as in cooling. This was specially noticeable in a copper-steel couple, and, moreover, in each successive heating the temperature of the neutral point fell until it became nearly constant. Here are the neutral points of a particular copper-steel couple examined:—

First heating .	328°	Second heating .	283°	Third heating .	268°C.
„ cooling .	258°	„ cooling .	241°	„ cooling .	241°C.

Hence the curve representing the relation between the temperature and E.M.F. of a copper-steel couple is not the same for a rising as a falling temperature, a considerable area being enclosed by the two curves. This *thermo-electric hysteresis,* as it may be called, the author also found to exist in many other couples, one element of which was iron or an alloy of iron. The explanation is probably to be found in the phenomenon of recalescence, and is intimately connected with the discovery made by Dr. Trouton, F.R.S.,[1] of a thermo-current produced in a closed circuit of iron wire by moving a flame steadily along the wire.

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[1] See *British Association Report,* 1889, p. 517.

5. *Report on the Heat of Combination of Metals in the Formation of Alloys.*—See Reports, p. 246.

6. *Report on Radiation from a Source of Light in a Magnetic Field.*—See Reports, p. 63.

7. *On the Production, in rarefied Gases, of Luminous Rings in rotation about Lines of Magnetic Force. By* C. E. S. PHILLIPS.

The apparatus used in this investigation consisted of an approximately spherical glass bulb, the ends of which were left open for the purpose of inserting two soft iron electrodes, half an inch in diameter, through air-tight flanges which themselves were cemented to the glass. The bulb was about 2½ in. in diameter, and the electrodes were chosen of a sufficient length to enable them, while almost meeting at the centre of the bulb, to project outwards slightly beyond the rims of the flanges. A side tube was attached for the purpose of connecting the apparatus to a Sprengel air-pump and McLeod vacuum gauge. Two powerful electro-magnets were then adjusted, so as to strongly magnetise the electrodes when necessary.

A low pressure having been produced in the bulb by the action of the air-pump, leading wires were attached to the iron electrodes to enable the discharge from the secondary of an induction coil to be passed through the rarefied gas. Under these conditions the effects produced in the usual glow-discharges by the magnetisation of the electrodes could be conveniently examined. It was seen that at a pressure represented by ·008 mm. of mercury, and with the discharge just able to pass in the bulb (the magnets meanwhile remaining unexcited), on shutting off the current from the induction coil and completing the magnet circuit, a luminous ring appeared within the bulb in a plane at right angles to the lines of force and in rotation about the magnetic axis. The number of such rings can be varied by special devices, and their brightness largely depends upon the electrostatic condition of the outer surface of the glass bulb. The circumferential speed of the ring or rings rapidly dies down, and the sense of the rotation reverses when the magnetic polarity of the electrodes is reversed. The rings, when once formed, usually last for many seconds, sometimes for a minute; and they momentarily brighten before disappearing, when the electrodes cease to be magnetised. The appearance of the rings is greatly affected by bringing charged bodies up to the outside of the bulb.

The effect also depends upon the manner of stimulation of the rarefied gas within the bulb. It is necessary to obtain a particular distribution of charged particles in order to get the best results when the magnet is excited. The shape of the magnetic field is also of importance. A single magnetic electrode projecting into the electrified gas shows the effect fairly well. Experiments with external magnetic electrodes have not given reliable results, the glow produced in such cases being generally irregular. An attempt will be made later on, when the experiments are more complete, to show that the formation of these luminous rings is associated with actions observed by the writer in connection with a separate research, the results of which were embodied in a note communicated to the Royal Society last June under the heading 'Diselectrification produced by Magnetism.'

8. *Note on Deep-Sea Waves.*
By VAUGHAN CORNISH, *M.Sc., F.C.S., F.R.G.S.*

The following questions are raised or discussed:—(1) What is the amplitude H and the wave-length L for different distances Δ from the windward shore, the wind being supposed to blow with velocity V of say 30 knots until the sea has reached a steady state? (2) Can wind create waves of considerable amplitude, having a speed greater than that of the wind? (3) Different periods of residual swell being, apparently, characteristic of different localities, will selective absorption cause waves of this period to be developed at a specially rapid rate when a wind blows in this or neighbouring areas? (4) What is the relation between growth of wave-length and diminution in curvature of wave-front?

Further, an examination is made of the numerical relations among the quantities recorded in Lieut. Paris' paper on deep-sea waves,[1] and in Antoine's collection of results,[2] and in Coupvent Desbois' summary of the observations of amplitude made on the *Astrolabe.* I find relations among Paris' numbers which are useful for the interpretation of his observations. I doubt if Antoine is justified in applying Desbois' formula $H \propto V^{\frac{2}{3}}$ to later observations than those of the *Astrolabe.* Paris' observations seem, however, to be pretty nearly comparable with Antoine's collected observations, of which, indeed, Paris' form part. Antoine, assuming from Desbois that $H \propto V^{\frac{2}{3}}$, finds $L \propto V^{\frac{3}{4}}$, and therefore that the 'modulus' $HL \propto V^{\frac{17}{12}}$, for what he records as fully developed waves. He thinks that this 'modulus' HL may ultimately be found proportional to V, with H remaining, I suppose, proportional to $V^{\frac{2}{3}}$ and L becoming proportional to $V^{\frac{1}{3}}$. He finds Desbois' empiric relation $H \propto V^{\frac{2}{3}}$ 'readily justified' on theoretic grounds.[3] I think this supposed theoretic justification is illusory, and that it has hindered Antoine from obtaining the best numerical relations from the data at his disposal. I consider that his numbers are better represented by taking H proportional to $V^{\frac{1}{2}}$ and L proportional to $V^{\frac{1}{2}}$, which gives the relation between L and H suspected by Antoine. These formulæ are statistical, not dynamic. Their value depends on the number of observations. H can only be regarded as varying with $V^{\frac{1}{2}}$ when we average H and V over a large area. Desbois' table of amplitudes in 'Comptes Rendus,' lxii. pp. 82–87, seems to indicate that a large fraction of the total turbulence of many parts of the ocean is due to their invasion by swells from a distance.

From an examination of Paris' numbers I find that—(1) The average steepness of the waves increases with excess of V (velocity of wind) over U (velocity of wave); (2) The law that persistence of amplitude (in time) is proportional to L^2 is recognisable; (3) That, even far from coasts, geographical position modifies the law in this way, that, for the same average wind velocity, the average amplitude is greatest in the Southern Ocean, *i.e.* south of the Cape of Good Hope and Cape Horn, where the wind blows always from the north-westward and the wave-pulses are free to chase one another round and round the globe. Perhaps there is also some increase, due to focussing. Further, the *specific* roughness in the regions of Indian Trades, Atlantic Trades, and Western Pacific is in the order of their exposure to the Southern Ocean, which is the order in which they have been here named. They may be regarded as branches of the Southern Ocean. The Western Pacific is greatly sheltered from the Southern Ocean by a screen of islands. Paris' observations do not extend to the Eastern Pacific, as do those of Desbois. The latter show that the specific roughness is much greater in the Eastern than in the Western Pacific. In the semi-closed Seas of China and Japan the specific roughness is less than in the above oceans.

SATURDAY, SEPTEMBER 16.

1. *On the Existence of Masses Smaller than the Atoms.*[4]

By Professor J. J. Thomson, *F.R.S.*

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[1] *Revue maritime*, xxxi.

[2] *Sur les Lames de Haute Mer.*

[3] See p. 8 of *Les Lames de Haute Mer.*

[4] Published in the *Phil. Mag.* Dec. 1899, pp. 547–67.

2. *On the Controversy concerning the Seat of Volta's Contact Force.*[1] *By* Professor OLIVER LODGE, *F.R.S.*

MONDAY, SEPTEMBER 18.

The Section was divided into two Departments.

The following Reports and Papers were read:

DEPARTMENT I.—MATHEMATICS.

1. *Report on Tables of certain Integrals.* See Reports, p. 65.

2. *Report on Tables of certain Mathematical Functions.* See Reports, p. 160.

3. *The Median Estimate.* *By* FRANCIS GALTON, *D.C.L., F.R.S.*

The usual method is very unsatisfactory by which the collective opinion of Councils, Senates, and other Assemblies is ascertained, in respect to the most suitable amount of money to be granted for any particular purpose. The opinions of individual members are sure to differ as to rewards for past services, as to compensation for damage, or as to the cost of carrying out some desirable object for which provision has to be made. How is that medium amount to be ascertained which is the fairest compromise between many different opinions? The method usually adopted is for some person in authority to consult his colleagues and then to lay a definite proposal before the meeting, to which another person may move an amendment; the amendment and the original motion are then put severally to the vote, and are carried or rejected by a simple majority. Jurymen are said to adopt a different way of assessing damages; each writes his own estimate on a separate paper, the estimates are added together, and the average of them all is occasionally accepted by the whole body of the jury and returned as their verdict. Averages are, however, objectionable to large assemblages on account of the tedious arithmetic that would then be needed. Moreover, an average value may greatly mislead, unless each several estimate has been made in good faith, because a single voter is able to produce an effect far beyond his due share by writing down an unreasonably large or unreasonably small sum. The middlemost value, or the *median* of all the estimates, is free from this danger, inasmuch as the influence of each voter has exactly equal weight in its determination. Again, few persons know what they want with sufficient clearness to enable them to express it in numerical terms, from which alone an average may be derived. Much deeper searching of the thought is needed to enable a man to make such precise affirmation as that 'in my opinion the bonus to be given should be 80*l.*,' than to enable him to say, 'I do not think the bonus should be so much as 100*l.*, certainly it should not be more than 100*l.*'

The plan that I would suggest for discovering the *median* of the various sums desired by the several voters is to specify any two reasonable amounts, A and B, A being the smaller, making it understood that A and B are intended to serve as *divisions*, and therefore no votes are to be given for either of those two precise

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[1] This paper will be published in the *Proceedings of the Physical Society of London.*

sums. Next, three shows and counts of hands are to be made: (1) for less than A; (2) for more than A, but less than B; (3) for more than B. The results are

a per cent. vote for less than A; 100–a vote for more than A.
b per cent. vote for less than B; 100–b vote for more than B.

Numerous analogies amply justify the assumption that the estimates will be distributed on either side of their (unknown) median, m, with an (unknown) quartile, q, in approximate accordance with the normal law of frequency of error. The following table of centiles (a better word than 'Per-centiles,' which I originally used), having a quartile = 1, is founded upon that law. It is extracted from my 'Natural Inheritance' (Macmillan, 1889, p. 205) to serve the present purpose.

Centiles to the Grades 0°–100°.

Grades	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
0°	–inf:	–3·45	–3·05	–2·79	–2·60	–2·44	–2·31	–2·19	–2·08	–1·99
10°	–1·90	–1·82	–1·74	–1·67	–1·60	–1·54	–1·47	–1·42	–1·36	–1·30
20°	–1·25	–1·20	–1·15	–1·10	–1·05	–1·00	–0·95	–0·91	–0·86	–0·82
30°	–0·78	–0·74	–0·69	–0·65	–0·61	–0·57	–0·53	–0·49	–0·45	–0·41
40°	–0·38	–0·34	–0·30	–0·26	–0·22	–0·19	–0·15	–0·11	–0·07	–0·04
50°	0·00	+0·04	+0·07	+0·11	+0·15	+0·19	+0·22	+0·26	+0·30	+0·34
60°	+0·38	+0·41	+0·45	+0·49	+0·53	+0·57	+0·61	+0·65	+0·69	+0·74
70°	+0·78	+0·82	+0·86	+0·91	+0·95	+1·00	+1·05	+1·10	+1·15	+1·20
80°	+1·25	+1·30	+1·36	+1·42	+1·47	+1·54	+1·60	+1·67	+1·74	+1·82
90°	+1·90	+1·99	+2·08	+2·19	+2·31	+2·44	+2·60	+2·79	+3·05	+3·45

Let a be the tabular number *inclusive of its sign*, that corresponds to the grade $a°$, and let β be that which corresponds to $b°$, then

$$m + qa = \mathrm{A}\ ;\ m + q\beta = \mathrm{B},$$

whence

$$m = \mathrm{A} - a\left\{\frac{\mathrm{B}-\mathrm{A}}{\beta - a}\right\} = \mathrm{B} - \beta\left\{\frac{\mathrm{B}-\mathrm{A}}{\beta - a}\right\}$$

Example:—$\mathrm{A}=100$, $\mathrm{B}=500$; $a=40°$, $b=80°$, whence $a=-0{\cdot}38$, $\beta=+1{\cdot}25$ and $m=193$. The truth of the determination of m may now, if so desired, be tested by putting two new values A′ B′ to the vote, in the same way as A and B, but A′ and B′ should not differ much from m, and it should be an honourable understanding that no member should deviate from his first opinion in giving his second vote.

When about to utilise this method, A and B ought to be so selected that A shall secure not less than 5 per cent. of the votes, and B not more than 95, because the curve of error ceases to be trustworthy near to its extremities, but a dependence upon it within the limits of 5° and 95° will seem pedantic only to those who are unfamiliar with its nature and with its numerous and successful applications.

It will be easily understood that this method is a particular case of the more general problem, that in any system of normal variables which has been arrayed between the grades of 0° and 100°, if the values be given that correspond to *any two* specified grades, those that correspond to each and every other grade can be found.

I heartily wish that when occasion offers, some Assembly may be disposed to experiment on the above method. The calculators should, of course, rehearse the work beforehand, and be well prepared to carry it through both rapidly and surely.

It is worth mentioning that when the above table is not at hand, a graphical substitute for it, that ranges between 5° and 95° and is true to the first place of decimals, may be quickly made by those who can recollect three simple factors. Thus, draw between two vertical limits, 0° and 100°, a straight line on squarely ruled paper, having a quartile equal to 1. Accept this line in lieu of the curve between 30° and 70°, add one-twentieth to the lengths of the centiles at 20° and 80°, one-fifth to those at 10° and 90°, and one-third to those at 50° and 95°. Then unite the tops of these centiles with a free-hand curve.

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4. *A System of Invariants for Parallel Configurations in Space.*
By Professor A. R. Forsyth, *Sc.D., F.R.S.*

There is one class of invariants appertaining to parallel configurations which I have not seen noticed; they arise in spaces of two, three, and any number of dimensions.

It is known that, for a plane curve parallel to a given plane curve, the normals at corresponding points are the same in direction, and therefore the angle between corresponding consecutive normals is the same, so that this infinitesimal angle is an invariantive element. Moreover, the centres of curvature are the same, so that the difference between the radii of curvature is the diameter of the rolling circle, the two enveloping curves of which are the given curve and its parallel.

Similarly, in the case of parallel surfaces, it is convenient to consider the principal directions of curvature at each point. They are respectively parallel to one another at corresponding points; the corresponding normals are coincident in direction; and the centres of principal curvatures for the two surfaces are the same. Hence the difference between a principal radius of curvature and the corresponding principal radius of curvature of the parallel surface is equal to the diameter of the rolling sphere, the other envelope of which is the parallel surface; and this holds for each of the two principal radii.

Likewise, in space of n dimensions. To render the explanations clearer, we consider a configuration

$$F(x_1, x_2, \dots x_n) = 0,$$

which, as for two and for three dimensions, will be considered devoid of special singularities. Let

$$l_s = \frac{\delta F}{\delta x_s} \div \Delta, \quad (s = 1, \dots, n),$$

where

$$\Delta^2 = \sum_{s=1}^{n} \left(\frac{\delta F}{\delta x_s} \right)^2.$$

If, then, a distance ρ be measured inwards along the direction indicated by $l_1, \dots, l_n$ (say along the normal to the surface $F = 0$), the coordinates of the extremities are given by

$$\xi_s = x_s - \rho l_s.$$

If this point be a point of intersection with a consecutive normal at $x_1 + dx_1, \dots, x_n + dx_n$, then

$$\xi_s = x_s + dx \ - \rho(l_s + dl),$$

for $s = 1, \dots n$; that is,

$$0 = \left(\frac{1}{\rho} - \frac{\partial l_s}{\partial x_s} \right) dx_s - \sum_{i=1}^{n} \frac{\partial l}{\partial n_i} dx_i,$$

the term in dx_s being omitted from the summation on the right-hand side, and the equation holding for $s = 1, \dots n$. The possible values of ρ are given by the equation

$$\begin{vmatrix} \frac{1}{\rho} - \frac{\partial l_1}{\partial x_1}, & \frac{\partial l_1}{\partial x_2}, & \frac{\partial l_1}{\partial x_3}, & \dots \\ \frac{\partial l_2}{\partial x_1}, & \frac{1}{\rho} - \frac{\partial l_2}{\partial x_2}, & \frac{\partial l_2}{\partial x_3}, & \dots \\ \frac{\partial l_3}{\partial x_1}, & \frac{\partial l_3}{\partial x_2}, & \frac{1}{\rho} - \frac{\partial l_3}{\partial x_3}, & \dots \\ \cdot & \cdot & \cdot & \cdot \end{vmatrix} = 0$$

which nominally is of degree n in $\frac{1}{\rho}$. One root, however, is zero, because the term independent of $\frac{1}{\rho}$ vanishes, on account of the relation

$$l_1^2+l_2^2+\ldots+l_n^2=1;$$

there are therefore $n-1$ values of ρ thus determined, which may be denoted by $\rho_1, \ldots, \rho_{n-1}$. Further, the $n-1$ directions from $x_1, \ldots, x_n$ along the surface $F=0$, in which the normal is met by the normal at a consecutive point, are given by taking any $n-1$ of the equations

$$0=\left(\frac{1}{\rho}-\frac{\partial l_s}{\partial n_s}\right)dx_s-\sum_{i=1}^{n}\frac{\partial l_s}{\partial x_i}dx_i,$$

and substituting, in the ratios determining the directions, the $n-1$ values of ρ in succession. Denoting by $d\sigma_r$ the arc along any one of these directions, which can be regarded as directions of principal curvature, by $d\psi$ the angle between the two consecutive normals, and by ρ_r the corresponding distance (say the corresponding radius of curvature), we have

$$d\sigma_r=\rho_r d\psi_r,$$

so that $d\psi_r$, for each value of r, is unchanged for the parallel surface.

In order to build integral invariants upon the invariantive differential element represented by the infinitesimal angle between consecutive normals, we proceed from the two simplest cases, viz. parallel curves in plane space, and parallel surfaces in three dimensions.

I. *Parallel Curves in plano.*

For a given oval plane curve without singularities, two characteristic magnitudes are its perimeter and its area. We shall compare their values with the values of the corresponding magnitudes of the parallel curve, which is the outer envelope of a circle of diameter a rolling on the outside of the given curve. Denoting the perimeter of the given curve by L, and its area by A, and the corresponding magnitudes for the parallel curve by L′ and A′ respectively, we have

$$A'-A=\tfrac{1}{2}\int\{(\rho+a)^2-\rho^2\}d\psi,$$

$$L'=\int(\rho+a)d\psi,\quad L=\int\rho d\psi,$$

where ρ is the radius of curvature at the given point; each of the integrals is to be extended through a range 2π. Thus

$$A'-A=aL+\pi a^2,$$
$$L'-L=2\pi a;$$

and therefore

$$A'-\frac{1}{4\pi}L'^2=A-\frac{1}{4\pi}L^2,$$

for all values of a; that is, the quantity

$$A-\frac{1}{4\pi}L^2$$

is invariantive for parallel curves, where A is the area enclosed by any one of them and L is its perimeter.

II. *Parallel Surfaces in Three Dimensions.*

For a given closed oval surface without singularities, three characteristic magnitudes are its volume, its superficial area, and the surface-aggregate of the mean[1] of the curvatures at any point. We shall compare their values with the values of the corresponding magnitudes of the parallel surface, which is the outer envelope of a sphere of diameter a rolling on the outside of the given surface. Denoting the volume by V, the superficial area by S, and (twice the) surface-aggregate of the mean of the curvatures by L, and the corresponding magnitudes for the parallel surface by V′, S′, L′ respectively, we have

$$\mathrm{V}'-\mathrm{V}=\iiint^{a}(\rho_1+x)(\rho_2+x)x\,d\psi_1 d\psi_2,$$

$$\mathrm{S}'=\iint(\rho_1+a)(\rho_2+a)d\psi_1 d\psi_2,\quad \mathrm{S}=\iint\rho_1\rho_2 d\psi_1 d\psi_2\,;$$

$$\mathrm{L}=\iint\left(\frac{1}{\rho_1}+\frac{1}{\rho_2}\right)d\mathrm{S}$$

$$=\iint\left(\frac{1}{\rho_1}+\frac{1}{\rho_2}\right)\rho_1\rho_2 d\psi_1 d\psi_2=\iint(\rho_1+\rho_2)d\psi_1 d\psi_2,$$

$$\mathrm{L}'=\iint(\rho_1+a+\rho_2+a)d\psi_1 d\psi_2,$$

all the integrals extending over the whole of the original surface. Thus

$$\mathrm{V}'-\mathrm{V}=a\mathrm{S}+\frac{1}{2}a^2\mathrm{L}+\frac{4}{3}\pi a^3,$$

$$\mathrm{S}'-\mathrm{S}=a\mathrm{L}+4\pi a^2,$$

$$\mathrm{L}'-\mathrm{L}=8\pi a\,;$$

and therefore

$$\mathrm{V}'-\frac{1}{8\pi}\mathrm{L}'\mathrm{S}'+\frac{1}{192\pi^2}\mathrm{L}'^3=\mathrm{V}-\frac{1}{8\pi}\mathrm{LS}+\frac{1}{192\pi^2}\mathrm{L}^3,$$

$$\mathrm{S}'-\frac{1}{16\pi}\mathrm{L}'^2=\mathrm{S}-\frac{1}{16\pi}\mathrm{L}^2,$$

for all values of a: that is, the quantities

$$\mathrm{S}-\frac{1}{16\pi}\mathrm{L}^2,$$

$$\mathrm{V}-\frac{1}{8\pi}\mathrm{LS}+\frac{1}{192\pi^2}\mathrm{L}^3,$$

are invariantive for parallel surfaces, where (for any one of such surfaces) V is the volume it contains, S is its superficial area, and L is twice the surface area of the mean of the curvatures.[2]

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[1] The surface-aggregate of the Gaussian measure of curvature is a pure constant, for

$$\iint d\psi_1 d\psi_2=\iint\frac{1}{\rho_1\rho_2}ds_1 ds_2=4\pi,$$

and is therefore an invariant.

[2] In evaluating integrals such as V′, S′, L′, care must be exercised in regard to the range of ψ_1 and ψ_2. As a matter of fact, the range of ψ_2 is affected by that of

It may be noted in passing that if, in the single invariant of parallel curves, we write

$$\mathrm{A}=\tfrac{1}{2}.2\pi\beta,\quad \mathrm{L}=2\pi a,$$

it becomes

$$\pi(\beta-a^2),$$

that is, the invariant effectively is $\beta-a^2$. Also if, in the two invariants of parallel surfaces, we write

$$\mathrm{V}=\tfrac{1}{3}.4\pi\gamma,\quad \mathrm{S}=4\pi\beta,\quad \mathrm{L}=2.4\pi a,$$

the invariants become

$$4\pi(\beta-a^2),\quad \tfrac{1}{3}4\pi(\gamma-3a\beta+2a^3),$$

that is, the invariants effectively are

$$\beta-a^2,\quad \gamma-3a\beta+2a^3.$$

The similarity in form to the leading coefficients of the simplest covariants of a binary quantic is obvious.

III. *Parallel Surfaces in n Dimensions.*

The geometry has been introduced solely to simplify the description of the analytical results, which may be regarded as invariantive relations among certain definite multiple integrals. Denoting by V the volume enclosed by the surface $\mathrm{F}=0$, and by V′ the volume enclosed by the parallel surface, which is the envelope of a sphere of diameter a, say

$$(\mathrm{X}_1-x_1)^2+\ \ldots\ +(\mathrm{X}_n-x_n)^2=a^2,$$

rolling on the outer side of $\mathrm{F}=0$, we have

$$\mathrm{V}'\quad \mathrm{V}=\int\ldots\int\int_0^a(\rho_1+x)\ldots(\rho_{n-1}+x)x\,d\psi_1\ldots d\psi_{n-1}.$$

$$\text{Let }\Theta=\int\ldots\int d\psi_1\ldots d\psi_{n-}$$

$$=\int d\Omega,$$

ψ_1, as can easily be seen from the consideration of the surface of a sphere; and really $d\psi_1\,d\psi_2$ is the elementary solid angle subtended at the centre of a sphere of radius unity by the two perpendicular arcs $d\psi_1$, $d\psi_2$ on the surface; so that

$$\int\int d\psi_1\,d\psi_2=\text{the whole solid angle}$$
$$=4\pi.$$

Similarly, in the case of n dimensions, the quantity Θ (with the notation adopted below) is the hypersolid angle subtended by the surface of a hypersphere at its centre. With the notation indicated, we have

$$\Theta=\int d\psi_1,\ldots.d\psi_{n-1}$$
$$=\int d\Omega,$$

which is

$$2\frac{\pi^{\frac{1}{2}n}}{(\frac{1}{2}n-1)\,!}$$

when n is even, and is

$$\frac{2^{\frac{1}{2}(n+1)}\,\pi^{\frac{1}{2}(n-1)}}{1.3.5\ldots\ldots\overline{n-2}}$$

when n is odd.

say, symbolically, so that $d\Omega$ represents the element $d\psi_1 \dots d\psi_{n-1}$; thus Θ is an absolute invariant for the system of parallel surfaces. Also, let

$$I_s = \int p_s d\Omega,$$

where $p_s = \Sigma\rho_1 \dots \rho_s$, the summation being for all the combinations of s of the $n-1$ quantities ρ; and the integral extends over the whole of the original surface. Then if I'_s denote the same magnitude for the parallel surface, we have

$$I'_s - I_s = \int [\Sigma\{(\rho_1 + a) \dots (\rho_s + a) - \rho_1 \dots \rho_s\}] d\Omega.$$

$$= \frac{(n-1)!}{s!\,(n-1-s)!} a\,\Theta + \sum_{j=1}^{s-1} \frac{(n-1-j)!}{(n-1-s)!\,(s-j)!} I_j a^{s-j},$$

where only the first term occurs when $s=1$; in particular,

$$I'_1 - I_1 = (n-1)a\Theta,$$

$$I'_2 - I_2 = \frac{(n-1)(n-2)}{2!} a^2\Theta + (n-2)aI_1,$$

$$I'_3 - I_3 = \frac{(n-1)(n-2)(n-3)}{3!} a^3\Theta + \frac{(n-2)(n-3)}{2!} a^2 I_1 + (n-3)aI_2,$$

and so on. Now let

$$I_\kappa = \Theta J_\kappa \frac{(n-1)!}{\kappa!\,(n-1-\kappa)!};$$

then

$$J'_\lambda - J_\lambda = a^\lambda + \sum_{s=1}^{\lambda-1} \frac{\lambda!}{\lambda - s!\ s!} a^{\lambda-s} J_s,$$

that is,

$$J'_\lambda = (J_\lambda, J_{\lambda-1}, \dots J_1, 1)\,(1, a)^\lambda.$$

Further, we have

$$V' - V = \frac{1}{n} a^n \Theta + \frac{1}{n-1} a^{n-1} I_1 + \dots + \frac{1}{2} a^2 I_{n-2} + aI_{n-1};$$

and, therefore, writing

$$V = \frac{1}{n} \Theta J_n,$$

we have

$$J'_n - J_n = a^n + \sum_{s=1}^{n-1} \frac{n!}{n - s!\ s!} a - J_s,$$

that is,

$$J'_n = (J_n, J_{n-1}, \dots J_1, 1)\,(1, a)^n.$$

The quantity J_s is of dimension s; so that these expressions conform to the conditions of homogeneity.

Moreover, they conform to the expressions obtained as by linear transformation of binary quantics. To verify this statement, we note that if, in

$$J'_n = (J_n, J_{n-1}, \dots J_1, 1)\ (1, a)^n,$$

a be replaced by $a + c$, we have (say)

$$J''_n = (J_n, J_{n-1}, \dots J_1, 1)\ (1, a + c)^n$$
$$= (J'_n, J'_{n-1}, \dots J'_1, 1)\ (1, c)^n:$$

and

$$J''_m = (J_m, J_{m-1}, \ldots J_1, 1)(1, a + c)^m$$
$$= (J'_m, J'_{m-1}, \ldots J'_1, 1)(1, c)^m,$$

for all values of m. There, accordingly, are combinations of the quantities J which, by the theory of binary forms, are invariantive for these linear transformations; as the transformations are characteristic of the parallel surfaces, it follows that these combinations of the quantities J are invariants of the system in question. The simplest are

$$J_2 - J_1^2,$$
$$J_3 - 3J_1J_2 + 2J_1^3,$$
$$J_4 - 4J_1J_3 + 3J_2^2,$$

and so on; in fact, every principal seminvariant gives an invariant of the system of parallel surfaces.

By way of verification, we take $n = 3$; then $\Theta = 4\pi$, $L = 2\Theta J_1$, $S = \Theta J_2$, $V = \frac{1}{3}\Theta J_3$ in our former notation; and then

$$J_2 - J_1^2 = \frac{1}{\Theta}\left(S - \frac{1}{16\pi}L^2\right),$$

$$J_3 - 3J_1J_2 + 2J_1^3 = \frac{3}{\Theta}\left(V - \frac{1}{8\pi}LS + \frac{1}{192\pi^2}L^3\right).$$

It may be pointed out that the single invariant, for a system of parallel plane curves, vanishes for a circle; and that both the invariants, for a system of parallel surfaces in space of three dimensions, vanish for a sphere.

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5. *On the Notation of the Calculus of Differences.*[1]

By Professor J. D. Everett, *F.R.S.*

In conjunction with the ordinary symbol Δ defined by

$$\Delta y_n = y_{n+1} - y_n,$$

the author employs another symbol δ defined by

$$\delta y_n = y_n - y_{n-1}.$$

This gives the relation

$$\Delta\delta = \Delta - \delta,$$

leading to a number of developments, such as

$$\left(\frac{\Delta}{\delta}\right)^n = (1 + \Delta)^n = 1 + n\Delta + \frac{n(n-1)}{2}\Delta^2 + \&c.;$$

$$\left(\frac{\delta}{\Delta}\right)^n = (1 - \delta)^n = 1 - n\delta + \frac{n(n-1)}{2}\delta^2 - \&c.;$$

$$\left(\frac{\Delta}{\delta}\right)^n = (1 - \delta)^{-n} = 1 + n\delta + \frac{n(n+1)}{2}\delta^2 + \&c.;$$

$$\left(\frac{\delta}{\Delta}\right)^n = (1 + \Delta)^{-n} = 1 - n\Delta + \frac{n(n+1)}{2}\Delta^2 - \&c.;$$

of which some express well-known properties, and others are believed to be new.

By performing the operation $\Delta^m\delta^n$ on any one of the entries in a table of

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[1] The Paper will be published in the *Messenger of Mathematics.*

differences (m and n being arbitrary integers, positive, negative, or zero), we are carried to any other. $\Delta^n\delta^{-n}$ carries us n steps down a column, $\delta^n\Delta^{-n}$ carries us n steps up it, and $\Delta^n\delta^n$ carries us $2n$ columns to the right. Δ^n carries us n steps obliquely down, and δ^n the same number obliquely up, both to the right. Reversal of the sign of n reverses the direction.

In the old notation, the fundamental property

$$\Delta\delta = \Delta - \delta$$

would be written

$$\Delta^2 y_{n-1} = \Delta y_n - \Delta y_{n-1};$$

which does not afford the same facility for manipulation.

6. *On the Partial Differential Equation of the Second Order.*

By Prof. A. C. Dixon.

Taking the equation

$$f(x, y, z, p, q, r, s, t) = o,$$

I suppose it solved by using two more relations,

$$u = a,\ v = b,$$

among the quantities x, y, z, p, q, r, s, t, to give values of r, s, t, which, substituted in

$$dz = pdx + qdy,\ dp = rdx + sdy,\ dq = sdx + tdy,$$

render these three equations integrable. This will not be possible, of course, unless the expressions u, v fulfil certain conditions. I consider the case in which u can be so determined that v is only subjected to one condition, and I find that then du is a linear combination of the expressions

$$dx + \mu dy,\ dz - pdx - qdy,\ dp - rdx - sdy,\ dq - sdx - tdy,$$

$$\mu\frac{\partial f}{\partial t}ds - \frac{\partial f}{\partial r}dr - \left(\frac{\partial f}{\partial x} + p\frac{\partial f}{\partial z} + r\frac{\partial f}{\partial p} + s\frac{\partial f}{\partial q}\right)dx,$$

where μ is a root of the quadratic

$$\frac{\partial f}{\partial t}\mu^2 + \frac{\partial f}{\partial s}\mu + \frac{\partial f}{\partial r} = 0.$$

These are the expressions used by Hamburger in his method of solution.

If such a function u can be found, the system $f = 0$, $u = a$ will have a series of solutions depending on an arbitrary function of one variable, and involving two further arbitrary constants.

7. *On the Fundamental Differential Equations of Geometry.*

By Dr. Irving Stringham.

Capitaine Feye Sainte-Marie, in his work 'Études Analytiques sur la Théorie des Parallèles,' after showing that the propositions of the Euclidean Geometry are true within an infinitesimal domain, achieves, through the processes of integration, a series of analytical formulæ for non-Euclidian geometry.

The foundation for this analytical theory is a group of differential equations.

I adopt the form given them by Professor Killing in his well-known work on 'Nicht-Euclidische Raumformen.'

The fundamental equations are

$$\frac{d\alpha}{da}=\frac{f(b)}{\sin\gamma};\quad \frac{db}{da}=\cos\gamma;\quad c\ f(b)=-\frac{d\gamma}{da};$$

where a, b, c are the sides of a triangle, α, β, γ their angles, α opposite a, β opposite b, &c. The solution of these equations is

$$(a)\quad \frac{f(a)}{\sin\alpha}=\frac{f(b)}{\sin\beta}=\frac{f(c)}{\sin\gamma};$$

from which, by appropriate partial differentiations and eliminations, we obtain

$$\frac{[f(a)]^2}{1-[f'(a)]^2}=\frac{[f(b)]^2}{1-[f'(b)]^2}=\frac{[f(c)]^2}{1-[f'(c)]^2}=-\kappa^2,$$

where κ^2 is a constant. A final integration now determines the form of the function $f(a)$; it is

$$f(a)=\frac{\kappa}{2}\left\{e^{(a+C)/\kappa}-e^{-(a+C)/\kappa}\right\},$$

where C is the constant of integration.

By defining

$$\sin_{\kappa}a=\frac{\kappa}{2}(e^{a/\kappa}-e^{-a/\kappa})$$

(read sine of a with respect to the modulus κ) the equation for $f(a)$ is more concisely written

$$f(a)=\sin_{\kappa}(a+C).$$

It is easy to show that $f(0)=0$, so that C is a period, that is, a multiple of $\kappa\pi\sqrt{-1}$, and therefore

$$f(a)=\sin_{\kappa}(a+ni\kappa\pi)=\pm\sin_{\kappa}a.$$

We choose the positive sign in this last equation, assigning arbitrarily, for the proper relative directions of the sides of our triangle, and equation (a) now becomes

$$\frac{\sin_{\kappa}a}{\sin\alpha}=\frac{\sin_{\kappa}b}{\sin\beta}=\frac{\sin_{\kappa}c}{\sin\gamma}.$$

These are the fundamental equations of trigonometry. Out of these the entire theory of measurement proceeds in the usual way.

The theory of measurement thus constituted is purely ideal. There is no real universe that can be measured by it without the arbitrary assumption of a definite value for κ, and there are only three kinds of value for κ possible. These are $\kappa^2=\infty$, $\kappa^2=$ a positive real number, $\kappa^2=$ a negative real number. What has appeared very startling to the modern world is that there is as yet no theory of knowledge that can tell us which of these three diverging paths we must take. This is an old story told in a new way.

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8. *Report on Recent Progress in the Problem of Three Bodies.*

By E. T. WHITTAKER, *M.A.*

See Reports, p. 121.

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9. *On Singular Solutions of Ordinary Differential Equations.*

By Professor A. R. FORSYTH, *Sc.D., F.R.S.*

10. *An Application and Interpretation of Infinitesimal Transformations.*

By Professor E. O. LOVETT.

1. An infinitesimal transformation is the linear operator represented by the symbol

$$Vf \equiv \sum_1^n i\xi_i(x_1, \ldots, x_n)\frac{\partial f}{\partial x_i}; \quad . \quad . \quad . \quad . \quad (1)$$

if $x_1 \ldots x_n$ be regarded as the co-ordinates of a point in space of n dimensions, the point $(x_1, \ldots, x_n)$ is displaced by the transformation (1) to the position $(x_1 + \delta x_1, \ldots, x + \delta x_n)$, where

$$\delta x_1 = \xi_1 \delta t, \ldots, \delta x_n = \xi_n \delta t, \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

t being an arbitrary differential. The corresponding increment assigned by (1) to any function $\phi\ (x_1, \ldots, x_n)$ is $V\phi\delta t$.

A function is said to be invariant under (1), when its increment due to (1) is zero. An equation of any sort whatever $w = 0$ is invariant under (1), or said to admit of (1) when the increment $\delta\omega$ assigned by (1) is zero in virtue of the given equation.

The trajectories of the group of transformations generated by (1) are given by the integration of the simultaneous system

$$\frac{dx_1}{\xi_1} = \frac{dx_2}{\xi_2} = \ldots = \frac{dx}{\xi_n} = dt. \quad . \quad . \quad . \quad . \quad (3)$$

2. The total differential equation

$$M_m \equiv \Sigma P(x_1, \ldots, x_n)_{\epsilon_1\epsilon_2\ldots\epsilon_n} dx_1^{\epsilon_1} dx_2^{\epsilon_2} \ldots dx_n^{\epsilon_n} = 0,\ \Sigma t_1 = m, . \quad . \quad (4)$$

homogeneous in the differentials $dx_1 \ldots x_n$, is called a Monge equation; when the Monge equation is linear in $dx_1 \ldots dx_2$, that is, of the form

$$\pi \equiv \sum_1^n iP_i(x_1, \ldots, x_n)dx_i = 0, . \quad . \quad . \quad . \quad . \quad (5)$$

it is called a Pfaff equation.

Pfaff equations and Monge equations are integrable or non-integrable, according as certain equations of condition are satisfied or not by the functions P.

Thus, for example, the Pfaff equation

$$P(x, y, z)dx + Q(x, y, z)dy + R(x, y, z)dz = 0 \quad . \quad . \quad . \quad (6)$$

is integrable or non-integrable according as the functions P, Q, R do or do not satisfy the well-known relation

$$P(Q_z - R_y) + Q(R_x - P_z) + R(P_y - Q_x) = 0 \quad . \quad . \quad . \quad (7)$$

By precisely the same method by which (7) is reached as a criterion we find the conditions for the integrability[1] of the Monge equation to be

$$\begin{vmatrix} P & U & T \\ U & Q & S \\ T & S & R \end{vmatrix} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$\frac{\partial}{\partial y}\left\{\frac{-T \pm \sqrt{T^2 - PR}}{R}\right\} = \frac{\partial}{\partial x}\left\{\frac{-S \pm \sqrt{S^2 - QR}}{R}\right\},$$

where the Monge equation is

$$M_2 \equiv Pdx^2 + Qdy^2 + Rdz^2 + 2Sdydz + 2Tdzdx + 2Udxdy = 0 \quad . \quad . \quad (9)$$

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[1] See Guldberg, 'Sur la Théorie des Solutions Singulières,' *Videnskabsselskabets Skrifter*, I. Math.-naturv. Klasse, 1899, No. 4, Christiania.

An integrable Monge equation may have three kinds of integrals, just as an ordinary differential equation of the first order, for example; and the terms general integral, particular integral, singular integral have the same signification when applied to integrable Monge equations as when used with reference to an ordinary differential equation; a singular integral is one which is neither general nor particular.

A non-integrable Monge equation may have singular solutions; by the latter we mean relations in the variables $x_1, \ldots, x_n$, which satisfy the equation.

3. The criteria for the invariance of the Pfaffian equation (5) under the infinitesimal point transformation may be found by a simple reckoning. Thus confining attention for convenience to the equation (6) in three variables we have

$$\begin{aligned}\delta\pi &= dx\delta\mathrm{P} + \mathrm{P}\delta dx + dy\delta\mathrm{Q} + \mathrm{Q}\delta dy + dz\delta\mathrm{R} + \mathrm{R}\delta dz,\\ &= dx\delta\mathrm{P} + \mathrm{P}d\delta x + dy\delta\mathrm{Q} + \mathrm{Q}d\delta y + dz\delta\mathrm{R} + \mathrm{R}d\delta z,\end{aligned}$$

by the commutative property of the operations d and δ. Substituting the values (2) of δx, δy, δz assigned by the given infinitesimal transformation (1), and neglecting the factor δt, we have

$$\begin{aligned}\delta\pi &= dx\delta\mathrm{P} + \mathrm{P}d\xi + dy\delta\mathrm{Q} + \mathrm{Q}d\eta + dz\delta\mathrm{R} + \mathrm{R}d\zeta\\ &= dx(\mathrm{P}_x\delta x + \mathrm{P}_y\delta y + \mathrm{P}_z\delta z) + \mathrm{P}(\xi_x dx + \xi_y dy + \xi_z dz) + \ldots\\ &= dx(\mathrm{P}_x\xi + \mathrm{P}_y\eta + \mathrm{P}_z) + \mathrm{P}(\xi_x dx + \xi_y dy + \xi_z dz) + \ldots \quad . \quad (10)\end{aligned}$$

Then the invariance demands that

$$\delta\pi = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

as a consequence of

$$\pi = 0;$$

hence the criteria are

$$\frac{\pi}{\mathrm{P}} = \frac{\kappa}{\mathrm{Q}} = \frac{\rho}{\mathrm{R}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

where

$$\left.\begin{aligned}\pi &= \mathrm{P}_x\xi + \mathrm{P}_y\eta + \mathrm{P}_z\zeta + \mathrm{P}\xi_x + \mathrm{Q}\eta_x + \mathrm{R}\zeta_x,\\ \kappa &= \mathrm{Q}_x\xi + \mathrm{Q}_y\eta + \mathrm{Q}_z\zeta + \mathrm{P}\xi_y + \mathrm{Q}\eta_y + \mathrm{R}\zeta_y,\\ \rho &= \mathrm{R}_x\xi + \mathrm{R}_y\eta + \mathrm{R}_z\zeta + \mathrm{P}\xi_z + \mathrm{Q}\eta_z + \mathrm{R}\zeta_z.\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (13)$$

Similarly for the equation (5) in n variables to admit of the infinitesimal point transformation (1) we find it necessary and sufficient that the quantities

$$\sum_{i=1}^{i=n}\left(\xi_i\frac{\partial \mathrm{P}_j}{\partial x_i} + \mathrm{P}_i\frac{\partial \xi_i}{\partial x_j}\right)/\mathrm{P}_j, \quad j = 1, 2, \ldots, n \quad . \quad . \quad . \quad (14)$$

shall all be equal.

Sometimes the calculations are facilitated by making use of the system of partial differential equations

$$\frac{p_1}{\mathrm{P}_1} = \frac{p_2}{\mathrm{P}_2} = \ldots = \frac{p_n}{\mathrm{P}_n}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

equivalent to equation (6), and of Sophus Lie's criterium for the invariance of a system of linear partial differential equations (complete or incomplete)

$$\mathrm{V}_j f \equiv \sum_{i=1}^{i=n} \mathrm{X}_{i,j}(x_1, \ldots, x_n)\frac{\partial f}{\partial x_i} = 0, \quad j = 1, 2, \ldots, r, \quad . \quad . \quad (16)$$

under the infinitesimal point transformation (1), namely

$$(\mathrm{U}, \mathrm{V}) \equiv \Sigma\rho\,(x_1, \ldots, x_n)\ \mathrm{V}_j f, \qquad (17)$$

where

$$(\mathrm{U}, \mathrm{V}_j) \equiv \mathrm{U}\mathrm{V}_j f - \mathrm{V}_j\mathrm{U}f.$$

4. Seeking now the variation of the Monge equation (9) due to the infinitesimal point transformation in three variables

$$\xi\frac{\partial f}{\partial x}+\eta\frac{\partial f}{\partial y}+\zeta\frac{\partial f}{\partial z} \quad . \quad . \quad . \quad . \quad . \quad (18)$$

as was done for the Pfaffian (6) in the preceding paragraph, we find

$$\begin{aligned}\delta \mathrm{M}_2 &= \mathrm{P}\delta dx^2 + dx^2\delta\mathrm{P} + \ \ldots\ + \mathrm{S}\delta(dydz) + dydz\delta\mathrm{S} + \ \ldots, \\ &= 2\mathrm{P}dxd\delta x + dx^2(\mathrm{P}_x\delta x + \mathrm{P}_y\delta y + \mathrm{P}_z\delta z) + \ldots + \mathrm{S}(dyd\delta z + dzd\delta y) + dydz(\mathrm{S}_x\delta x + \\ &\qquad \mathrm{S}_y\delta y + \mathrm{S}_z\delta z)\ \ldots ;\end{aligned}$$

observing as before that (18) gives to x, y, z the respective increments

$$\delta x=\xi\delta t,\ \delta y=\eta\delta t,\ \delta z=\zeta\delta t,$$

substituting and neglecting the factor δt, we have, after an easy reduction,

$$\delta\mathrm{M}_2 \equiv \pi dx^2+\kappa dy^2+\rho dz^2+2\sigma dydz+2\tau dzdx+2\upsilon dxdy, \quad . \quad . \quad (19)$$

where

$$\left.\begin{aligned}\pi &= 2(\mathrm{P}\xi_x+\mathrm{U}\eta_x+\mathrm{T}\zeta_x)+\xi\mathrm{P}_x+\eta\mathrm{P}_y+\zeta\mathrm{P}_z, \\ \kappa &= 2(\mathrm{U}\xi_y+\mathrm{Q}\eta_y+\mathrm{S}\zeta_y)+\xi\mathrm{Q}_x+\eta\mathrm{Q}_y+\zeta\mathrm{Q}_z, \\ \rho &= 2(\mathrm{T}\xi_z+\mathrm{S}\eta_z+\mathrm{R}\zeta_z)+\xi\mathrm{R}_x+\eta\mathrm{R}_y+\zeta\mathrm{R}_z, \\ \sigma &= \mathrm{T}\xi_y+\mathrm{U}\xi_z+\mathrm{S}\eta_y+\mathrm{Q}\eta_z+\mathrm{R}\zeta_y+\mathrm{S}\zeta_z+\xi\mathrm{S}_x+\eta\mathrm{S}_y+\zeta\mathrm{S}_z, \\ \tau &= \mathrm{P}\xi_z+\mathrm{T}\xi_x+\mathrm{U}\eta_z+\mathrm{S}\eta_x+\mathrm{T}\zeta_z+\mathrm{R}\zeta_x+\xi\mathrm{T}_x\eta\mathrm{T}_y+\zeta\mathrm{T}_z, \\ \upsilon &= \mathrm{U}\xi_x+\mathrm{P}\xi_y+\mathrm{Q}\eta_x+\mathrm{U}\eta_y+\mathrm{S}\zeta_x+\mathrm{T}\zeta_y+\xi\mathrm{U}_x+\eta\mathrm{U}_y+\zeta\mathrm{U}_z\,;\end{aligned}\right\} \quad . \quad (20)$$

hence the Monge equation (9) admits of the transformation (18) if the following conditions

$$\frac{\pi}{\mathrm{P}}=\frac{\kappa}{\mathrm{Q}}=\frac{\rho}{\mathrm{R}}=\frac{\sigma}{\mathrm{S}}=\frac{\tau}{\mathrm{T}}=\frac{\upsilon}{\mathrm{U}}, \quad . \quad . \quad . \quad . \quad . \quad (21)$$

hold.

By the same method the invariance criteria for a Monge equation of the second degree in n variables may be found. If the equation is

$$\phi \equiv \Sigma \mathrm{M}_{i,j}(x_1,\ldots,x_n)dx_idx = 0,\quad i,j=1,\ldots,n,\quad \mathrm{M}_{i,j}=\mathrm{M}_{j,} \quad . \quad (22)$$

the variation of ϕ, due to the infinitesimal point transformation (1), is found to be

$$\Sigma m_{i,j}\ dx_idx_j, \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

where

$$m_{ij}=\sum_{h=1}^{h=n}\xi_h\mathrm{M}_{i,j}+\sum_{i=1,}^{i=n,}\sum_{j=1,}^{j=n,}\sum_{k=1}^{k=n}\left(\mathrm{M}_{j,k}\xi_{k_{x_i}}+\mathrm{M}_{i,k}\xi_{k_{x_j}}\right). \quad . \quad . \quad (24)$$

Then the necessary and sufficient conditions that the equation (22) shall admit of the infinitesimal point transformation (1) are expressed by the equality of the quantities

$$\frac{m_{i,j}}{\mathrm{M}_{i,j}},$$

where both i and j take all values from 1 to n, and both may take the same value.

It may be remarked, in passing, that these forms show that not every Monge equation admits of an infinitesimal point transformation; they indicate at the same time how complicated the invariance criteria become for equations of higher degrees and higher orders.

5. The geometrical expression of the invariance of a differential equation under an infinitesimal point transformation is that the latter leaves invariant the family

of integral configurations of the equation, *i.e.* integral curve or surface is transformed into an integral curve or surface by the transformation.

When we know, then, an infinitesimal transformation of which a given differential equation admits, at least one family of configurations, which (family) is invariant under the transformation, is of interest to us, namely, the family of integral configurations of the given equation. But it may happen that other integral invariants under the transformation may satisfy the equation. That there are other invariant configurations is clear from the fact that a given infinitesimal point transformations may leave invariant a great variety of equations; conversely also a given equation may admit of none, one, or several infinitesimal transformations.

The direction $(dx_1, dx_2, \ldots, dx_n)$ on the envelope of the integral configurations, since this envelope is a trajectory of the transformation, is given by the continued proportion

$$\frac{dx_1}{\xi_1} = \frac{dx_2}{\xi_2} = \ldots = \frac{dx_n}{\xi_n}, \qquad \qquad (25)$$

if the infinitesimal transformation be written in the form (1); further, if this envelope is to be an integral configuration of the Monge equation

$$\Sigma P_{\epsilon_1 \epsilon_2 \ldots \epsilon_n} dx_1^{\epsilon_1} dx_2^{\epsilon_2} \ldots dx_n^{\epsilon_n} = 0,\ \Sigma \epsilon_i = m, \qquad \qquad (26)$$

the equation which is assumed to admit of the infinitesimal transformation (1), then the same system of differentials $(dx_1, \ldots, dx_n)$ must satisfy (26), that is, we have

$$\Sigma P_{\epsilon_1 \epsilon_2 \ldots \epsilon_n} \xi_1^{\epsilon_1} \xi_2^{\epsilon_2} \ldots \xi_n^{\epsilon_n} = 0. \qquad \qquad (27)$$

It is clear then that the equation (27) may give a singular solution of the equation (26), if it have one; it is also clear that no part, or only a part, of the locus represented by (27) need be a singular solution of (26). In case the transformation leaves every single integral configuration invariant the relation (27) is satisfied identically and yields nothing new.

We have here then a method, which consists of a simple extension of Lie's method for the integration of ordinary differential equations of the first order, for discovering singular solutions of a Monge equation without resorting to integration.

Furthermore, it should be remarked that not only is the method applicable to integrable and non-integrable Monge equations, but that nothing forbids the analytical application of the theorem to forms no longer homogeneous in the differentials, should such forms be possessed of interest or show themselves capable of interpretation, since it is easy to construct consistent criteria for the invariance of such forms under infinitesimal point transformations.

6. Since the Monge equation of the mth degree

$$\Sigma_1 P(x_1, \ldots, x_n)_{\epsilon_1 \epsilon_2 \ldots \epsilon_n} dx_1^{\epsilon_1} dx_2^{\epsilon_2} \ldots dx_n^{\epsilon_n} = 0,\ \Sigma \epsilon_1 = m \qquad \qquad (28)$$

is homogeneous of the mth degree in the differentials, it is equivalent to m Pfaff equations of the form

$$\sum_{i=1}^{i=n} Q_{ij}(x_1, \ldots, x_n) dx_i = 0; \quad j = 1, \ldots, m. \qquad \qquad (29)$$

A solution of any one of these Pfaff equations is a solution also of the Monge equation, and the problem of finding an infinitesimal transformation of which a Pfaff equation admits is obviously simpler than the resolution of the same problem relative to the Monge equation; in fact, there are cases in which the finding of m different infinitesimal transformations of which the m Pfaff equations (29) admit would be simpler than that of constructing one of which the Monge equation admits. It should be remarked that the invariance of the Monge equations under a given transformation by no means carries with it the invariance of a factor equation, nor reciprocally. The invariance is reciprocal only in the case where the Monge equation can be broken up into m equal linear factors.

These observations bring into light the double usefulness of the method as applied to finding singular solutions of Pfaff equations.

In the latter particular form it is, again, applicable both to integrable Pfaff equations and to non-integrable ones, and thus generalises[1] a theorem of Guldberg's inserted in the 'Comptes Rendus' of December 26, 1898, to the effect that linear integrable total differential equations can admit of singular solutions whose determination can be effected without integration. Guldberg's theorem makes no reference to Lie's theories in its statement or demonstration. The corresponding theorem for ordinary differential equations of the first order was given by Page.[2]

In Guldberg's later memoir already referred to the classic theory relative to singular solutions of ordinary equations is extended directly to total equations of the first order, and first and second degrees, without use of Lie's methods.

7. Before appending a few concrete examples we shall find a new interpretation of the ( ) operation of Lagrange and Poisson which plays so capital a *rôle* in the theory of continuous groups; it came to light in constructing a new proof of Guldberg's theorem above referred to.

Consider again the non-integrable linear total differential equation in three variables.

$$P(x,y,z)dx + Q(x,y,z)dy + R(x,y,z)dz = 0. \quad . \quad . \quad . \quad (30)$$

An integral of this equation satisfies the linear partial differential equations

$$\left.\begin{aligned} Uf &= \frac{\partial f}{\partial x} - \frac{P\partial f}{R\partial z} = 0, \\ Vf &\equiv \frac{\partial f}{\partial y} - \frac{Q\partial f}{R\partial z} = 0; \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (31)$$

in order that the system (31) have a solution it is sufficient that the relation

$$(U,V) \equiv UVf - VUf = 0 \quad . \quad . \quad . \quad . \quad . \quad (32)$$

shall be satisfied.

Developing this relation (32) we find

$$(U,V) \equiv -\frac{1}{R^2}\left\{P(Q_z - R_y) + Q(R_x - P_z) + R(P_y - Q_x)\right\}\frac{\partial f}{\partial z} = 0; \quad . \quad (33)$$

the hypotheses

$$R = \infty, f_z = 0$$

exclude themselves, then we have

$$P(Q_z - R_y) + Q(R_x - P_z) + R(P_y - Q_x) = 0. \quad . \quad . \quad . \quad (34)$$

The solutions $z = f(x,y)$ of this algebraic equation which satisfy the non-integrable equation (30) are singular integrals of the latter.

If the equation (30) is integrable the relation (34) becomes an identity, and (33) furnishes the interpretation of the 'Klammerausdruck' of the infinitesimal transformations Uf and Vf above, namely, that its vanishing expresses the condition, necessary and sufficient, that the linear total differential equation (30) shall be integrable.

8. Examples.

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[1] *Comptes Rendus*, 31 juillet 1899.

[2] *American Journal of Mathematics*, 1896.

1st. Consider the non-integrable linear total differential equation

$$(z - xy - y)dx + (z^2 - xyz - x)dy + dz = 0;$$ [1]

the equation

$$P(Q_z - R_y) + Q(R_x - P_z) + R(P_y - Q_x) = 0$$

gives

$$(z - xy)\ (z - xy - y) = 0,$$

and

$$z - xy = 0$$

is a singular solution of the given equation.

2nd. The Pfaff equations

$$(y + xy^2 - yz)dx + (x + x^2y - zx)dy - dz = 0,$$
$$(y - xy^2 + yz)dx + (x + x^2y - zx)dy - dz = 0,$$

both admit of the infinitesimal point transformation

$$(z - xy)\frac{\partial f}{\partial z},$$

as is readily verified; both admit of the singular integral

$$z = xy.$$

The first of the two equations is integrable, hence the construction of the previous example is not applicable here; but by Lie's general theory the function $(z - xy)^{1}$ is an integrating factor of the equation, by which we find the general integral to be

$$xy + \log(xy - z).$$

3rd. The non-integrable Monge equation

$$e^{2z(z - x - y)}dx^2 + e^{2(z - x - y)}dy^2 - dz^2 + 2e^{(z + 1)(z - x - y)}dxdy = 0$$

admits of the infinitesimal point transformation

$$\frac{\partial f}{\partial x} - \frac{\partial f}{\partial y};$$

the equation (27) becomes

$$e^{2z(z - x - y)} + e^{2(z - x - y)} - 2e^{(z + 1)(z - x - y)} = 0,$$

which gives the singular solution

$$z = x + y.$$

11. *On Fermat's Numbers.* *By* Lieut.-Col. ALLAN CUNNINGHAM, *R.E.*, *Fellow of King's College, London.*

These are numbers of form $N_n = 2^{2^n} + 1$. Until about 1729 they were *supposed to be all prime*, although only the first five (N_0, N_1, N_2, N_3, N_4) had been proved prime. But, about December, 1729, N_5 was *completely factorised* by Euler: and between 1876–86 *four* more were determined *composite* by various mathematicians, viz., N_6 completely factorised; and N_{12}, N_{23}, N_{36}, *one factor of each* found.

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[1] This form is taken from Guldberg's note in the *Comptes Rendus*, to which reference has been made.

The author now finds that N_{11} is *composite*, containing the factors 319,489 and 974,489; also that (most probably) there are no more prime factors < one million of *any* Fermat's Number (other than those now known to be contained in the above-named eleven numbers); this last result requires confirmation by an independent computer.

DEPARTMENT II.—METEOROLOGY.

1. *Interim Report on Solar Radiation.* See Reports, p. 159.

2. *On a Connection between Sunspots and Meteorological Phenomena.*
By DR. VAN RIJCKEVORSEL.

If from a sufficiently large number of years the mean temperature for each day is computed, and if these means are—generally after more or less smoothing—plotted down in a curve, this will be found to be no smooth curve. It will show a great number of secondary maxima and minima. Now, on the one hand, these seem to be sensibly the same all over our globe. On the other hand, if we treat in the same way the barometer readings, the wind pressure, the rainfall, the magnetic phenomena, we always find the same result; a curve, very different from others often in a general sense, but showing maxima and minima about the same dates.

The phenomenon is not in each single case very striking; in some cases there is very slender evidence of it indeed. But few of our series of observations as yet are long enough and good enough, and there is in each case evidence enough to hope that as soon as this will be the case the phenomena will be apparent enough throughout.

This renders it probable that the cause of these irregularities is not terrestrial. It was natural to look in the first place to the sun-spots for an explanation. The relative numbers of sun-spot frequency for the fifty years 1849–1898 were plotted down in a curve, and the temperature of each day of the year for the same period as observed at the Helder in another curve. The resemblance between both curves is striking. With the exception of two or three out of some twenty-five, all the notches of one curve correspond to similar features in the other. Moreover nearly without an exception each maximum or minimum of the temperature occurs a couple of days later than the corresponding sun-spot one. These facts seem to point towards a decided relation between the two phenomena.

Next the sun-spot numbers as well as the mean temperatures were plotted down, arranged in Mercury years. The two curves thus obtained also show a decided relation.

The next step will be an investigation as to a possible influence of the revolution of Venus. As to Mars, it is not probable that the series of years is long enough to give more than an indication of such an influence—if even that.

3. *Report on Seismology.* See Reports, p. 161.

4. *Seismology at Mauritius.* *By* T. F. CLAXTON, *F.R.A.S.*

A Milne's seismograph for recording unfelt earth movements has been at work at the Royal Alfred Observatory, Mauritius, since September 1898.

All the seismograms have been tabulated and subjected to analysis, and the results will be published as soon as possible.

They may conveniently be discussed under five heads:

(*a*) Diurnal waves.
(*b*) Rapid changes in the vertical.
(*c*) Gradual changes in the vertical.
(*d*) Air tremors.
(*e*) Earthquake shocks.

At Mauritius, the diurnal waves are of greater amplitude than at any other observing station, with a well marked bi-diurnal effect, as shown by Bessel's interpolation formula, which, for the months of October 1898 to March 1899, is

$$2''{\cdot}61 \cdot \sin(\theta + 295^\circ{\cdot}47') + 0''{\cdot}73 \cdot \sin(2\theta + 331^\circ{\cdot}57') + 0''{\cdot}30 \cdot \sin(3\theta + 272^\circ{\cdot}57'),$$

indicating a possible connection with the barometric pressure, the formula for the diurnal variation of which is

$$0\text{in}{\cdot}0108 \cdot \sin(\theta + 49^\circ{\cdot}32') + 0\text{in}{\cdot}0285 \cdot \sin(2\theta + 163^\circ\, 2') + 0\text{in}{\cdot}0020 \cdot \sin(3\theta + 26^\circ\, 4').$$

In connection with the diurnal waves and gradual changes in the vertical it is very desirable that observations should be made with the boom lying east and west as well as north and south, and also with instruments in different localities and under varying conditions.

Rapid changes in the vertical have occasionally occurred on a large scale, notably on December 5, 6, and 7, 1898, and January 7, February 10 and 11, 1899.

On December 5 the boom went out of range at 12h. 17m., after an easterly movement of $7''{\cdot}5$ in 10 minutes, due to very heavy rain at and to the west of the Observatory. On the other days the movements were nearly as large.

A gradual change in the vertical has been going on since September last, the top of the boom pillar moving systematically towards the west. The gradual change in the sensibility of the instrument also indicates a north and south change in the vertical.

Air tremors occur every night in spite of every precaution to insure copious ventilation, and to guard against convection currents. They begin at sunset with small movements which rapidly become larger, but, though of varying amplitude during the night, do not show a marked maximum. They finally die away at sunrise.

As a general rule the tremors are greatest when the fall of temperature during the night is greatest, but this is not always the case.

The earthquake effects have, on the whole, been disappointing, the amplitude of motion being small in every case. This gives rise to the question whether it is possible for the ocean to act as a damper to earthquake shocks. Records from the proposed observatory at Honolulu may throw more light on this subject.

5. *Progress in Exploring the Air with Kites. By* A. LAWRENCE ROTCH, *S.B., A.M., Director of Blue Hill Meteorological Observatory, Massachusetts, U.S.A.*

Since the report presented at Bristol no radical changes in the kites or apparatus at Blue Hill have been made, nor have the heights been increased greatly. Thus, while the average of the highest points attained by the meteorograph in each of the thirty-five flights during 1898 was 7,350 feet above the sea, the average of the ten flights during the first four months of 1899 was 7,680 feet, and that of the five flights between February 23 and 28 was 10,280 feet. The maximum height in 1898, viz. 12,070 feet above sea-level on August 26, was exceeded by 370 feet on February 28, 1899. The smaller increase of altitude than in previous years indicates that the extreme heights to which our kites can rise is being approached. The features of the Blue Hill practice that enable great heights to be reached are the use of cellular kites having curved surfaces, giving greater lift, with self-regulating bridles, limiting the wind-pressure on each kite, and the attachment of the kites at different points on the wire, whereby their pull is distributed. The meteorological results obtained during the past year have been important; some records in cyclones and anti-cyclones are discussed by my assistant, Mr. Clayton, in the Observatory 'Bulletin,' No. 1, 1899, and his deductions from this investigation support the convectional theory of the formation of cyclones. The writer has given a general account of the use of kites at Blue Hill in a paper published in 'Quart. Journ. Roy. Met. Soc.,' October 1898.

The value of kites for meteorological observations, which was demonstrated at Blue Hill, has led to their trial in the United States and in Europe. The attempt of the United States Weather Bureau to secure each day records with kites a mile above sixteen stations was unsuccessful for forecasting, on account of light winds, which prevented daily flights at all the stations. The German and Russian meteorological bureaux will employ kites at Hamburg, Berlin, and St. Petersburg; and at Trappes, near Paris, M. L. Teisserenc de Bort has already got records at great heights. It appears, therefore, that henceforth the equipment of a meteorological observatory should include the kite (and perhaps the captive balloon for use when wind is lacking), so that automatic records may be obtained at the height of a mile or two in the free air at the same time that observations are made at the ground.

6. *Remarks concerning the First Crossing of the Channel by a Balloon.* *By* A. LAWRENCE ROTCH.

The author gave a brief account of the balloon voyage of M. Blanchard and Dr. Jeffries from Dover on January 7, 1785.

7. *The Hydro-Aërograph.* *By* F. NAPIER DENISON, *Victoria, B.C.*

In 1897 I had the honour of presenting an illustrated paper before the Toronto Meeting of this Association, entitled 'The Great Lakes as a Sensitive Barometer.' It was then mentioned that the writer, in order to prove the direct action of atmospheric waves upon the lake's surface, had devised an automatic instrument to synchronously record both phenomena upon the same time sheet, and suggested for it the above name. The records from this instrument have not only demonstrated the direct action of atmospheric undulations upon the water, but have graphically shown that various types of undulations occur before the approach of important storms.

In order to more thoroughly prove the practical value of this instrument, Mr. Stupart, Director of the Canadian Meteorological Service, permitted me to instal another upon the harbour at Victoria, British Columbia, the records to be studied in conjunction with the synoptic weather charts recently instituted here for the issuing of British Columbian forecasts.[1] The instrument, which was set up on the Government Wharf last May, consists of a recording cylinder three feet in length by two in circumference, which, actuated by clockwork, completes one revolution every twenty-four hours. Upon this cylinder rest two automatic inking pens; the one on the left records the tidal action, the other the barometric changes. The movement of the float in the tidal shaft is transmitted to the instrument by means of a special non-oxidisable and flexible wire, which passes up to and is coiled several times round the large grooved circumference of the reduction pulley on the floor to the left. From the small grooved circumference of this pulley is attached another flexible wire, which passes up to and over a finely centred pulley on the left of the instrument, then through a clamp upon the underside of the pen carriage, and finally over another small pulley to a counterweight below.

The 'aërographic' portion of this instrument is decidedly unique, for the huge air chamber used is nothing less than an illicit copper whisky still, which was con-

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[1] A photograph representing the instrument temporarily mounted was exhibited to the Section.

fiscated years ago by the Canadian Government, and by their permission I have converted it into an 'air barometer.' To effect this it was only necessary to place within its centre a four-inch tube extending from top to bottom, and to seal hermetically the large chamber with the exception of two small holes at the bottom of the central pipe. To complete this device water is poured into the central pipe until the confined air in the large chamber is sufficiently compressed to sustain a column of water in the central tube. Upon the water in the latter a float is placed and connected to the recording pen on the right of the instrument in a similar manner to the other as already described. Both carriages bearing the recording pens are mounted on small rollers which move on two horizontal and parallel brass rods. The effect of changes of atmospheric pressure upon this air barometer when increasing is to depress the column of water and float in the central tube, which causes an upward movement of the pen upon the paper; when the external pressure is reduced, a contrary movement occurs. In order to keep the temperature in the air chamber as constant as possible, the latter is deeply imbedded in sawdust.

The recording sheet is 36 inches by 24; it is ruled one way for hours, half, and quarter hours, each being ·25 of an inch apart. The tidal range of 10 feet occupies the lower portion, and is ruled for feet and every two tenths of a foot, the ratio of movement between the float and pen being 10 to 1. The remainder of the sheet is graduated into barometric tenths and every two hundredths of an inch, each tenth corresponding to 1·2 of an inch upon the paper.

The object of this instrument is not so much to furnish a very accurate measurement of barometric changes as are now obtained from standard ones, as to magnify the movements to enable one to study the characteristic forms and amplitude of the ripples, waves, and billows which are now known to exist in our atmosphere during all conditions of weather. Although this instrument has only been in operation during the summer type of fine settled weather, numerous interesting forms of undulations have been recorded by both tidal and barometric pens. The former are known as 'Secondary tidal undulations,' and though the writer thinks these are due at all stations to atmospheric waves or billows travelling over the surface of the ocean, he is inclined to believe their relative amplitude and time interval vary according to the configuration, area, and depth of the semi-enclosed basins where they usually occur.[1]

As previously observed upon the Great Lakes,[2] and along our Atlantic Coast, so also here, that when the water undulations are most pronounced, so are the barometric ones, and as the latter become less disturbed so do those on the water.

In order to increase the value of these records I made them up into monthly rolls, which form lengths of either 60 or 62 feet. Upon these are entered the hourly direction and velocity of the wind for Victoria, the hourly height of the Esquimalt tides as taken from its gauge, also the same from the Sand Heads which are situated in the Gulf of Georgia near the mouth of the Fraser River. The curves for these are then drawn in, in red and blue pencil, as will be seen upon the accompanying sheet, which not only graphically shows various primary tidal phenomena, but the marked secondary undulations upon the Victoria trace, and how these diminish as the barometric trace becomes less disturbed.

It is the writer's intention to continue this work for the following reasons:—

That, whereas the great winter storms that sweep over this Province approach from the Pacific, it is thought that their advent may be preceded by certain types of barometric waves and tidal secondaries, also by abnormal tidal elevations or depressions which are known to occur when great barometric differences prevail over the adjacent ocean though the local barometer may still be high. The tabulating of the exact times of high and low water will assist in checking the present American tidal predictions for our coast, which being based upon limited data are not invariably correct. As one of Professor Milne's seismographs is now in most successful operation here, and frequently recording tremors and quakes, it is

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[1] 'The Origin of Ocean Tidal Secondary Undulation,' by F. Napier Denison, *Can. Institute Proc.* Read April 23, 1898.

[2] 'The Great Lakes as a Sensitive Barometer,' by F. Napier Denison, *Brit. Assoc. Report*, 1897.

thought this instrument may assist in this work by recording not only any seismic sea waves that may cross the Pacific, but atmospheric ones that in great volcanic eruptions are set up, as in the case of Krakatoa.

It is hoped these observations, and data obtained during the coming winter, may not merely assist our local weather predictions, but lead to a similar investigation upon the important seaboard of Great Britain.

8. *Report on Meteorological Observations on Ben Nevis.* See Reports, p. 250.

9. *Report on Meteorological Photography.* See Reports, p. 238.

10. *Report on the Meteorological Observatory, Montreal.* See Reports, p. 65.

11. *The Rainfall of the South-Eastern Counties of England.*

By JOHN HOPKINSON, *F.R.Met.Soc., Assoc.Inst.C.E.*

The rainfall of the south-eastern counties is here treated in the same manner as was that of the south-western counties at the Bristol Meeting of the Association last year. The counties considered as south-eastern are Oxford, Bucks, Berks, Herts, Middlesex, Essex, Hants, Surrey, Sussex, and Kent. They cover an area of 9,901 square miles, which is nearly one-fifth that of England, and one-twelfth that of the British Isles. The mean monthly rainfall for the ten years 1881 to 1890 at seventy stations in these counties has been computed, and the mean annual rainfall at ninety-nine stations, being one to the nearest 100 square miles in each county. Thus, for example, the mean annual rainfall of the smallest county, Middlesex (282 square miles), is deduced from the records of three stations, and that of the largest, Hampshire (1,625 square miles), from the records of sixteen stations.

The monthly and annual means for each county and for the whole area at the seventy stations are as follows:—

Mean Rainfall in the South-Eastern Counties of England, 1881–1890.

	Oxford, 2 stations	Bucks, 2 stations	Herts, 6 stations	Middlesex, 3 stations	Essex, 9 stations	Berks, 5 stations	Hants, 12 stations	Surrey, 7 stations	Sussex, 12 stations	Kent, 12 stations	Mean, 70 stations
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
Jan. .	2·00	2·00	1·93	1·90	1·58	2·33	2·57	1·95	2·51	2·03	2·14
Feb. .	1·89	1·88	1·79	1·83	1·55	2·07	2·07	1·77	2·23	1·82	1·91
Mar. .	1·73	1·68	1·76	1·80	1·60	1·80	1·94	1·67	2·16	1·81	1·84
April .	1·78	1·86	1·80	1·72	1·55	1·89	1·80	1·73	1·88	1·73	1·77
May .	1·96	2·14	2·14	2·10	1·80	2·05	2·11	1·98	1·98	1·76	1·97
June .	2·07	1·82	1·95	1·98	1·71	2·07	1·93	1·79	1·83	1·76	1·86
July .	2·59	2·93	2·55	2·47	2·39	2·67	2·36	2·43	2·70	2·41	2·50
Aug. .	1·97	2·05	1·96	2·16	2·10	2·04	2·05	1·93	2·33	1·97	2·07
Sept. .	2·17	2·37	2·20	2·21	2·20	2·24	2·39	2·20	2·68	2·59	2·37
Oct. .	2·54	2·66	2·85	2·57	2·53	2·60	3·04	2·58	3·60	3·25	2·97
Nov. .	2·75	2·88	2·85	2·80	2·57	2·99	3·34	2·73	3·64	3·03	3·06
Dec. .	2·00	2·19	2·09	1·92	1·79	2·18	2·55	1·86	2·65	2·31	2·24
Year .	25·45	26·46	25·87	25·46	23·37	26·93	28·15	24·62	30·19	26·47	26·72

The annual means at the ninety-nine stations are: Oxford, eight stations, 26·18 inches: Bucks, seven stations, 25·28 inches; Herts, six stations, 25·87 inches; Middlesex, three stations, 25·46 inches; Essex, thirteen stations, 23·68 inches; Berks, eight stations, 27·28 inches; Hants, sixteen stations, 28·80 inches; Surrey, eight stations, 24·90 inches; Sussex, fifteen stations, 30·22 inches; and Kent, fifteen stations, 26·41 inches; the mean for the whole area being 26·80 inches. This differs very slightly from the mean at the seventy stations for which the monthly means are given.

During the ten years, 1881 to 1890, the rainfall in this part of England was rather less than that for the twenty-five years ending 1890, and that for the thirty years ending 1895. Twenty stations give a mean for the ten years, 1881–90, of 26·22 inches, for the twenty-five years, 1866–90, of 27·74 inches, and for the thirty years, 1866–95, of 27·55 inches, the excess in this period thus being 1·33 inches, or nearly 5 per cent. (4·8), over the mean fall at the same stations for the ten years 1881–90. The true mean for the larger number of stations for the thirty years would therefore probably be about 28 inches.

The mean fall for the thirty years at the twenty stations in five-yearly periods was as follows: For the first lustrum, 1866–70, 27·09 inches; for the second, 1871–75, 27·76 inches; for the third, 1876–80, 31·41 inches; for the fourth, 1881–85, 27·08 inches; for the fifth, 1886–90, 25·36 inches; and for the sixth, 1891–95, 26·63 inches.

The rainfall in these counties does not throughout follow the general rule of increase from east to west. It does so only from Essex, through Middlesex and Herts, to Bucks, north of the Thames, and from Kent to Sussex, south of the Thames. Dividing the counties into three groups, north, south-west, and south-east, thirty-seven stations for the northern group, Oxford, Bucks, Herts, Middlesex, and Essex, give an annual mean of 25·02 inches; thirty-two stations for the south-western group, Berks, Hants, and Surrey, give an annual mean of 27·43 inches; and 30 stations for the south-eastern group, Sussex and Kent, give an annual mean of 28·32 inches. In the first group the driest months are March and April, each with a mean fall of 1·69 inch; in the second the driest month is April, with a mean fall of 1·80 inch; and in the third the driest month is June, with the same mean fall. In the first group the wettest month is November, with a mean fall of 2·58 inches; in the second, the same month, with a mean fall of 3·10 inches; and in the third, the wettest is October, with a mean fall of 3·43 inches. From October to April, and in June, Essex is the driest county; in May, Kent; in July, Hants; in August, Surrey; and in September, Oxford. In February, and from July to December, Sussex is the wettest county; in January and March, Hants; in April, Berks; in May, Bucks; and in June, the wettest are Oxford and Berks.

The complete paper contains the details from which the above summary has been compiled, and is accompanied by a map showing the position of the rainfall stations and their height above mean sea-level.

TUESDAY, SEPTEMBER 19.

The following Papers and Report were read:—

1. *On a Gravity Balance. By* Professor R. Threlfall, *F.R.S.*, *and* Professor J. A. Pollock.[1]

2. *Report on Electrical Standards.* See Reports, p. 240.

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[1] This paper will be published in the *Philosophical Transactions of the Royal Society.*

3. A discussion on platinum thermometry was opened by the reading of papers by Professor H. L. CALLENDAR, F.R.S., and by Dr. P. CHAPPUIS and Dr. J. A. HARKER, which are appended to the Report on Electrical Standards, p. 242.

WEDNESDAY, SEPTEMBER 20.

The following Papers were read:—

1. *Recent Magnetic Work in North America. By* L. A. BAUER, *Chief of Division of Terrestrial Magnetism of U.S. Coast and Geodetic Survey.*

1. An account of the recent magnetic work carried out by the United States Coast and Geodetic Survey in various parts of the United States and Alaska, and a general outline of the proposed more detailed work were given. The General Government, through the Coast and Geodetic Survey, has recently made preparations for having a detailed magnetic survey made of its possessions, the general scheme of which is to be completed in 10 to 15 years. Observations on ocean areas are likewise to be made. In the general scheme the stations are to be about 30 to 35 miles apart. After the completion of the general survey, stations will be added in regionally disturbed areas. The desirability that Canada and Mexico will likewise undertake at the same time similar surveys was set forth.

2. The general results of the recent magnetic survey of Maryland, made by the author, under the auspices of the Maryland Geological Survey and the Coast and Geodetic Survey, were briefly laid before the Association and charts exhibited, showing the isogonic, the isoclinic, and the isodynamic lines over Maryland for the epoch January 1, 1900. Areas of marked regional disturbances were mapped out on a special chart. The secondary residual field of the earth's magnetism, *i.e.* the portion remaining after deducting the uniform magnetisation, was represented graphically for the year 1900.

2. *The Spectral Sensitiveness of Mercury Vapour in an Atmosphere of Hydrogen, and its Influence on the Spectrum of the latter. By* E. PERCIVAL LEWIS, *Ph.D.*[1]

An account was given of some experiments carried on in the University of Berlin. The spectrum of hydrogen at different pressures, contained in vacuum tubes with external electrodes, first pure and then containing varying quantities of mercury vapour, was examined photometrically with the following results:—

1. A quantity of mercury vapour corresponding to the saturation density of −5° produced a spectrum of measurable intensity, but did not appreciably affect the intensity of the hydrogen spectrum.

2. A quantity of mercury vapour corresponding to the saturation density at 21° produced a diminution of one-half or more in the intensity of the entire visible hydrogen spectrum.

3. The intensity of the mercury spectrum seemed proportional to the amount of its vapour present.

4. The visible radiant energy of the hydrogen and the mercury seemed to be divided between them in the proportion of their relative quantities in the mixture.

The weakening of the hydrogen spectrum by the presence of mercury can

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[1] See *Wied. Ann.* 1899, vol. 69, p. 398.

scarcely be attributed to the greater proportionate share of the current conducted by the latter, but is possibly due to some characteristic difference between the radiation of metals and non-metals, as also illustrated in flame spectra.

3. *On the Theory of the Electrolytic Solution Pressure. By* R. A. Lehfeldt.

According to Nernst's theory, when a metal is immersed in an electrolyte a minute amount of it goes into solution in the ionic form, giving a positive charge to the liquid as compared with the metal, or ions from the solution are deposited in metallic form, giving the metal a positive charge according as the osmotic pressure of the ions in solution falls short of or exceeds an amount known as the electrolytic solution pressure. This view has been generally adopted by physical chemists, it being supposed that the amount of metal to be deposited or dissolved is too small to measure. By combining the calculated value of the solution pressures with the known theorems of electrostatics on the tension exerted by electric charges, it may be shown, in the case of zinc at least, that the amount dissolved would be some centigrammes per square centimetre immersed, and could easily be weighed. Hence the theory seems to break down.

4. *Temperature and the Dispersion in Quartz and Calcite.*
By J. W. Gifford.

A prism of 30° quartz and prisms of 30° and 60° calcite were used. Measurements of the deviations of the ordinary ray for W.L. 5892, and of the angle of the prism, were made at temperatures from 66° F. to 77·5°. With quartz both deviations and angles decrease with rise of temperature; with calcite they increase.

If the deviation at any given temperature and the angle observed at that same temperature be taken for i in the formula $\sin\frac{D+i}{2} \Big/ \sin\frac{i}{2}$, we have a series of refractive indices decreasing with rise of temperature for both quartz and calcite, of which the following are average instances:—

Temp. F.	Quartz prism 30°	Temp. F.	Calcite prism 30°	Temp. F.	Calcite prism 60°
°		°		°	
68·5	1·5441530	67·75	1·6584402	65·5	1·6584320
75·5	1·5441337	75·25	1·6584029	72·5	1·6584190

But, if all the angles at all temperatures are added together and the mean taken for i, the following series of indices result:—

Temp. F.	Quartz prism 30°	Temp. F.	Calcite prism 30°	Temp. F.	Calcite prism 60°
°		°		°	
66	1·5441638	65·25	1·6583344	63·5	1·6583259
67	1·5441632	70	1·6583891	65	1·6583443
68	1·5441616	70·5	1·6583983	67·5	1·6583528
69	1·5441560	74	1·6584305	67·75	1·6583564
74·5	1·5441512	75·25	1·6584603	69·5	1·6583842
75	1·5441307	76	1·6584929	76·5	1·6585075
75·5	1·5441117				
77·5	1·5441013				

If, omitting the two last of quartz, we deduce the coefficients for unit temperature, we have ·00000368, ·0000147, and ·0000140 for the three columns respectively. And if from these coefficients indices be calculated for a temperature of 59° F. (equals 15 C. nearly) we have the following:—

Quartz prism 30°.		Calcite prism 30°.		Calcite prism 60°.
1·5441896	...	1·6582423	...	1·6582624

For Quartz at 15° C. Rudberg and Mascart give ... 1·54418
„ „ Sarasin gives ... ... 1·54419
For Calcite „ „ „ ... ... 1·65839
„ „ „ „ 2nd prism 1·65825

The above indices are uncorrected for air.

5. *A Workshop Form of Resistance Balance.* *By* Professor J. A. Fleming, *F.R.S.*

6. *A Method of Making a Half-shadow Field in a Polarimeter by two inclined Glass Plates.* *By* J. H. Poynting, *Sc.D.*, *F.R.S.*

When a beam of light polarised in a plane neither parallel nor perpendicular to the plane of incidence falls on a plate of glass with parallel sides, Fresnel's formula shows that it emerges still plane polarised, but with the plane of polarisation rotated away from the plane of incidence. Regarding the incident beam as resolved into two polarised respectively in and perpendicular to the plane of incidence, the former suffers most loss by reflection at the two faces, so that in emergence it bears a less proportion to the latter, and the resultant plane is therefore turned round from the plane of incidence.

To make use of this rotation to obtain a half-shadow field—*i.e.* a field divided into two halves in which the planes of polarisation are slightly inclined to each other—two glass plates are bevelled each at one edge and fitted with the bevels together to form a **V**. This **V** is fixed in a frame and put in the usual position of the half wave plate, with the sharp edge down the middle of the field and turned towards the polariser. The frame can be rotated about a horizontal axis—the 'tilt-axis'—through the middle of the edge and perpendicular to the axis of the instrument.

Let us suppose the plane of polarisation of the light incident on the **V** plates to be vertical. If the edge of the **V** is also vertical, the light passes through the two plates unchanged in plane, and the two halves will suffer extinction at the same time when the analyser is crossed. But if the **V** is turned through any angle about the tilt-axis the planes of polarisation of the two halves on emergence from the **V** are rotated each slightly from the vertical in opposite directions by equal amounts, and now when the analyser is crossed the two halves have equal brightness, and extinction occurs for the two in different positions of the analyser. The **V** therefore serves to give a half-shadow field. The sensitiveness of the instrument can be increased or diminished by lessening or increasing the tilt of the **V**.

In general, when light comes through a parallel plate, that which comes straight through is mixed with that which has suffered two or more internal reflections, and if the incident beam is polarised the components of the emergent beam have suffered different rotations. But looking towards the **V** from the concave—*i.e.* the analyser-side—it can easily be shown that there is a strip on each side of the junction of the plates in which the light has no admixture of internally reflected beams, and is therefore in each strip all in one plane of polarisation. The thicker the plates the wider are these strips, and they must be so thick that the strips wholly fill the aperture of a diaphragm placed just in front of the **V**.

Like all other half-shadow instruments, this instrument gives the best results with monochromatic light, but the same **V** of course serves equally well for any single wave length.

If the angle between the plates is twice the complement of the polarising angle, say 67°, no light is reflected when the edge of the V is vertical, and therefore this angle gives the best illumination. If the angle is about 80°, the strips mentioned above have the greatest width. Probably any angle between these values will serve almost equally well, and I do not find in practice much difference in efficiency with different angles.

The device acts well for projection with a lantern if very thick plates are used.

SECTION B.—CHEMISTRY.

PRESIDENT OF THE SECTION—HORACE T. BROWN, LL.D., F.R.S.

THURSDAY, SEPTEMBER 14.

The President delivered the following Address:—

THE subject which I have chosen for my Address is the fixation of carbon by plants, one which is the common meeting-ground of Chemistry, Physics, and Biology. I must, however, confine myself only to certain aspects of the question, since it is manifestly impossible to fully discuss the whole of a subject of such magnitude and importance within the time at my disposal.

We have become so accustomed to the idea that the higher plants derive *the whole* of their carbon from atmospheric sources that we are apt to forget how very indirect is the nature of much of the experimental evidence on which this belief is founded. There can, of course, be no doubt that the primary source of the organic carbon of the soil, and of the plants growing on it, is the atmosphere; but of late years there has been such an accumulation of evidence tending to show that the higher plants are capable of being nourished by the direct application of a great variety of ready-formed organic compounds, that we are justified in demanding further proof that the stores of organic substances in the soil must necessarily be oxidised down to the lowest possible point before their carbon is once more in a fit state to be assimilated.

It was the hope of gaining more direct evidence on this important question which led me some time ago to attack the problem experimentally in conjunction with Mr. F. Escombe, the resources of the Jodrell Laboratory at Kew having been kindly put at our disposal by Sir W. Thiselton-Dyer and Dr. D. H. Scott. Up to the present time our experiments have not been carried far enough to enable us to give a positive answer to the main question, but they have already suggested a new method of attack which will enable us in the future to determine, with a fair amount of certainty, whether any particular plant, growing under perfectly natural conditions, derives any appreciable portion of its carbon from any other source than the gaseous carbon dioxide of the atmosphere.

During the course of the inquiry, many interesting side issues have been raised which we believe to be of some importance in their bearing on the processes of plant nutrition, and it is to a consideration of these that I intend to devote the greater part of my Address.

I must, however, in the first place indulge in a little historical retrospect, and am the more tempted to do this, as far as the early pioneers in this branch of knowledge are concerned, since a critical study of their writings has shown me very clearly that the relative merits of some of these older workers, and the respective parts which they took in founding the true theory of assimilation, have in our own time been much misrepresented by more than one historian of science whose name carries great weight.

There is no chapter in the history of scientific discovery of greater abiding interest than that which was opened by Priestley in 1771, when he commenced his work on the influence of plants on the composition of the air around them. It has often been assumed that these experiments of Priestley, which were unquestionably the starting-point for all succeeding workers, were the result of some haphazard method of working, and of one of those happy chances to which he is in the habit of attributing some of his most important discoveries. However much the element of chance entered into some of his work, and in this respect I think Priestley often does himself injustice, the discovery of the amelioration of vitiated air by plants was certainly not a case of this kind. Of all his contemporaries belonging to the old school of Chemistry Priestley had the clearest conception of the processes of animal respiration and of their identity with the process of combustion. This is clearly shown by his 'Observations on Respiration and the Use of the Blood,' which he presented to the Royal Society in 1776. This memoir, written of course from the phlogistic point of view, only requires translating into the language of the newer Chemistry to be an accurate statement of the main facts of animal respiration. We have it on Priestley's own authority that it was these studies which produced in his mind a conviction that there must be some provision in nature for dephlogisticating the air which was constantly being vitiated by the processes of respiration, combustion, and putrefaction, and for rendering it once more fit for maintaining animal life. In his search for this compensating influence, which he justly regarded as one of the most important problems of natural philosophy, he made many attempts to bring back the vitiated air to its original state by agitating it with water, and by submitting it to the continued action of light and heat, and it was in the course of these systematic attempts that he was led to study the influence of plants in this direction.

It was in the month of August, 1771, that he made the memorable experiments at Leeds of immersing sprigs of mint in air which had been vitiated by the burning of a candle or by animal respiration. To quote his own words, this observation led him 'to conclude that plants, instead of affecting the air in the same manner with animal respiration, reverse the effects of breathing, and tend to keep the atmosphere sweet and wholesome when it is become noxious in consequence of animals either living or breathing, or dying and putrefying in it.' That he was fully convinced that these observations, which he repeated and amplified in the following year, presented the true key to the problem, is sufficiently shown by another passage in which he says: 'These proofs of the partial restoration of air by plants in a state of vegetation, though in a confined and unnatural situation, cannot but render it highly probable that the injury which is continually done to the atmosphere by the respiration of such a number of animals, and the putrefaction of such masses of both vegetable and animal matter, is, in part at least, repaired by the vegetable creation; and notwithstanding the prodigious mass of air that is corrupted daily by the above causes, yet if we consider the immense profusion of vegetables upon the face of the earth growing in places suited to their nature, and consequently at full liberty to exert all their powers, both inhaling and exhaling, it can hardly be thought but that it may be a sufficient counterbalance to it, and that the remedy is adequate to the evil.'

Between the time of Priestley temporarily relinquishing his experiments in this direction in 1772, and his resumption of them in 1778, owing to the adverse criticism of Scheele and others, he had discovered dephlogisticated air or oxygen, and had elaborated his method for ascertaining the purity of air, or its richness in oxygen, by determining its diminution in volume after mixing with an excess of nitric oxide over water.[1] This method gave of course a much greater degree of precision to his results than was attainable in his earlier work, where the purity of the air at the end of an experiment was only determined by ascertaining if it would support the combustion of a candle or allow a small animal to live in it.

The results of his later work were published in 1779, and were not altogether

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[1] Nitric oxide was discovered by Priestley in 1772, and was described by him under the name of 'nitrous air.'

confirmatory of those arrived at six years before. It is true that he generally found evidence of an evolution of oxygen by the plants, but occasionally the air was less 'pure' at the end of an experiment than it was at the beginning, and this occurred in a sufficient number of cases to lead Priestley to doubt to some extent the accuracy of his previous conclusions. On the whole, however, he still thinks it *probable* that the vegetation of healthy plants has a salutary effect on the air in which they grow.

The reason for this want of complete consistency in these later experiments was, of course, his failure at that time to recognise the important influence of *light* in bringing about the evolution of oxygen, an explanation which was given shortly afterwards by Ingen-Housz.

Priestley's attention was now taken up with another observation, which led him within a very short distance indeed of the discovery that the evolution of oxygen by plants is conditioned not only by a sufficient degree of illumination, but also by the pre-existence of carbon dioxide. It is the more necessary to treat of this point somewhat in detail, since it is a part of his work which has received but scanty justice at the hands of recent writers, who have apparently failed to see how much our modern conceptions of plant nutrition really owe to the initiative of Priestley. In his 'History of Botany,' Sachs deals very unfairly with Priestley in this respect, owing to a want of intimate knowledge of his writings, and to the lack of anything like perspective in estimating the relative merits of his contemporaries Ingen-Housz and Senebier, whose position can only be completely understood after a careful study of their numerous original memoirs, some of which are by no means readily accessible.

In the course of his experiments on plants partially immersed in water more or less fully impregnated with 'fixed air,' Priestley had observed a fact which had not escaped the notice of Bonnet at an earlier date, that bubbles of gas arose spontaneously from the leaves and stems, and it occurred to him that an examination of the nature of this gas by means of his new eudiometric process ought to settle the question whether plants really do contribute in any way to the purification of ordinary air. It was in June, 1778, that he put this to the test, and he found that the air thus liberated was much richer in oxygen than ordinary air. On removing the plants he found to his astonishment that the water in which they had been placed, and which had a considerable amount of 'green matter' adhering to the sides of the phials, still continued to evolve a gas which increased in amount when the vessels were placed in sunlight. On testing this gas with his eudiometric process, he found that it consisted to a great extent of 'dephlogisticated air' or oxygen; in fact, from the experimental results which he gives it is evident that the gas contained from 74 to 85 per cent. of oxygen. Having observed that the 'green matter' appeared much more readily in pump water than in rain or river water, and knowing that pump water contained considerable amounts of 'fixed air,' he was led to make a series of experiments with water artificially impregnated with carbon dioxide, which left no doubt in his mind that the production of the 'green matter' and the evolution of dephlogisticated air were in some way due to the presence of 'fixed air.' Up to this point Priestley was following a path which seemed about to lead him to a complete solution of his previous difficulties. He had beyond all question succeeded in showing not only that the evolution of oxygen was dependent on the pre-existence of carbon dioxide, but that light was also required for the process. It only wanted in fact the recognition of the vegetable nature of the alga which constituted his 'green substance' to bring these observations into line with his previous work, and to complete a discovery which would have eclipsed in importance all the others with which Priestley's name is associated. It was just this one step which he most provokingly failed to take. It is true that he examined the 'green substance' under the microscope, but owing to want of skill in the use of the instrument, and also to his defective eyesight, he was unable to determine its true nature, and unfortunately adopted the view that it had merely a mechanical action in separating the oxygen from the water, and, to use his own words, that 'it was only a circumstance preceding the spontaneous emission of the air from water.' He was in fact now inclined to regard the process as a purely chemical one, due to the direct action of light on the carbon dioxide dissolved in the water.

But this was by no means Priestley's final view, as shown by a further description of his experiments on plants set forth in the new edition of his works published in 1790, where he clearly recognised the error into which he had been led.[1] Meanwhile the subject had been taken up by two other observers, Ingen-Housz and Senebier, and in order to thoroughly understand the respective shares which these men took in advancing our knowledge of the assimilatory process, it is necessary to consult not only their books but also the numerous scattered memoirs which appeared at intervals between the years 1779 and 1800.

To Ingen-Housz must unquestionably be awarded the merit of having experimentally demonstrated that the amelioration of the surrounding air by plants is not, as Priestley at first believed, due to vegetative action *per se*, but is dependent on the access of light of a sufficient degree of intensity, and, moreover, that the power is confined to the green parts of the plants. At the same time, whilst recognising, as Priestley had done before him, that the combined action of plants and light on the air was a dephlogisticating process, he did not know, until after its demonstration by Senebier, that the particular form of phlogisticated air which was essential to plants was 'fixed air' or carbon dioxide. In fact Ingen-Housz had but a slender knowledge of the chemistry of his day, so much so indeed that he constantly confuses 'phlogisticated air' or nitrogen with 'fixed air,' and attributes the source of the evolved oxygen either to air imprisoned within the leaf, or, in the case of submerged plants, to a metamorphosis of the water itself. I must, however, recall the fact that Ingen-Housz was the first to show that the green parts of plants in the dark, and the roots both in the light and in darkness, vitiate the air in the same way as animals do. On the strength of these experiments he is generally given credit for having first observed the true respiration of plants, but I cannot avoid the conclusion that, in the controversy which ensued on this point between Ingen-Housz and Senebier, the adverse criticisms of the latter were well founded. Whilst not denying that plants in the dark have some mephitic influence on the air around them, Senebier maintained that the greater part of the observed effect was due to a fermentative action set up in the large bulk of leaves which Ingen-Housz employed. Certainly some of the results appear to be largely in excess of those we should now expect to obtain from respiratory processes only.[2]

Senebier's work falls between the years 1782 and 1800. The fact that he was an early convert to the new ideas and generalisations of Lavoisier gives his views on plant nutrition far greater precision than those of Priestley and Ingen-Housz. His experiments, for the most part well devised, proved beyond all doubt that the oxygen disengaged from submerged and insolated plants could not be derived from air contained in the leaf parenchyma, but that it depended on the pre-existence of carbon dioxide, and that its evolution was strictly proportional to the amount of carbon dioxide which the water contained.

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[1] The view which was taken by Priestley's contemporaries of his position with regard to the discovery of the fundamental facts is well exemplified by the following remarks taken from a paper published by Ingen-Housz in 1784 (*Annales de Physique*, xxiv. 44): 'C'est à M. Priestley seul que nous devons la grande découverte que les végétaux possèdent le pouvoir de corriger l'air mauvais, et d'améliorer l'air commun ; c'est lui qui nous en a ouvert la porte. J'ai été assez constamment attaché à ce beau système, dans le temps que lui-même, par trop peu de prédilection pour ses propres opinions, paroissoit chanceler.'

[2] It is by no means uncommon to find Ingen-Housz put forward as the discoverer of the fixation of carbon by plants from carbon dioxide. This claim is generally based on certain statements made in his essay on the 'Food of Plants and the Renovation of the Soil,' published in 1796 as an appendix to the outlines of the fifteenth chapter of the *Proposed General Report from the Board of Agriculture*. All that is good and sound in this essay is taken from Senebier's papers without any acknowledgment, but, in appropriating ideas which he evidently understands very imperfectly, he has built up a system of plant economy which is almost unintelligible.

Although positive experimental proof was still wanting that aerial plants also derive their carbon from carbon dioxide, Senebier regarded this as extremely probable; but, taking into consideration the small amount of this gas present in the atmosphere, he concluded that it must reach the plant by the roots and leaves entirely in a state of solution in water.

The work of Priestley, Senebier, and Ingen-Housz fortunately attracted the attention of a young chemist of high attainments, who, within a period of less than ten years, did more for the advancement of vegetable physiology than any single observer before or since his time. Théodore de Saussure, the second of that illustrious name, and the son of the famous explorer and natural philosopher, commenced his researches about the year 1796, and in 1804 published his 'Recherches Chimiques sur la Végétation,' a modest little octavo volume of some 300 pages which must certainly take rank as one of the great classics of scientific literature, and one of the most remarkable books of the century.

De Saussure was a past master in the art of experiment, and the methods which he devised for demonstrating the influence of water, air, and soil on vegetation have been the models on which all such investigations have been conducted ever since. It is indeed very difficult, when reading this masterly essay, to bear in mind that it was not written fifty or sixty years later than the date on its title-page, so essentially modern are its modes of expression and reasoning, and so far is the author in advance of his contemporaries. It is to this work we must refer for the first experimental proof that plants derive at any rate the greater part of their carbon from the surrounding atmosphere. This was shown by De Saussure by a variety of quantitative experiments of a sufficient degree of accuracy to bring out the great leading facts. By making known mixtures of carbon dioxide and air, and submitting them to the action of plants in sunlight, he was able to show not only that the gaseous carbon dioxide was decomposed and the carbon assimilated, but also that the volume of oxygen disengaged was approximately equal to that of the carbon dioxide decomposed.[1] He also showed that plants growing in the open in moist sand, or in distilled water, and therefore under conditions in which they could not derive any carbon from other than atmospheric sources, not only materially increased in dry weight, but contained much more carbon at the close of the experiment than at the beginning, and had also fixed an appreciable amount of water in the process. That atmospheric carbon dioxide is not only beneficial to plants in sunlight, but is also essential to their very existence, De Saussure proved by introducing an absorbent of this gas into the vessel containing a plant or the branch of a tree rooted naturally in the soil. Under these conditions the portions of the plant enclosed always died. He also ascertained by experiment the increase in dry weight of a sunflower plant during four months of natural growth; and knowing approximately the amount of water transpired during that period, and the maximum amount of solids which this transpired water could possibly introduce into the plant, he calculated that these solids, and the carbon dioxide in solution in the transpiration water, fell far short of accounting for the observed increase in the dry weight of the plant. This increase must, therefore, be mainly due to the fixation of atmospheric carbon dioxide and water.

It is certainly a remarkable fact that the rigid experimental proofs which De Saussure brought forward in support of his views did not carry conviction to the minds of every one. His book, however, suffered the fate of many others which have appeared in advance of their time. It is true that De Saussure's doctrines were always kept alive by the advanced physiologists of the French school, such as De Candolle and Dutrochet, but when Liebig first turned his attention to the subject he found the field in possession of the humus theory of Treviranus, a theory

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[1] Although clearly indicating that no change of volume occurred in the mixture of air and carbon dioxide so treated, his final analytical results show a small apparent evolution of nitrogen. This was due to the eudiometric methods he employed—methods, it is true, far superior in point of accuracy to those of his predecessors, but still necessarily imperfect.

which no longer took any account of the decomposition of carbon dioxide by the leaves, but which derived the whole of the elements of the growing plant from a solution of the soil extract taken up by the roots. We may well say with Sachs, 'Nothing can be conceived more deplorable than this theory of nutrition; it would have been bad at the end of the seventeenth century, it is difficult to believe that it could have been published thirty years after De Saussure's work.' It is well known how by the cogency of his reasoning and the force of his genius Liebig successfully overthrew this heresy, and once more established the doctrine of carbon assimilation as taught by De Saussure; and the accurate work of Boussingault, who, whilst elaborating far more delicate analytical processes than were possessed by chemists in the early days of the century, still in the main used De Saussure's methods, gave the final death-blow to the humus theory, at any rate in the crude form in which it was presented by its originators. No one since that time has questioned the fact that green plants owe the greater part of their carbon to atmospheric sources, and the accumulated experience of two succeeding generations of workers has added proof on proof of the correctness of this great generalisation.

But whilst it cannot be doubted that green plants devoid of parasitic or saprophytic habit derive the principal part of their carbon from the air, is the experimental evidence at present so complete as to exclude all other sources of supply? De Saussure himself certainly left the door open to such a possibility, and although Boussingault held a different view, we find Sachs as late as 1865 maintaining that it is not contrary to the generally accepted theory of assimilation to suppose that there are chlorophyllous plants which decompose carbon dioxide and at the same time absorb ready-formed organic substances whose carbon they utilise in the formation of new organs.

Up to comparatively recently there was little or no experimental evidence to justify this supposition, for the early experiments of De Saussure on the influence of solutions of sugar, and of other organic substances, on growing plants, although very suggestive, were not of a sufficiently precise nature to lead to any conclusions, and we must come down to within fifteen years of the present time for anything like a demonstration that the green organs of plants can, under favourable conditions, build up their tissue from already elaborated carbon compounds just as do the fungi and the non-chlorophyllous plants generally.

The active centres of the decomposition of carbon-dioxide in green leaves are the chlorophyll corpuscles or chloroplastids, and the first visible indication of this decomposition is the formation within these chloroplastids of minute granules of starch whose presence can be shown by suitable micro-chemical means. I have elsewhere discussed the question of how far the appearance of this starch is dependent on the pre-existence of other carbohydrates of a simpler constitution, and also the probability that the whole of the products of assimilation do not necessarily pass through the form of starch: this is a subject which need scarcely concern us at the present moment; it is sufficient to draw attention to the main fact that in an assimilating cell the chloroplastids, in the vast majority of cases, give rise to these minute starch granules, which once more disappear when the plant is placed in darkness, or when the air around it is deprived of carbon dioxide. Now in 1883 Böhm made the interesting discovery that when green leaves are placed in the dark until the starch of their chloroplastids has completely disappeared, there is a reappearance of starch when the cut end of the leaf-stalk is immersed in a solution of cane-sugar and of dextrose, or when the leaf is brought directly in contact with solutions of these substances. He found, in fact, that the elements of the cell which, under ordinary circumstances, manufacture their materials for plant growth by the reduction of carbon dioxide under the influence of sunlight, can, under other conditions, supply their requirements from suitable ready-formed organic substances. These observations of Böhm were fully confirmed two years later by Schimper, and were subsequently much extended by A. Meyer and E. Laurent, who found that fructose, maltose, mannitol, dulcitol, and glycerol could also contribute directly to the nutrition of leaves.

Bokorny, working with *Spirogyra* immersed in dilute solutions, found that starch production in the chlorophyll bodies could be induced by a large number of organic substances, including, amongst many others, asparagin, citric, tartaric, and lactic acids, leucine, tyrosine, and peptone.[1]

Very much more to the point are the experiments of Acton, made in 1889, and the still more recent work of J. Laurent and of Mazé.

In his experiments on terrestrial plants Acton, after depleting them of starch, immersed the cut branches or roots, as the case might be, in culture fluids containing certain organic substances, and took precautions to prevent any normal assimilation from taking place by depriving the air around the plant of any trace of carbon dioxide. He was not able to show the direct nutritive influence of so large a range of substances as Bokorny had done for *Spirogyra,* but his results leave no room for doubt that several of the carbohydrates, and even glycerine, can be absorbed by the roots, and can contribute to the nutrition of the green parts. Acton tried, amongst other substances, an 'extract of natural humus,' which was an aqueous solution of the extractives of a light soil which are soluble in dilute alcohol. This extract was found to be effective in producing a small quantity of starch in the leaves, and it evidently contained some substance or substances directly assimilable by the plant.

Apparently without knowing anything of this work of Acton, J. Laurent has recently made a series of experiments on the culture of the maize plant in mineral solutions containing saccharose, glucose, or invert-sugar, and in this way has not only obtained, as Acton had done before him, evidence of the active formation of starch in the leaves, but has also found a very notable increase in the dry weight of the plant. Although assimilation of the carbohydrate may under these circumstances go on in darkness, Laurent found that the process was much enhanced when light had access to the plant. Mazé, within the last few months, has obtained even more pronounced effects of this kind.

When all these new facts are taken into consideration, I think they justify what I have already said, that we ought to demand more direct evidence than is at present available before we accept the view that the majority of chlorophyllous plants take in *the whole* of their carbon from the atmosphere. In the cycle of change which the organic matter of the soil is constantly undergoing under the influence of micro-organisms, it seems by no means improbable that intermediate substances may be formed which in some measure directly contribute to the nutrition of the higher plants, and we must also by no means lose sight of the possible effect, in the same direction, of the symbiotic union of certain fungi with the root extremities of many plants, the Mycorhizæ, whose functions are still so imperfectly understood. Then, again, we must remember that we have another possible extra-atmospheric source of carbon dioxide in the transpiration water of the plant, which is derived from a soil whose gases may contain 5 per cent. or more of carbon dioxide. From the amount of water transpired in a given time, and an application of the law of partial pressures, it may be readily shown that the supply of carbon dioxide to the aërial organs of a plant from this source is by no means negligible.

Before these problems can be attacked for a particular plant with any hope of success, it is clear that we must have some means of establishing an accurate debtor and creditor account as between the plant and the surrounding atmosphere, and this account must extend over a sufficiently long period, and allow of an

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[1] By far the most interesting and important result of Bokorny is the proof he gives that formaldehyde is directly assimilable by *Spirogyra.* His early attempts to show this had been rendered abortive by the highly poisonous nature of this substance. The difficulty was surmounted by using a dilute solution of sodium oxymethylsulphonate, which on warming with water splits up into formaldehyde and acid sodium sulphite. To prevent the unfavourable action of the acid sodium sulphite, dipotassium or disodium phosphate was added to the plant cultures. In such a solution, with rigid exclusion of carbon dioxide, *Spirogyra majuscula* forms starch in its chlorophyll bodies, but the access of light appears to be necessary.

The importance of this experiment is very great in connection with Baeyer's well-known hypothesis that the first act of assimilation is the reduction of carbon dioxide and water to the state of formaldehyde.

accurate balance being struck with the amount of carbon found in the plant at the end of the experiment.

Up to within a few years ago we had no means of even approximately determining the actual rate at which the assimilatory process goes on in a plant other than that afforded by its increase in weight in a given time. Such experiments, necessarily extending over weeks or months, can, at the best, only give us certain average results, and consequently afford no measure of the activity of assimilation under fixed conditions of insolation. In the year 1884 Sachs, who had for some time been at work on the formation of starch in leaves under the action of sunlight, found that the accumulation of freshly assimilated material in a leaf may, under favourable conditions, go on so rapidly as to give rise to a very appreciable increase of weight in the leaf lamina within the short space of a few hours. By observing at different times of the day the varying dry weight of equal areas of large leaves, Sachs obtained an approximate measure of the rate of the assimilatory process which he could express in terms of actual number of grams of substance assimilated by a unit area of leaf in unit of time. In this manner he was able to show, for instance, that a sunflower leaf, whilst still attached to the plant, increases in weight when exposed to bright sunshine at the hourly rate of about one gram per square metre of leaf area. In the case of similar leaves detached from the plant, and of course under conditions in which the products of assimilation were entirely accumulated in the leaf, he found an increase in weight of rather more than 1½ gram per square metre per hour.

I was able to confirm this work of Sachs in the course of an investigation on the Chemistry of Leaves which I made with Dr. G. H. Morris in 1892–93, and there can be no doubt that the variations in the weight of leaves can be used as a fair index of the activity of a leaf in assimilating, but it is not a method which admits of much refinement of accuracy, owing, amongst other things, to the want of perfect symmetry in the leaves as regards thickness and density of the laminæ and to the possible migration of the assimilated material into the larger ribs, which of course cannot be included in the weighings.

It is evident that a far better plan of measuring the rate of assimilation under varying conditions would be the estimation of the actual amount of carbon dioxide entering a given area of the leaf in a certain time, and it was to the perfection of a method of this kind that Mr. Escombe and I first turned our attention.

In all previous attempts to measure the rate of ingress of carbon dioxide, such as those of Corenwinder, and more recently still of Mr. F. F. Blackman, it has been necessary to use air containing comparatively large quantities of carbon dioxide, amounting to 4 per cent. and upwards. Interesting and useful as such experiments undoubtedly are from the point of view from which they were undertaken, we must not lose sight of the fact that such conditions are highly artificial, and very far removed from those under which a plant finds itself in the natural state, where its leaves are bathed with air containing not 4 or 5 per cent. but only ·03 per cent. of carbon dioxide. I shall have occasion later on to show how remarkably the rate of intake of carbon dioxide into a plant is influenced by extremely small variations in the tension of that gas, and that on this account no deduction can be drawn as to the rate of assimilation under natural conditions from any experiments in which the air contains even so small an amount of carbon dioxide as 1 per cent.

Before proceeding further in this direction, however, it will be well to consider the amount of carbon dioxide which must enter a leaf in a given time in order to produce an influence on its weight comparable with that indicated by the Sachs method of weighing definite areas. For this purpose I will consider a leaf with which we have made many experiments—that of *Catalpa bignonioides.* It is a very symmetrical leaf and a good assimilator, and since the intake of carbon dioxide takes place only on the under side, the question to which I wish to draw your attention can be stated in a simple manner. When such a leaf is subjected to a modified form of the half-leaf weighing method of Sachs, into the details of which I cannot here enter, it may, under favourable conditions, show an increase in dry weight equal to about one gram per square metre per hour. Since this increase in weight is due almost entirely to the formation of carbohydrates, we can calculate with a close approximation to accuracy the corresponding amount of carbon dioxide. This will of course depend, within certain narrow limits, on the nature of the carbohydrate formed. The formation of a gram of starch requires 1·628 grams of carbon dioxide, whilst an equal amount of a $C_6H_{12}O_6$ or a $C_{12}H_{22}O_{11}$ sugar requires 1·466 and 1·543 grams respectively. From the knowledge we possess of the nature of the carbohydrates of the leaf, we are quite sure that the mean of these values, that is 1·545 grams, must be very near the truth. This amount corresponds to 784 c.c. of carbon dioxide at normal temperature and pressure, which must represent the volume abstracted by the square metre of leaf surface in one hour from air containing only three parts of carbon dioxide in 10,000, supposing the method of leaf weighing to give correct results. We shall see later on that this intake can be verified by direct estimations; it is equivalent to the total amount of carbon dioxide in a column of air of a cross section equal to that of the leaf, and of a height of 26 decimetres.

The extraordinary power which an assimilating leaf possesses of abstracting carbon dioxide from the air is best shown by comparing it with an equal area of a freely exposed solution of caustic alkali. We have made a very large number of experiments on the rate at which atmospheric carbon dioxide can be taken up by a solution of caustic soda under varying conditions, and have been surprised to find how constant the absorption is. In a moderately still air a square metre of surface of such a freely exposed solution will absorb about 1,200 c.c. of carbon dioxide per hour, and this can only be increased to about 1,500 c.c. even if the dish is exposed to the full influence of a strong wind out in the open. When the surface of the liquid is constantly renewed during the experiment by means of a mechanical stirrer, the rate of absorption is not sensibly affected, providing the agitation does not appreciably increase the surface area, and considerable variations in the strength of the alkaline solution are also without any effect. On the other hand, slight variations in the tension of the carbon dioxide of the air have a marked influence on the rate of absorption, and in order to study this point we have constructed an apparatus which allows us to pass over an absorptive surface of liquid a current of air in a stratum of known thickness, and with a known average velocity.

By introducing definite amounts of carbon dioxide into this stream of air we have been able to determine the influence of its tension on the rate of absorption. At present we have only employed air containing amounts varying from 0·8 to 13 parts per 10,000, that is to say, from about one-quarter to a little more than four times the amount contained in normal air. Within these limits, and probably beyond them, the rate of absorption by the alkaline surface is strictly proportional to the tension of the carbon dioxide in the air current. I shall have occasion to show later on that the same rule holds good with regard to an assimilating leaf, and that in this case also, within certain limits, the intake of the gas is proportional to its tension.

The fact which I wish more particularly to bring out in these comparisons is that a leaf surface which is assimilating at the rate of one gram of carbohydrate per square metre per hour is absorbing atmospheric carbon dioxide *more than half as fast as the same surface would do if wetted with a constantly renewed film of a strong solution of caustic alkali.*

From what I have just said about the influence of tension on the absorption of carbon dioxide by an assimilating leaf, it is clear that any attempts to determine by direct means the natural intake of that gas during assimilation must be made with *ordinary* air, and that such experiments can only be carried out on a comparatively large scale. We had in the first instance to devise an apparatus which would rapidly and completely absorb the whole of the carbon dioxide from a stream of air passing through it at the rate of from 100 to 200 litres per hour, and at the same time admit of an extremely accurate determination of the absorbed carbon dioxide.

The absorbing apparatus which we finally adopted is a modification of one used by Reiset in his estimations of the carbon dioxide of the atmosphere. It consists essentially of a glass tube 50 cm. long, fixed vertically in a wide-mouthed glass vessel furnished with a second aperture and tubulure. The height of the vertical tube is invariable, but its width is regulated according to the amount of air required to be drawn through the apparatus in a given time. The bottom of this tube is closed with a platinum or silver plate pierced with a large number of very small holes, and two other similar perforated plates are inserted in the tube at certain intervals. The upper part of the tube is put in connection with an aspirating water-pump, and the absorbing liquid is placed in the lower glass vessel, whose second tubulure is connected with the supply of air in which the carbon dioxide has to be determined. When the aspirator is started the liquid is first drawn up into the vertical tube, and the air then follows through the perforated plates which act as 'scrubbers.' Reiset, in his work, used baryta water as the absorbent, an aliquot part of which was titrated before and after the experiment, the changes in the volume of the liquid being corrected for by certain devices which I need not describe.

The efficiency of the apparatus as a complete absorber of atmospheric carbon dioxide leaves nothing to be desired, but in dealing with large quantities of baryta solution, amounting to 400 c.c. or more, the errors due to inaccurate titrations, or to over or under estimation of the volume changes, are all thrown on the final result, of which they may form a considerable part. We have consequently altogether discarded the use of baryta as an absorbent in favour of caustic soda. The carbonate is estimated by a double titration process, suggested a few years ago by Hart, and we have succeeded in so far improving this method that there is no difficulty in determining in 100 c.c. of the alkaline solution an amount of carbonate corresponding to $\frac{1}{10}$ c.c. of carbon dioxide.

There is practically no limit to the amount of air which can be passed through an absorbing apparatus such as I have described, and one of very moderate dimensions will allow from 100 to 150 litres per hour to pass with perfect safety. Larger amounts can be dealt with either by increasing the size of the apparatus or by using several smaller ones arranged in parallel.

With proper precautions, determinations can certainly be made to within ·02 part of carbon dioxide in 10,000 of air, so that with an apparatus of this kind it is possible to estimate the intake of carbon dioxide into a leaf or plant from ordinary atmospheric air, and to keep a sufficiently rapid stream of air passing over the leaf to maintain the tension of the carbon dioxide only slightly below the normal amount.

The air is measured by carefully standardised meters, reading to about 20 c.c.; and since the amounts of air aspirated vary from 100 to 900 litres or more, there are practically no errors of measurement. The tension at which the air passes through the absorption apparatus is measured by a manometer, and all the volumes are reduced to standard temperature and pressure.

All such experiments of course necessitate not only a determination of the carbon dioxide in the air which has passed over the leaf or plant, but also a simultaneous determination of the carbon dioxide in the ordinary air used. The accumulation of these air determinations clearly shows that the ordinary statements of our text-books as to the amount of carbon dioxide and its limits of variation are altogether misleading.

In our experiments the air was in all cases taken from a height of four feet six inches from the ground, the amounts aspirated varying from 100 to 500 litres.

In the month of July 1898 the minimum amount of carbon dioxide found was 2·71 parts per 10,000 of air, and the maximum 2·86. During the winter months, when the ground was almost bare of vegetation, it rose to from 3·00 to 3·23 parts per 10,000; and on one foggy day, March 16, 1899, after a whole week of similar weather, we found the very exceptional amount of 3·62. As a rule we may take it that the amount of carbon dioxide in the atmosphere during the period of greatest plant growth rarely falls short of 2·7 parts per 10,000, and rarely exceeds 3·0 parts, with an average of about 2·85. These numbers come very close to the determinations of Reiset, and of Müntz and Aubin, and agree also fairly well with the Montsouris determinations.

If, instead of taking the air from a height of three or four feet from the ground, we examine the stratum only one or two centimetres above the surface of a soil free from vegetation, we find, as might be expected, a very large increase in the amount of carbon dioxide, which may exceed, under these circumstances, 12 or 13 parts per 10,000 of air. Such a soil, in fact, gives off by diffusion into the surrounding air an amount of carbon dioxide which is comparable to that evolved by a respiring leaf, that is to say about 50 c.c. per square metre per hour. This is probably a factor which has to be taken into account in considering the assimilative power of vegetation of very low growing habit, but in all other cases we may assume with safety that aërial plants have to take in their carbon dioxide from air in which its tension does not exceed $\frac{3}{10000}$ of an atmosphere.

The actual intake of carbon dioxide is determined by enclosing the entire leaf in specially constructed air-tight glazed cases, through which a sufficiently rapid air stream is passed. These cases are so arranged that the leaf can be enclosed whilst still attached to a plant which is growing out in the open under perfectly natural conditions, and some of them are sufficiently large to take the entire leaf of a sunflower.

The carbon dioxide content of the air is determined both before and after its passage through the apparatus, and since the amount of air passed is known we have all the data requisite for determining the actual amount retained by the leaf.

An experiment generally lasts from five to six hours, and the carbon dioxide fixed in this time may amount to 150 c.c. or more, the actual error of determination being very small indeed.

For purposes of comparison the volumes are reduced to the actual number of cubic centimetres of the gas absorbed by a square metre of leaf in one hour, which of course necessitates an exact determination of the area of the leaf. This is most conveniently effected by printing the leaf on sensitised paper, and tracing round its outline with a planimeter set to read off square centimetres—a far more accurate and expeditious plan than that of cutting out a facsimile of the leaf from paper of a known weight per unit of area.

If it is desired to estimate the assimilative power of a leaf in an atmosphere artificially enriched with carbon dioxide, the air stream before entering the leaf case is passed through a small tower containing fragments of marble, over which there drops a very slow stream of dilute acid, whose rate of flow is so proportioned to the air stream as to give about the desired enrichment with carbon dioxide. The stream of air is then divided, one part going on directly to the leaf case, whilst the other passes through a separate absorption apparatus and meter for the accurate determination of its carbon dioxide content.

In order to show the kind of results obtained in this manner I will give one or two examples.

A leaf of the sunflower, having an area of 617·5 sq. c.m., was enclosed in its case whilst still attached to the plant, and was exposed to the strong diffuse light of a clouded sky for five and a half hours, air being passed over it at the rate of nearly 150 litres per hour. The content of the air in carbon dioxide as it entered the apparatus was 2·80 parts per 10,000, and this was reduced to 1·74 parts per 10,000 during its passage over the leaf. This corresponds to a total absorption of 139·95 c.c. of carbon dioxide, or to an intake of 412 c.c. per square metre per hour. If we assume that the average composition of the carbohydrates formed is that of a $C_6H_{12}O_6$ sugar, the above amount of carbon dioxide corresponds to the formation of 0·55 gram of carbohydrate per square metre per hour. But we must bear in mind that the average tension of the carbon dioxide in the leaf case was only equal to 1·93 parts per 10,000—that is, only about seven-tenths of its tension in the normal air. A correction has therefore to be made if we wish to know how much the leaf would have taken in, under similar conditions of insolation, if it had been bathed with a current of air of sufficient rapidity to practically keep the amount of carbon dioxide constant at its normal amount of 2·8 per 10,000. We shall see later on that, well within the limits of this experiment, the intake is proportional to the tension, so that applying this correction we may conclude that under identical conditions of insolation and temperature this leaf would have taken in an amount of carbon dioxide from the free air at a rate sufficient to produce 0·8 gram of carbohydrate per square metre per hour. This is almost exactly equal to the assimilation rate of the sunflower which I deduced in 1892 from the indirect process of weighing equal areas of the leaf lamina before and after insolation, and it also agrees fairly well with some of Sachs's original experiments of a similar nature.

In another experiment made with the leaf of *Catalpa bignonioides* in full sunlight the amount of carbon dioxide in the air passing over the leaf fell from 2·80 to 1·79 parts per 10,000, the total hourly intake for the square metre being 344·8 c.c. When this is corrected for tension it corresponds to an assimilation in free air of 0·55 gram of carbohydrate per square metre per hour.

An increase in the intensity of the daylight, as might be expected, influences to some extent the rate of intake of atmospheric carbon dioxide; but providing the illumination has reached a certain minimum amount, a further increase in the radiant energy incident on the leaf does not result in anything like a proportional amount of assimilation. We have found, for instance, that the rate of assimilation of a sunflower leaf, exposed to the clear northern sky on a warm summer's day, was about one-half of what it was when the leaf was turned round so as to receive the direct rays of the sun almost normal to its surface. Now in this latter case the actual radiant energy received by the leaf was at least twelve times greater than was received from the northern sky, but the assimilation was only doubled.

These differences in the effect of great variation of illumination become still less marked when we use air which has been artificially enriched with carbon dioxide. In one instance of this kind, for example, we found the assimilation in the full diffuse light of the northern sky to be 87 per cent. of what it was in direct sunshine.

This brings me to another interesting point on which I have already touched slightly—the enormous influence which slight changes in the carbon dioxide content of the air exert on the rate of its ingress into the assimilating leaf.

With a constant illumination, either in direct sunlight or diffuse light, the assimilatory process responds to the least variation in the carbon dioxide, and within certain limits, not yet clearly defined, the intake of that gas into the leaf follows the same rule as the one which holds good with regard to the absorption of carbon dioxide by a freely exposed surface of a solution of caustic alkali; that is to say, from air containing small but variable quantities of carbon dioxide *the intake is directly proportional to the tension of that gas.*

A single experiment will be sufficient to illustrate this.

A large sunflower leaf, still attached to the plant, and exposed to a clear northern sky, gave an assimilation rate equal to 0·331 gram of carbohydrate per square metre per hour, when air was passed containing an average amount of 2·22 parts of carbon dioxide per 10,000. When the experiment was repeated under similar conditions of illumination, but with air containing 14·82 parts of CO_2 per 10,000, the intake corresponded to an hourly formation of 2·409 grams of carbohydrate per square metre. The ratio of the tensions of the carbon dioxide in the two experiments is 1 to 6·7, and the assimilatory ratio is 1 to 7·2, so that the increased assimilation is practically proportional to the increase in tension of the carbon dioxide.

Since an increase of carbon dioxide in the atmosphere surrounding a leaf is followed by increased assimilation even in diffuse daylight, it is clear that, under all ordinary conditions of illumination, the rays of the right degree of refrangibility for producing decomposition of carbon dioxide are largely in excess of the power of the leaf to utilise them. Under natural conditions this excess of radiant energy of the right wave-length must, from the point of view of the assimilatory process, be wasted, owing to the limitation imposed by the high degree of dilution of atmospheric carbon dioxide. But although the actual manufacture of new material within the leaf lamina is so largely influenced by small variations in the carbon dioxide of the air, we are not justified in concluding that the plant *as a whole* will necessarily respond to such changes in atmospheric environment, since the complex physiological changes involved in metabolism and growth may have become so intimately correlated that the perfect working of the mechanism of the entire plant may now only be possible in an atmosphere containing about three parts of carbon dioxide in 10,000.

We have commenced a series of experiments which will, I hope, throw considerable light on this point, but the work is not at present in a sufficiently advanced state for me to make more than a passing allusion to it.

The penetration of the highly diluted carbon dioxide of the atmosphere into the interior air-spaces of the leaf on its way to the active centres of assimilation must, in the first instance, be a purely physical process, and no explanation of this can be accepted which does not conform to the physical properties of the gases involved.

Since there is no mechanism in the leaf capable of producing an ebb and flow of gases within the air-spaces of the mesophyll in any way comparable with the movements of the tidal air in the lungs of animals, and since also the arrangement of the stomatic openings is such as to effect a rapid equalisation of pressure within and without the leaf, we must search for the cause of the gaseous exchange, not in any mass movement, but in some form of diffusion. This may take place in the form of *open diffusion* through the minute stomatic apertures, which are in communication both with the outer air and the intercellular spaces, or the gaseous exchange may take place through the cuticle and epidermis by a process of *gaseous osmosis*, similar to that which Graham investigated in connection with certain colloid septa.

For many years there has been much controversy as to which form of gaseous diffusion is the more active in producing the natural interchanges of gases in the leaf. The present occasion is not one in which full justice can be done to the large amount of experimental work which has from time to time been carried out in this direction. Up to comparatively recently the theory of cuticular osmosis has been the one which has been more commonly accepted, free diffusion through the open stomata being considered quite subsidiary. In 1895, however, Mr. F. F. Blackman brought forward two remarkable papers which opened up an entirely new aspect of the subject. After showing the fallacy underlying certain experiments of Boussingault, which had been generally supposed to prove the osmotic theory of exchange, Mr. Blackman gave the results of his own experiments with a new and beautifully constructed apparatus, which enabled him to measure very minute quantities of carbon dioxide given off from small areas of the upper and under sides of a respiring leaf, and also to determine the relative intake of carbon dioxide by the two surfaces during assimilation in air artificially charged with that gas. The conclusions drawn are that respiratory egress, and assimilatory ingress of carbon dioxide, do not occur in the upper side of a leaf if this is devoid of stomatic openings, and that when these openings exist on both the upper and under sides the gaseous exchanges of both physiological processes are directly proportional to the number of stomata on equal areas; hence in all probability the exchanges take place only through the stomata.[1]

These observations of Mr. Blackman are of such far-reaching importance, and lead, as we shall see presently, to such remarkable conclusions with regard to the rate of diffusion of atmospheric carbon dioxide, that we felt constrained to inquire into the matter further, and for this purpose we employed a modified form of the apparatus which we have used throughout our work on assimilation. This was so

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[1] There is one important fact to be borne in mind when considering how far these observations exclude the possibility of cuticular osmosis. In the many leaves we have examined, Mr. Escombe and I have found that the occurrence of stomata on the upper surface of the leaf is always correlated with a much less dense palisade parenchyma. The cuticle and epidermis under these conditions are in a much more favourable state to allow carbon dioxide to pass into the leaf by osmosis than when the closely packed palisade cells abut against the epidermis, as they do when this is imperforate.

arranged that a current of ordinary air could be passed, just as in Mr. Blackman's experiments, over the upper and lower surface of a leaf separately, the increase or decrease in the carbon dioxide content of the air being determined by absorption and titration in the manner I have already alluded to.

In this way we were able to employ comparatively large leaf areas, and to continue an experiment for several hours, so that we had relatively large amounts of carbon dioxide to deal with, and the ratios of gaseous exchange of the two sides of the leaf could consequently be determined with considerable accuracy.

Our results, on the whole, are decidedly confirmatory of Mr. Blackman's observations. The side of a leaf which is devoid of stomatic openings certainly neither allows any carbon dioxide to escape during respiration, nor does it permit the ingress of that gas when the conditions are favourable for assimilation. On the other hand, when stomata exist on both the upper and under sides of a leaf gaseous exchanges take place through both surfaces, and, as a rule, in some sor of rough proportion to the distribution of the openings. There is, however, under strong illumination, a greater intake of carbon dioxide through the upper surface than would be expected from a mere consideration of the ratio of distribution of the stomata.[1] Nevertheless, the general connection between gaseous exchange and distribution of stomata is so well brought out that we must regard it as highly probable that these minute openings are the true paths by which the carbon dioxide enters and leaves the leaf.

We must now look at certain physical consequences which proceed from this assumption, and see how far they can be justified by the known or ascertainable properties of carbon dioxide at very low tensions.

The leaf of *Catalpa bignonioides* is hypostomatic, and therefore takes in carbon dioxide only by its lower surface. Under favourable conditions it is quite possible, during assimilation, to obtain an intake of atmospheric carbon dioxide into this leaf at the rate of 700 c.c. per square metre per hour (measured at 0° and 760 mm.), corresponding to an average linear velocity of the carbon dioxide molecules of 3·8 *centimetres per minute,* supposing the intake to be distributed evenly over the whole of the lower leaf surface. This velocity is almost exactly one-half of that at which carbon dioxide will enter a freely exposed surface of a solution of caustic alkali. But if the intake of the gas is confined to the stomatic openings of the leaf, its velocity of ingress must be very much greater than this.

We have carefully determined the number of stomata occurring on a given area of this particular leaf, and also the dimensions of the openings, and find that the total area of the openings, supposing them to be dilated to the fullest possible extent, amounts to just under *one per cent.* of the leaf surface. It follows from this that the average velocity of the atmospheric carbon dioxide in passing through these openings must be 380 *centimetres per minute,* that is to say, just *fifty* times greater than into a freely exposed absorbent surface of alkali. In other words,

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[1] Granted that the stomata constitute the paths of gaseous exchange, it is clear that the amount of diffusion through them, other things being equal, must depend very largely on the extent to which they are opened. The delicate self-regulating apparatus which governs the size of the openings is so readily influenced, amongst other things, by differences of illumination, that *a priori* we should not expect the stomata on the upper surface of an insolated leaf to be in the same condition as those of the more shaded lower surface. This may very well account for the stomatic ratio of the two sides not being in closer correspondence with the assimilatory ratios, as found in most of our experiments carried out in bright sunlight. In light of lesser intensity there is always a closer correspondence of the two ratios.

There is also another possible explanation of the fact. Since we have good reason to believe that the principal part of the assimilatory work is carried on by the palisade parenchyma, which occurs in the upper side of the leaf, the tension of the carbon dioxide in the air spaces of that part of the mesophyll is probably less than it is in the spongy parenchyma. There will, therefore, be a higher 'diffusion gradient' between the carbon dioxide of the outer and inner air in the former case than in the latter, and this would certainly tend to a more rapid diffusion through the openings in the upper side of the leaf.

supposing every one of the stomatic openings of this leaf could be filled up with a solution of caustic alkali, the absorbent power of the leaf as a whole would only be $\frac{1}{50}$ of what it actually is when assimilating.

These are some of the consequences which flow from an acceptance of the hypothesis of stomatic exchange, and it appeared to be impossible to accept that hypothesis unreservedly without some collateral evidence that these comparatively high velocities of diffusion are physically possible when dealing with such low gradients of tension as must necessarily exist when the highest amount of carbon dioxide does not exceed ·03 per cent.

The well-known general law expressing the rate of the spontaneous intermixture of two gases when there is no intervening septum, was, as every one knows, established by Graham, and the more elaborate investigations of Loschmidt many years later served to confirm the general accuracy of this law, and to show that, within very narrow limits, the diffusion constant varies in different gases inversely as the square roots of their densities.

But a mere knowledge of the diffusion constants of air and carbon dioxide does not, as far as I can see, materially assist us in the particular case we have under consideration. In order to gain some idea of what is actually possible in the way of stomatic diffusion in an assimilating leaf, we must know something of the *actual rate* at which atmospheric carbon dioxide can be made to pass into a small chamber containing air at the outside tension, but in which the carbon dioxide is kept down almost to the vanishing point by some rapid process of absorption; and we must also determine the influence of varying the size of the aperture through which the diffusion takes place.

Our attempts to answer these questions experimentally have led us into a long investigation, which promises to be of wider interest than we had first imagined. I only propose to give on this occasion a general account of the results so far as they affect the physical question of the intake of carbon dioxide into the plant.

When a shallow vessel containing a solution of caustic alkali is completely covered, the air above the liquid is very speedily deprived of the whole of its carbon dioxide. If we now imagine a hole to be made in the cover of the vessel, carbon dioxide will enter the air-space by free diffusion, and its amount can be very accurately determined by subsequent titration in the manner I have previously referred to. The time occupied by the experiment and the dimensions of the aperture being known, we can express the results in actual amounts of carbon dioxide passing through unit area of aperture in unit of time; or, since the tension of that gas in the outer air is known, we can express the average rate of the carbon dioxide molecules across the aperture in terms of actual measurement, say centimetres per minute.

We have made a very large number of experiments of this kind, using, in the first instance, dishes of about 9 cm. in diameter, and varying the size of the holes in the cover, the air-space over the absorbent liquid being always the same.

The accompanying curve, fig. 1, illustrates the effect which a gradually decreasing orifice has on the rate of diffusion of atmospheric carbon dioxide under these conditions. The diameters of the orifice in millimetres are given on the abscissa line, and the rates of diffusion through equal areas of the apertures are taken as ordinates, the rate of absorption in the open dish under similar conditions being taken as unity.

It will be seen that in the first instance a gradual reduction of the diameter of the opening is accompanied by a very regular increase in the rate of passage of the carbon dioxide until a diameter of about 50 mm. is reached; that is to say, up to a point at which about two-thirds of the area of the dish is covered. A further progressive diminution in the size of the aperture makes comparatively little difference in the diffusion rate until we reach about 20 mm., beyond which the curve again begins to rise, increasing rapidly in steepness as the apertures become smaller.

The experiments with open dishes are too crude for a study of the influence of very small apertures, so for this part of our work we constructed a special form of apparatus which has enabled us to determine the relative rates of diffusion through orifices in thin metal plates ranging down to 1 mm. in diameter.

I have plotted the results of such a series of experiments (see fig. 2), showing the relative rates of diffusion of atmospheric carbon dioxide through equal areas of apertures between 20 mm. and 1 mm. in diameter, under constant conditions, and it will be noticed how very steep the curve becomes after diameters of 5 or 6 mm. are reached.

The speed at which the diffusion of atmospheric carbon dioxide takes place through unit area of an orifice of 1 mm. in diameter is just sixteen times as fast as it is through unit area of an aperture of 20 mm.; and since we know that the rate of passage in the latter case is two and a half times greater than the absorption rate of an equal area of a freely exposed surface of a solution of caustic alkali, we arrive at the conclusion that, under the particular conditions of our experiment, the diffusion rate through an aperture of 1 mm. is *forty times* greater than the rate of absorption of a free alkaline surface of equal area.

FIG. 1.

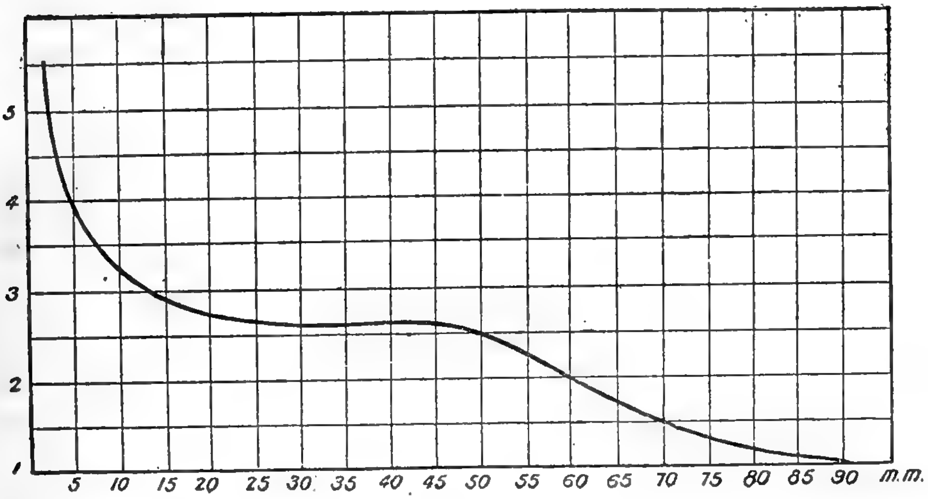
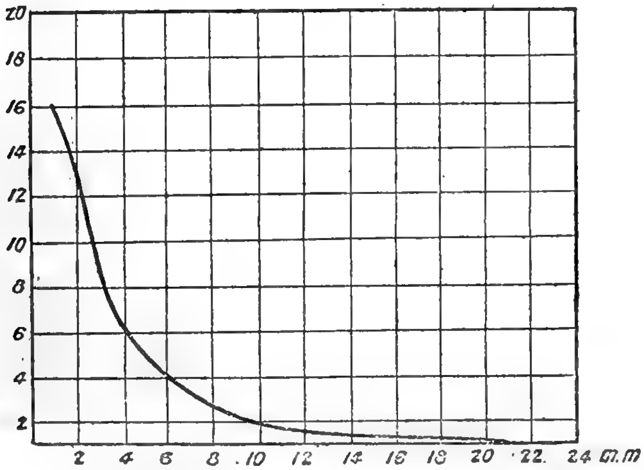


FIG. 2.



This corresponds to an actual average rate of passage of the molecules of the atmospheric carbon dioxide of about 266 centimetres per minute.

Now, we have already seen, in the case of a Catalpa leaf, that if the gaseous exchange during assimilation goes on only through the stomatic openings, we require a minimum velocity of something like 380 centimetres per minute, a velocity which we are sensibly approaching in our experiments with apertures of about 1 mm. in diameter. But the effective area of a stomatic opening of the Catalpa leaf is equal to that of a circle with a diameter of less than $\frac{1}{100}$ mm., and since our experiments indicate a very rapid increase in the velocity of diffusion as the aperture is diminished, it is clear that no difficulty, as regards the physics of the question, can be raised against the idea that atmospheric carbon dioxide reaches the active centres of assimilation by a process of free diffusion through the leaf stomata.

One of the most interesting problems connected with plant assimilation relates to the efficiency of a green leaf as an absorber and transformer of the radiant energy incident upon it.

It is already well known that the actual amount of energy stored up in the products of assimilation bears a very small proportion to the total amount reaching the leaf: in other words, the leaf, regarded from a thermo-dynamic point of view, is a machine with a very low 'economic coefficient.' We require, however, to know much more than this, and to ascertain, amongst other things, how the efficiency of the machine varies under different conditions of insolation, and in atmospheres containing varying amounts of carbon dioxide.

The measure of the two principal forms of work done within the leaf, the vaporisation of the transpiration water on the one hand, and the reduction of carbon dioxide and water to the form of carbohydrates on the other, can be ascertained by modifying our experiments in such a manner as to allow the transpiration water to be determined, as well as the intake of carbon dioxide.

For the actual measurement of the total energy incident on the leaf under various conditions we are now using one of Professor Callendar's recording radiometers of specially delicate construction, which will be ultimately calibrated in calories. This instrument gives promise of excellent results, but up to the present time the work we have done with it is not sufficiently advanced for me to describe. We may, however, obtain a very fair idea of the variation in the efficiency of a leaf from one or two examples in which the amount of incident energy was deduced from other considerations.

In the case of a sunflower leaf exposed to the strong sunlight of a brilliant day in August the average amount of radiant energy falling on the leaf during the five hours occupied by the experiment was estimated at 600,000 calories per square metre per hour. The average hourly transpiration of water during that time was at the rate of 275 c.c. per square metre, and the assimilated carbohydrate, estimated by the intake of carbon dioxide, was at the rate of 0·8 gram per square metre per hour.

The vaporisation of 275 c.c. of water must have required the expenditure of 166,800 calories, and the endothermic production of 0·8 gram of carbohydrate (taking the heat of combustion at 4,000 gram calories) corresponds to the absorption of 3,200 calories. Thus, as the final result under these particular conditions of experiment, we find that the leaf has absorbed and converted into internal work about 28 per cent. of the total radiant energy incident on it, 27·5 per cent. being used up in the vaporisation of water, and only *one-half per cent.* in the actual work of assimilation.

In strong diffuse light, such as that from a northern sky on a clear summer's day, the leaf has a higher 'economic coefficient,' using that term in relation to the permanent storage of energy in the assimilatory products. In one instance of this kind in which the total energy received by the leaf was approximately 60,000 calories per square metre per hour, it was found that 96 c.c. of water were evaporated and 0·41 gram of carbohydrate was formed for the same area and time. This indicates an absorption and utilisation by the leaf of something like 95 per cent. of the incident energy, of which 2·7 per cent. has been made use of for actual work of assimilation as against 0·5 per cent. in brilliant sunshine.[1]

From what I have said previously about the effect of increased tension of carbon dioxide on the rate of assimilation, it must follow that the 'efficiency' of a leaf as regards the permanent storage of energy must, *cæteris paribus*, be increased when small additions of that gas are made to the surrounding air.

In one such instance, in which the air had been enriched with carbon dioxide to the extent of about five and a half times the normal amount, it was estimated that the 'efficiency' of the leaf for bright sunshine was raised from 0·5 to 2·0 per cent.

Up to the present we have been regarding the efficiency of the assimilatory mechanism of a plant in reference to the *total* energy of all grades which falls upon the leaf. It is of course well known that the power of decomposing carbon dioxide is limited to rays of a certain refrangibility, and the researches of Timiriazeff, Engelmann, and others leave little room to doubt that the rays of the spectrum which are instrumental in producing the reaction in the chloroplastids have a distinct relation to the absorption bands of the leaf-chlorophyll. By far the greater amount of the assimilatory work, probably more than 90 per cent. of it, is effected by the rays which correspond to the principal absorption band in the red, lying between wave lengths 6,500 and 6,975.[2] If, therefore, we express the distribution of energy in a normal solar spectrum in the form of a curve, we have the means of approximately determining the *maximum theoretical efficiency* of a green leaf, that is to say, the maximum amount of assimilatory work which could be produced, supposing the conditions so favourable as to admit of the whole of the energy corresponding to this absorption band being stored up within the leaf.

It is not without interest to get an approximate idea of this theoretical maximum.

For this purpose I have here reproduced a curve given by Professor S. P. Langley, representing the distribution of energy at the sea-level in the normal spectrum of a vertical sun shining in a clear sky. The total amount of incident energy represented by the whole area of the curve is 1·7 calories per square centimetre per minute, or 1,020,000 calories per square metre per hour.

I have drawn a thick black vertical band in the red end of the spectrum corresponding in position and breadth with the principal absorption band of chlorophyll as seen in a green leaf. By integration it may be shown that the area of this part of the curve is about 6·5 per cent. of that of the whole curve, so that this value represents something like the theoretical maximum efficiency of a leaf in bright vertical sunshine, supposing the conditions could be made so favourable as to

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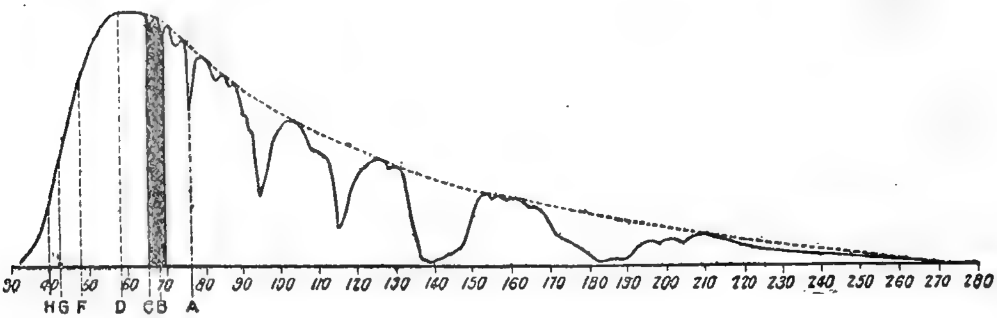
[1] The principal factor which determines the amount of transpiration in a plant must be the amount of radiation falling on it. It is essential that the water-bearing mechanism should be able to keep up a good supply of water to the leaf lamina in order to prevent the temperature rising to a dangerously high point. This 'safety valve' function of the transpiration current is not always sufficiently borne in mind, and we are too apt to think that the plant requires these enormous amounts of water in order to supply itself with the requisite mineral salts. The absolute necessity for the supply as a dissipator of energy will become evident by taking one or two facts into consideration. A square metre of the lamina of the leaf of a sunflower weighs about 250 grams, and its specific heat is about 0·9. We have seen that the hourly transpiration in bright sunshine may be as much as 275 c.c. per square metre, requiring the expenditure of 162,800 calories, and it therefore follows that, if the loss of water were stopped, the temperature of the leaf would rise at the rate of more than 12° C. *per minute*. In making our experiments in glazed cases it has sometimes been very interesting to watch the result of any accidental stoppage of the water-current in the leaf-stalk, and the almost instantaneous effect this has in destroying the leaf when the insolation is of high intensity.

[2] These limits are those of the band as measured by passing sunlight through the leaf itself. In an alcoholic solution of chlorophyll the band lies between λ 6,400 and λ 6,850. I must here express my thanks to Mr. Charles A. Schunck for having kindly undertaken to make these measurements for me.

result in a complete filtering-out and utilisation of the whole of the rays of the right period for producing decomposition of carbon dioxide.

FIG. 3.



This maximum efficiency expressed in calories per square metre per hour is 66,300, corresponding to the heat of formation of about 16·5 grams of carbohydrate. Under the most favourable conditions we have employed up to the present we have not obtained a larger production than about 3·0 grams of carbohydrate per square metre per hour, or about 18 per cent. of the theoretical maximum; but this was in air containing only 16·4 parts of carbon dioxide per 10,000, which must be very far below the true optimum amount.

The brilliant discoveries of recent years on the constitution and synthesis of the carbohydrates have not brought us sensibly nearer to an explanation of the first processes of the reduction of carbon dioxide in the living plant. The hypothesis of Baeyer still occupies the position it did when it was first put forward nearly thirty years ago, although it has, it is true, received a certain amount of support from the observations of Bokorny, who found that formaldehyde can, under certain conditions, contribute to the building up of carbohydrates in the chloroplasts.

The changes which go on in the living cell are so rapid, and are of such a complex kind, that there seems little or no hope of ascertaining the nature of the first steps in the process unless we can artificially induce them under much simpler conditions.

The analogy which exists between the action of chlorophyll in the living plant and that of a *chromatic sensitiser* in a photographic plate, was, I believe, first pointed out by Captain Abney, and was more fully elaborated by Timiriazeff, who was inclined to regard chlorophyll as the sensitiser *par excellence,* since it absorbs and utilises for the assimilatory process the radiations corresponding approximately to the point of maximum energy in the normal spectrum. The view which Timiriazeff has put forward, that there is a mere physical transference of vibrations of the right period from the absorbing chlorophyll to the reacting carbon dioxide and water, is, I think, far too simple an explanation of the facts. Chromatic sensitisers have been shown to act by reason of their antecedent decomposition and not by direct transference of energy, and the same probably holds good with regard to chlorophyll, which is also decomposed by the rays which it absorbs. We must probably seek for the first and simplest stages of the assimilatory process in the interaction of the reduced constituents of the chlorophyll and the elements of carbon dioxide and water, the combinations so formed being again split up in another direction by access of energy from without.

The failure of all attempts to produce such a reaction under artificial conditions is, I think, to be accounted for by the neglect of one very important factor. We are dealing with a reaction of a highly endothermic nature, which is probably also highly *reversible,* and on this account we cannot expect any sensible accumulation of the products of change unless we employ some means for removing them from the sphere of action as fast as they are formed.

In the plant this removal is provided for by the living elements of the cell, by the chloroplast, assisted no doubt by the whole of the cytoplasm. We have here, in fact, the analogue of the *chemical sensitisers* of a photographic plate, which act as halogen absorbers and so permit a sensible accumulation of effect on the silver salts.

When we have succeeded in finding some simple chemical means of fixing the initial products of the reduction of carbon dioxide, then, and then only, may we hopefully look forward to reproducing in the laboratory the first stages of the great synthetic process of Nature on which the continuance of all life depends.

The following Paper and Reports were read:—

1. *The Solidification of Hydrogen. By* Professor J. Dewar, *F.R.S.*

2. *Report on a New Series of Wave-length Tables of the Spectra of the Elements.* See Reports, p. 257.

3. *Interim Report on the Continuation of the Bibliography of Spectroscopy.* See Reports, p. 256.

FRIDAY, SEPTEMBER 15.

The following Reports and Papers were read:—

1. *Report on the Relation between the Absorption Spectra and Chemical Constitution of Organic Bodies.* See Reports, p. 316.

2. *Report on Isomeric Naphthalene Derivatives.* See Reports, p. 362.

3. *A Discussion on the Laws of Substitution, especially in Benzenoid Compounds. Opened by* Professor H. E. Armstrong, *F.R.S.*

1. In considering the formation of substitution derivatives from benzene and allied compounds, it is necessary to account for the very distinct behaviour of substances containing compound acid radicles (*i.e.* radicles which in combination with OH form acids), which yield a large proportion of meta- derivative, whilst compounds containing other radicles yield ortho- and para-, and little if any meta- derivative. But no absolute distinction can be drawn, as much depends on the conditions under which the change takes place, a considerable proportion of meta- derivative being obtained, for example, from aniline by nitrating it in presence of a large excess of sulphuric acid.

2. In the case of an amino- compound, it is possible to trace the action through a series of stages. Thus in sulphonating aniline, the sulphate first undergoes conversion into sulphamic acid, and this is converted into either ortho- or para-sulphonic acid, according to the conditions under which it is placed.

3. The process involved in the passage of sulphamic into sulphonic acid may be regarded as one of *isomeric change—i.e.* it may be supposed that the SO_3H group wanders from one part of the molecule to another, without leaving the system and temporarily entering into some other form of combination.

In favour of this view is the fact that sulphonic acids are produced by the action of a sulphite on nitro- compounds under conditions which render the occurrence of independent sulphonation of the nucleus, to say the least, unlikely; it is scarcely possible to doubt that in such cases the sulphamate is an intermediate product, as phenylhydroxylamine is converted into phenylsulphamic acid by the action of sulphur dioxide (Bamberger).

4. The possibility of isomeric change occurring in such a case cannot be denied in view of the fact that secondary nitrosamines, for example, are converted into paranitrosamines by the action of acids, and of the many similar cases of change which have been brought to light in recent years by Bamberger, Hantzsch, and others.

In many such cases the change is so complete that it is impossible to believe that the radicle which wanders is first displaced from the molecule, and that the compound which is formed from it then enters into action with the molecule from which it was derived: for example, that in the case of the nitrosamines referred to the nitroso- group is split off in the form of nitrous acid, which then acts so as to form a para-nitroso-derivative; or, again, that when pariodo-orthonitrophenetol is formed on nitrating orthiodophenetol the iodine becomes separated from the molecule and then attacks it afresh.

Moreover, bearing in mind the extreme readiness with which change takes place, for example, in the case of the formation of parachloracetanilide from the compound PhNClAc, or of sulphanilic from phenylsulphamic acid, it is difficult to believe that the formation of the one compound is not a necessary stage in the formation of the other: the readiness with which the substituted benzenoid compound is obtained is so great that it is to be expected that both compounds would be formed together if they were independent products of the action of a single agent—just as, in fact, often happens in the case of para- and ortho- compounds.

5. It is very difficult to form any precise conception of the manner in which such 'isomeric changes' are brought about. Something more than a mere interchange of position of the radicles is involved in them: some agent intervenes; but the operation of the agent is easily overlooked, as only a minute quantity suffices in many cases, the action being 'fermentative' in character.

6. Very probably the peculiar structure of benzene and the tendency to pass from the centric to an ethenoid form and back again is the determining cause of the change; maybe the function of the transforming agent is to bring about the change from the centric to a highly unstable ethenoid form, and the radicles change places at the moment that the agent is extruded from the compound and the system relapses into the centric form. A rough parallel is afforded by the well-known game of chairs, in which chairs are provided for all but one of a number of players; at a given signal all rise up and join their seatless companions, and then at another signal all seek to obtain seats: at this moment players are somewhat guided in their choice of places by the desire of certain couples to sit together; eventually the seats are again all occupied, but the order of the occupants is different, and as before one remains out.

7. Only primary and secondary amines can furnish sulphamic acids, and their formation is necessarily impossible in the case of tertiary amines; but it can scarcely be doubted that these are converted in the first instance into a sulphonated ammonium compound. The formation of *o*- and *p*- dimethylanilinesulphonic acids from dimethylaniline oxide and sulphur dioxide cannot well be otherwise interpreted, and in fact is so formulated by Bamberger:

$$Me_2PhN(OH)_2 + SO_2 = Me_2PhN(OH).SO_3H.$$

8. Bamberger assumes that the formation of para-sulphonic acid from sulphamic acid is preceded by that of the ortho- acid, but in view of the stability of the ortho- acid this is improbable; it is to be expected that it would in a large measure persist under the conditions which, as a matter of fact, entail the production of only the para- acid. Thus, if acetanilide be carefully sulphamated, the product poured on to ice, and the solution then boiled, only sulphanilic acid is obtained; but if the solution of sulphamic acid in sulphuric acid be allowed to absorb water very gradually at a low temperature, a large proportion of ortho-acid is formed.

Apparently the ortho- acid is formed from the sulphamic acid if the sulpho-group be, as it were, let down gently; otherwise the para- acid is produced.

When the ortho- is converted into the para- acid by heating it with sulphuric acid, probably it is first hydrolysed, and sulphamic acid is then formed, and this in turn undergoes conversion into para- acid.

9. Whatever the changes involved in the production of ortho- and para- compounds, the nitrogen in amino- compounds clearly exercises both an attractive and a directive influence.

The nature, and more particularly the degree, of its influence depends, in a remarkable manner, on the nature of its immediate associates; hydrogen especially exercises an altogether peculiar influence on the course of substitution.

Nitrogen *per se* has little attractive or directive power, compounds such as azobenzene and diazobenzene bromide manifesting a singular inertness in presence of substituting agents; and it would seem that the more the influence of the hydrogen in amines is counteracted and the basic properties of the nitrogen neutralised, the more nearly do aminoid compounds generally approximate in their behaviour to simple azo- derivatives.

10. But not only does nitrogen cease to be attractive and directive when deprived of hydrogen and neutralised; it apparently even acquires inhibiting powers.

Thus dimethylanilinepara-sulphonic acid exchanges only a single atom of hydrogen for bromine, and the SO_3H group is displaced with difficulty by the further action of bromine. This behaviour is in striking contrast with that of sulphanilic acid, which is very readily converted into tribromaniline by the mere addition of bromine to its aqueous solution.

The effect of acid radicles is even more striking, and somewhat different in character from that exercised by alkyls: thus when a single molecular proportion of bromine is added to a solution of acetylsulphanilic acid, less than half the acid is converted into the monobrominated acid; a major proportion simply exchanges the sulphonic group for bromine. Benzoylsulphanilic acid in like manner yields a mixture of monobrominated acid and parabromobenzanilid.

The stability of the brominated acid from *di*methylanilinesulphonic acid is perhaps accounted for—on the assumption that the attack proceeds from the nitrogen atom—by the fact that it forms a relatively stable dibromide. In the case of the *mon*-acetylated acid, on the other hand, it may be supposed that the hydrogen in the amino- group is initially displaced, and that the bromine 'wanders out' from this position partly into the ortho- and partly into the para- position.

11. When the conditions under which meta- derivatives are formed from amines are considered, it is clear that they are such as to favour the neutralisation of the basic properties of the amines, and to prevent the displacement of aminoid hydrogen.

The nitration of aniline in presence of excess of sulphuric acid may be taken as an example. A major proportion of the molecules being present as sulphate, the access of nitric acid to the azo-radicle, and therefore to the system, is prevented: consequently no nitramine is formed, and a necessary stage in the formation of both *o*- and *p*-nitro- derivative is eliminated and their production prevented. On the other hand, as the action takes place at a low temperature, and nitric acid is present in its most concentrated form—perhaps, to some extent, as anhydride—the conditions are such as to favour the attack of the benzenoid portion of the molecule, but only in the meta- position, the ortho- and para- positions being in a measure protected, owing to the inhibitive influence exercised by the fully saturated azo-radicle.

Although the basic properties of aniline are much reduced by the introduction of acetyl, acetanilid is still sufficiently basic to be attractive of nitric acid, and it therefore undergoes conversion into nitramine, and subsequently into ortho- and para-nitro- derivative.

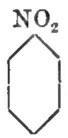
Benzanilid, being far less basic, is only very partially acted upon in this manner; the benzenoid portion of the molecule is therefore preferred for attack, and consequently a considerable number of molecules become meta-nitrated.

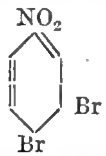
Dimethylaniline is converted entirely into para- acid when sulphonated by ordinary sulphuric acid at about 180°, or by chlorosulphonic acid; but when carefully sulphonated by fuming acid it yields a large proportion of meta- acid. Doubtless, in this latter case, the conditions correspond to those pictured in the case of benzanilid undergoing nitration. That the formation of meta- acid is a consequence of the sulphate undergoing sulphonation, and is not merely due to the use of the more powerful agent SO_3, clearly follows from the fact that so powerful an agent as SO_3HCl converts dimethylaniline only into para- acid.

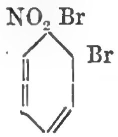
The behaviour of acetanilid and benzanilid towards fuming sulphuric acid is precisely similar to their behaviour towards nitric acid—the former gives only *o*- and *p*-acid; the latter a considerable proportion of meta- acid. Probably both are initially converted into sulphamic acid, but the acid formed from the latter being less prone to undergo isomeric change it becomes in part meta-sulphonated.

12. In the case of compounds other than amines which afford meta- derivatives, it may be supposed that the radicle is both unattractive and 'ortho-para inhibitive,' and that consequently opportunity is given for the attack to become concentrated upon the benzenoid portion of the molecule in the meta- position.

As in such cases some proportion of *o*- and *p*- compound is usually obtained, it is necessary to assume—if the radicle be regarded as altogether unattractive—that the benzenoid portion of the molecule is open to attack at several points—indeed, this may be more or less true of all compounds. Thus it may be supposed that when nitrobenzene is brominated two compounds are initially formed, thus:







The 1 : 2 compound being a very minor product, but little ortho- compound is eventually obtained, and owing to the unattractive and inhibitive influence exercised by the NO_2 group, bromine is chiefly separated from the para- position of the 3 : 4 compound; consequently but little para- derivative is formed.

13. The phenols in many ways closely resemble the amines in their behaviour towards substituting agents. The hydrogen in association with the oxygen clearly plays an important part; in fact, the extreme activity of phenols is probably, in large measure, due to the presence of hydrogen in the extra-benzenoid radicle, as in the case of the amines, but the part which the hydrogen plays cannot at present be at all clearly made out.

By displacing the hydroxylic hydrogen by alkyls, effects are produced very similar to those observed in the case of amines. Thus phenol-parasulphonic acid, like sulphanilic acid, at once exchanges two atoms of hydrogen for bromine, and then quite readily exchanges the SO_3H group for bromine. But the acids obtained by introducing methyl, ethyl, or benzyl in place of the hydroxylic hydrogen yield only monobrominated acids, which on further treatment exchange the SO_3H group for bromine; and this action takes place only partially, as a large proportion of the acid directly exchanges the SO_3H group for bromine, a monobrominated compound being formed, just as in the case of acetyl- and benzoyl-sulphanilic acid.

Benzoyl appears to exercise a very remarkable inhibitive effect, as preliminary experiments show that benzoylated phenolparasulphonic acid remains unattacked by bromine under conditions which involve the conversion of the unbenzoylated acid into tribromo-phenol.

It may therefore be supposed that oxygen in phenols, being possessed of residual affinity, exercises an influence on substitution similar to that which nitrogen exercises in amines; and as it has no basic qualities, it is difficult, if not impossible, to deprive it of its activity, and consequently of its para-ortho-orienting power: hence it is that phenols do not yield meta- derivatives. Should conditions be discovered which will make it possible to hold the activity of oxygen in check, it will probably be found possible to directly prepare meta-phenolic derivatives.

14. Sulphur, whilst resembling oxygen, apparently has a still stronger inhibitive

influence. Thus phenyl ethyl thio-ether may be para-sulphonated without difficulty, but para-bromophenyl ethyl thio-ether is not sulphonated either by sulphuric or by chlorosulphonic acid, although the corresponding oxygen compound is very readily acted on.

15. The behaviour of halogen derivatives may be correlated with that of phenols, or rather with that of their ethers, especially in view of the existence of compounds such as phenyl iodosochloride $PhICl_2$. On the assumption that the residual affinity of iodine was satisfied in this compound, it appeared not improbable that it might furnish a meta-sulphonic acid. It is sulphonated without difficulty, but the product is highly chlorinated, and its nature has yet to be ascertained.

The hydrocarbons homologous with benzene are the most difficult group to discuss. The paraffinyl radicle certainly exercises a directive effect; whether it is in any way attractive is open to question. Bearing in mind the inactivity of the paraffins, it is difficult to believe that the radicles derived from them are possessed of sufficient activity to account for the striking readiness with which the homologues of benzene are acted upon in comparison with benzene. The introduction of hydrogen radicles seems, in fact, to produce a fundamental modification in the centric complex, the behaviour of hydrocarbons such as mesitylene being ethenoid rather than benzenoid; and from this point of view it seems probable that the derivatives of benzenoid hydrocarbons are formed more in accordance with the process formulated in paragraph 12.

16. The fact that when the paraffinyl radicle undergoes chlorination or oxidation, for example, the attack, as a rule, takes place at the point of attachment, is proof that, if not itself attractive, it immediately adjoins the centre of attraction; and it is possible that initially some change takes place in which both radicles are involved.

4. *The Relative Orienting Effect of Chlorine and Bromine.*

By HENRY E. ARMSTRONG, *F.R.S.*

The object of this note was to correct a statement made by Armstrong and Briggs[1] that when parachlorobromobenzene is sulphonated only a single acid, viz. 1:4 chlorobromobenzene- 2 sulphonic acid, is produced, not, as was to be expected, a mixture of this with the isomeric, 1 : 4 chlorobromobenzene-, 3 sulphonic acid.

Further investigation has shown that the product is actually a mixture of the two acids. The mistake arose from the fact that corresponding derivatives of the two acids are isomorphous.

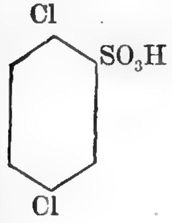
Experiments made by Dr. E. C. Jee show that metachlorobromobenzene is, in like manner, converted into a mixture of isomeric acids on sulphonation.

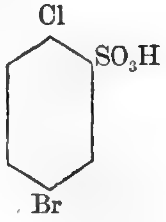
5. *Isomorphism in Benzenesulphonic Derivatives.*

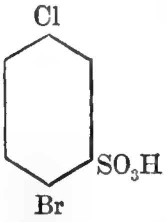
By HENRY E. ARMSTRONG, *F.R.S.*

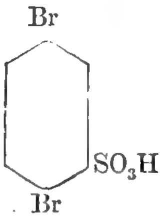
In the course of the work referred to in the previous note, it became necessary to study the crystallography of the isomeric parachlorobromobenzene sulphonic acids, and ultimately it was determined to compare with these the analogous acids derived from dichloro- and dibromo-benzene.

The sulphonic chlorides and bromides were chosen for examination. Four acids are obtainable, viz.:


I.


II.


III.


IV.

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[1] *Chem. Soc. Proceedings*, 1892, p. 40.

As each of these yields a chloride and a bromide, a series of eight closely allied compounds can be obtained. The chloride of I. and both chloride and bromide of III. have not been prepared in a form fit for measurement, but the remaining five members of the series have been fully measured by Mr. W. T. Gidden, and proved to be isomorphous.

The 1 : 3 diderivatives of benzene containing halogens should yield three similar sets of allied sulphonic derivatives, viz. a 1 : 3 : 4, a 1 : 3 : 5, and a 1 : 3 : 2 set; and the 1 : 2 diderivatives should yield two such sets, a 1 : 2 : 4 and a 1 : 2 : 3 series. It is proposed to prepare all these in order to determine their morphological relationship.

The 1 : 3 : 4 series has already been measured by Dr. E. C. Jee, who has discovered that they form a remarkable *isotrimorphous* group. No relationship is apparent between this meta- series and the para- series.

6. *Oxidation in the Presence of Iron.*
By HENRY J. HORSTMAN FENTON, *M.A.*, *F.R.S.*

The remarkable influence which iron exerts upon the oxidation of certain organic substances was first pointed out by the author in 1876 in the instance of tartaric acid. This observation has since been fully investigated, and has led to an extensive study of the behaviour of various other substances under similar conditions of oxidation and of the resulting products.[1]

The peculiar advantage of the method consists in the fact that the extent of oxidation may be regulated, and consequently that it is often possible to obtain products of limited oxidation which cannot be prepared in any other way.

Hydrogen peroxide is the most efficient oxidising agent for the purpose, although others may sometimes be substituted. The iron, which is essential to the process, must in almost all cases be present in the ferrous condition; its proportion, however, bears little if any relation to the yield.

With regard to the general nature of the oxidation products, it may be observed that in the case of tartaric acid the change may be represented as a removal of the two non-hydroxylic hydrogen atoms; in the polyhydric alcohols, the (primary) CH_2OH groups are attacked in preference to the (secondary) CHOH groups, whilst in certain carbohydrates the CHOH group adjacent to an aldehyde group appears to be oxidised; the aldehyde group itself is remarkably resistant. In the benzenoid compounds H is usually replaced by OH, and a similar behaviour would appear to obtain in the furfurane derivatives. In all cases it might be assumed that the initial result is the replacement of H by OH, tartaric acid, for example, being supposed to give, in the first instance, trioxysuccinic acid.

The part played by the iron in these changes is still a matter for discussion. In a previous note[2] a provisional theory was proposed, in which it was suggested that the ferrous iron first replaces non-hydroxylic hydrogen and is subsequently oxidised; and it is certainly remarkable that in the case of every substance found to be sensitive to this reaction, non-hydroxylic hydrogen is present, associated in almost every case with alcoholic hydroxyl.

With a view of throwing further light upon the general nature of this oxidation process, the author is at present studying a variety of substances of typical constitution; and the following is a brief account of results which have recently been obtained with certain acids:—

Tartronic acid gives a large yield of mesoxalic acid. The hydrazone of the latter acid separates at once on the addition of phenylhydrazine hydrochloride, and it is probable that the process may be found advantageous for the preparation of

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[1] Fenton, *Chem. News*, 1876, xxxiii. 190; 1881, xliii. 110: *Trans. Chem. Soc.* 1894, 899; 1895, 48 and 774; 1896, 546; 1897, 375; 1898, 71 and 472, &c. Fenton and Jackson, 1899, 1 and 575: Cross and Bevan, 1898, 463; 1899, 747: Morrell and Crofts, 1899, 786: Martinon, *Bull. Soc. Chim.* 1885, ii. 23, 196: Ruff, *Ber.* 1898, 1573; 1899, 550.

[2] *Proc. Chem. Soc.* 1898.

the free acid, especially as the production of tartronic acid has been much simplified.[1] This transformation has not hitherto been effected, although the converse operation—the reduction of mesoxalic to tartronic acid—is well known.

Lactic acid, in a similar manner, yields pyruvic acid, but the operation requires especial care.

Glyceric acid, when oxidised in the same way, produces a substance having strong reducing properties, and which gives an intense violet colour with ferric salts in the presence of alkalis. On treatment with phenylhydrazine acetate an osazone is produced which crystallises in golden needles, melts at 203°, and gives a beautifully crystalline sodium salt and pyrazolon. It appears to coincide in every way with the osazone of oxypyruvic acid $C_{15}H_{14}N_4O_2$, which was obtained by Nastvogel from dibrompyruvic acid,[2] and by W. Will from the product of the action of soda on collodion wool.[3] The substance produced in the present case may therefore be (1) oxypyruvic acid, (2) the semi-aldehyde of tartronic acid or (3) the semi-aldehyde of mesoxalic acid.

Malic acid.—Judging from previous results, it was to be expected that this substance would yield oxal-acetic acid, and it is possible that such may be the result in the first instance, since, on treatment of the product with sulphuric acid, a certain amount of pyruvic acid is obtained. If, on the other hand, the product be treated with phenylhydrazine acetate, a substance is obtained which crystallises in golden prisms, melts at 216°–218°, and gives crystalline sodium and potassium salts.

The above-mentioned products are being fully investigated, and the results will shortly be published.

The author wishes to express his thanks to Mr. H. O. Jones, B.Sc., for the valuable assistance which he is giving in this portion of the work.

7. *Condensation of Glycollic Aldehyde.* *By* HENRY J. HORSTMAN FENTON, *M.A., F.R.S., and* HENRY JACKSON, *B.A., B.Sc.*

It has been pointed out by one of the authors in previous communications that tartaric acid, when oxidised in presence of a small quantity of ferrous iron, gives rise to dioxymaleic acid, $C_4H_4O_6$; and that this acid readily decomposes in aqueous solution, giving glycollic aldehyde, $C_2H_4O_2$. This aldehyde has recently been isolated by the present authors in a crystalline state.[4] It was further shown[5] that glycollic aldehyde, when heated to 100°–105° under reduced pressure, undergoes polymerisation, giving rise to a true hexose, $C_6H_{12}O_6$. The condensation effected in this way is not complete, and the resulting product has to be purified from the unaltered glycollic aldehyde by treatment with absolute alcohol; the yield of the sugar is consequently small, so that further study of its nature was extremely difficult.

The authors have therefore sought to modify the method of production with a view to increasing the yield, and have studied the results of effecting the condensation (1) at higher temperatures; (2) under the influence of alkalis.

If the aldehyde be heated to about 130°–140° for a short time, a substance is obtained which dissolves easily in water, but is precipitated as a brownish-white powder on addition of alcohol; whereas at a temperature of about 160°–170° a brown spongy substance is formed, which is nearly insoluble in boiling water, and on analysis its composition is found to be approximately $C_6H_{10}O_5$.

When an aqueous solution of the aldehyde is mixed with a dilute (1 per cent.) solution of caustic soda, it begins to turn brown almost immediately. After standing for about twenty-four hours at the ordinary temperature (about 15°), the mixture no longer reduces Fehling's solution in the cold, nor answers Schiff's aldehyde reaction with magenta. The solution now gives with phenylhydrazine a precipitate consisting of clusters of bright yellow needles, which melt at 158° and

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[1] *Trans. Chem. Soc.* 1898, 72.

[2] *Annalen*, 248, 85.

[3] *Ber.* 1891, 400.

[4] *J. C. S. Trans.* 1899, p. 575.

[5] Fenton, *ibid.* 1897, p. 375.

have the composition of a hexosazone $C_{18}H_{22}N_4O_4$. The pure osazone is very soluble in ethylacetate, sparingly soluble in ether, benzene, and boiling water. The crystalline form, melting point, and behaviour towards solvents appear definitely to establish its identity with β acrosazone, which was obtained by Fischer and Tafel from the condensation product of 'glycerose' by alkalis.

When calcium hydroxide is employed in place of caustic soda, an exactly similar result is obtained. After removing the calcium from the solution by exact precipitation with oxalic acid and evaporating to small bulk at 40° under diminished pressure, it was dissolved in alcohol, filtered, and then precipitated with ether. The sugar was thus obtained in the form of white flocks which aggregate to a pasty solid on standing in a vacuum.

The properties and configuration of β acrose have not hitherto been studied, owing to the fact that it could not be obtained in quantity unaccompanied by other sugars; the authors hope, however, by the present method of preparation to obtain the sugar in quantity sufficient for a more complete study.

The formation of a true hexose, and a substance resembling starch and cellulose, from glycollic aldehyde, is of especial interest from its bearing on carbohydrate formation in plants. The remarkable part which a small quantity of ferrous *iron* plays as a carrier of *atmospheric oxygen* in presence of direct *sunlight* has already been pointed out:[1] in the absence of any of these three conditions, the oxidation does not take place. In plant metabolism these conditions coexist; this reaction may not only throw light upon the function of small quantities of iron existing in chlorophyll, but may explain the conversion of tartaric acid, which is so common in unripe fruits, to the sugars of the mature fruit.

8. *Some New Silicon Compounds.*

By Professor J. EMERSON REYNOLDS, *F.R.S.*

Some years ago the author communicated to the Section an account of a new silicon compound of the amidic class having the formula:

$$Si(NHPh)_4$$

obtained by complete interaction of silicon haloids with excess of aniline.

This well-defined crystalline substance when cautiously heated changes in two stages. In the first stage 1 mol. of aniline is evolved, and crystalline silicophenyl-guanidine results.

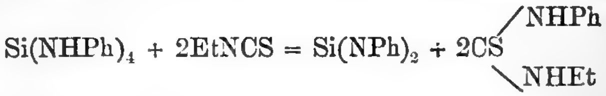
$$Si(NHPh)_4 = NH_2Ph + Si\begin{cases} NHPh \\ = NPh \\ NHPh \end{cases}$$

On further heating another aniline molecule is lost, and a di-imide is obtained which may also be regarded as diphenyl-silico-cyanimide; or the latter can be at once produced from the parent compound:

$$Si(NHPh)_4 = Si(NPh)_2 + 2NH_2Ph.$$

In the production of the di-imide, which is somewhat soluble in benzene, prolonged heating leads to molecular rearrangement, and a porcelain-like form of the di-imide results which is insoluble in benzene. Two modifications of silico-phenyl-di-imide exist, just as in the case of the analogous carbon compounds.

The readiness with which the tetra-amidic compound loses aniline by heat suggested the further experiments which were described to the Section, as it appeared that the following interaction with a mustard oil should take place:



$$Si(NHPh)_4 + 2EtNCS = Si(NPh)_2 + 2CS\begin{cases} NHPh \\ NHEt \end{cases}$$

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[1] Fenton, *Brit. Assoc. Report*, 1895; Fenton and Jackson, *Trans. Chem. Soc.* 1899, 1.

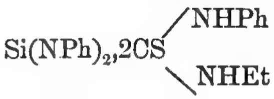
On mixing in the above proportions in benzene solution no apparent change took place even on prolonged heating, but the graduated addition of ligroin to the solution led to the separation of fine long crystals, which are very friable, of the compound $Si(NHPh)_4,2EtNCS$, and later of another addition compound in small plates which consisted of $Si(NHPh)_4,EtNCS$, but no trace of the ethyl-phenyl-urea.

The solvent benzene was then discarded and the requisite materials were heated in pressure tubes.

Up to 140° C. the addition compounds only were produced, but at 160° further change was obtained, and a yellowish fluid mass was produced, which remains a very viscid liquid at ordinary temperatures, and can be kept in this state for many months.

Benzene dissolves the viscid mass, which is reprecipitated in oily droplets, but no trace of the urea separated. On redissolving in benzene and adding a small proportion of alcohol to the liquid, decomposition was obtained, and crystals of the ethyl-phenyl-urea separated.

It is evident, then, that the primary interaction anticipated occurs at 160°, but that the urea formed at once unites with the silico-phenyl-di-imide to form:



$$Si(NPh)_2,2CS\begin{smallmatrix}\diagup NHPh\\ \diagdown NHEt\end{smallmatrix}$$

This tendency of the silicon amide to unite with urea is similar to that which I found the Si haloids to possess many years ago, and the very viscid liquid in the above instance is not unlike the compound $SiBr_4,8CSNH_2,NHC_3H_5$, which flows so slowly that nearly a month is required at ordinary temperatures for the liquid to descend from one end of a vertical tube to another.

9. *Report on recording the Results of the Chemical and Bacterial Examination of Water and Sewage.* See Reports, p. 255.

10. *Intermittent Bacterial Treatment of Raw Sewage in Coke-beds.*

By Professor FRANK CLOWES, *D.Sc.*

The above process as originally experimentally carried out by the London County Council was applied to the effluent from chemical treatment only. The process has now been applied to raw sewage, screened through coarse gratings. More recent experience of over twelve months' treatment in beds of varying depth has proved that when coke fragments of about the size of walnuts are used, the suspended fæcal matter wholly disappears, together with an average of about 50 per cent. of the dissolved organic matter. A further treatment in a second similar bed removes an additional 20 per cent. of the dissolved organic matter. It has been found sufficient to leave the sewage in contact with the coke for about three hours, and then to give the coke an exposure to the air in its interstices of about seven hours' duration.

The depth of the experimental coke-beds has varied from 4 to 13 feet in different experiments, and this variation has in no way affected the degree of purification effected.

On no occasion has either the coke or the effluent been foul, nor does the effluent become foul when it is allowed to stand in either open or closed vessels, provided that it is not sterilised after it has left the coke-bed.

The amount of sewage which can be treated by the coke-bed 13 feet in depth, and with two fillings per day, amounts to three and a half million gallons per acre. This amount, however, undergoes gradual reduction, owing to the accumulation in the filter of matter from the sewage which appears to consist almost wholly of cellulose. This matter is mainly the chaff derived from the horsedung of the roadways, and from the wear of the wooden paving-blocks of the streets. If the sandy detritus brought down by the sewage in storm weather is allowed to settle before the sewage flows upon the coke-beds, a second process of sedimentation removes the larger amount of cellulose matter, and of this latter sediment about 70 per cent. is combustible when the matter has been dried.

Hence it appears possible to carry on the solid fæcal matter to the coke-bed, and to deal with the sand and cellulose matters by sedimentation, the latter being subsequently disposed of by combustion.

The comparative bacteriological study of the raw sewage and of the effluent by Dr. Houston shows that practically no bacterial improvement is brought about by the treatment of the sewage in the coke-bed. The presence of bacteria in the effluent is, however, advantageous in securing its final purification.

The effluent has supported the life of fish, which were immersed in it, for several months. Their health suffered no appreciable deterioration; apparently they could live in it indefinitely.

That the coke-beds become fully aërated by the intermittent treatment is evident from the fact that after 70 hours' rest in an empty condition the air at the bottom of the 13-foot bed contained 14·7 per cent. of oxygen and only 0·8 per cent. of carbon dioxide.

11. *On the Place of Nitrates in the Biolysis of Sewage.* *By* W. SCOTT-MONCRIEFF.

SATURDAY, SEPTEMBER 16.

Joint Meeting with Section K.

The following Papers were read:—

1. *The Excretory Products of Plants.* *By* Professor HANRIOT.

2. A Discussion on Symbiotic Fermentation, opened by the reading of the following papers:—

Symbiosis. *By* Professor MARSHALL WARD, *F.R.S.*

Synopsis.

Origin of the idea and of the term. Differences between parasitism and symbiosis.

Lichens, previously regarded as autonomous plants, are shown to be dual organisms, a symbiosis of alga and fungus. Controversy regarding the lichen theory, and establishment of the latter by means of synthetic cultures.

Other cases of symbiosis known previous to 1880. Algæ in the stems of *Gunnera* and the roots of *Cycas*, in the thallus or fronds of *Anthoceras* and *Blasia*, *Azolla*, *Lemna*, &c.

Extension of the idea of symbiosis: insect fertilisation, epiphytes, &c.

Galls not necessarily due to insects, but may be due to the irritating action of fungi or bacteria. Phytocecidia of the Aleppo pine, &c.

Symbiosis in animals. Green infusoria, hydra, sponges, &c.

Mycorhiza, the roots of many humus plants curiously swollen and modified owing to the presence of fungi, which do not injure the plant, but link its roots to the decomposing leaves around. Explanation as an instance of symbiosis. Evidence partly anatomical and partly experimental.

'Budding' and 'grafting' are processes involving the establishment of a symbiosis.

The nodules on the roots of leguminous plants. Discovery and controversy as to their nature. They contain living bacteroids, which penetrate the root hairs and flourish in the living cells. Universality of these nodules on healthy roots. Hellriegel and Willfarth's cultures, and evidence as to the fixation of nitrogen. Laurent and Schloesing's proof that nitrogen is fixed from the air.

The leguminous nodules a case of symbiosis, comparable to galls.

Other instances not yet explained. Nodules on the roots of *Juncus, Myrica,* and other plants.

Symbiotic fermentations. All natural fermentations mixed. Pure cultures and the importance of synthetic cultures.

Kephir, the ginger-beer plant, and other instances of symbiotic ferments. Decomposition of cellulose. Nitrifying and denitrifying organisms. The direct alcoholic fermentation of starch by the simultaneous action of two fungi.

Return to the idea of symbiosis. Necessity of limiting the term. Antibiosis (antagonism). Metabiosis. Difficulty of distinguishing in given cases. Hypothetical considerations, and importance of further investigations.

Particular Cases.

The above may be accepted as affording general headings under which the subject of symbiosis might be treated.

For the purposes of this discussion, I proceed to consider some special cases, and limit myself—as requested to do—to certain aspects of symbiotic fermentations.

Several cases of symbiosis among bacteria are now known. Apart from numerous instances of temporary association between pathogenic micro-organisms and animals such as earth-worms, rats, flies, ticks, and mosquitoes, and which disseminate their germs and infect cattle, sheep, horses, and men, reminding us of the transference of the spores of *Botrytis* by bees, which carry this parasite with the pollen and infect the stigmas of bilberries with the parasite; or which act the part of intermediate hosts to the disease germs, much as certain pond snails do to the liver-fluke of sheep, we now know several cases of symbiosis between two species of bacteria or of fungi, or between a bacterium and a fungus, each symbiont being incapable of carrying on alone the work which the symbiotic association is able to perform—a point which is essential to the definition of symbiosis in the narrower sense, *i.e.* the co-operation of two associated organs to their mutual advantage.

A striking example is afforded by certain bacteria concerned in the destruction of cellulose in ponds, bogs, rivers, &c. Van Senus found that a certain anaërobic bacterium, resembling, if not identical with, Van Tieghem's *B. Amylobacter,* though incapable of dissolving cellulose by itself, can do so if associated with another bacterium, also incapable of itself attacking cellulose. *B. Amylobacter* can ferment pectose compounds, and is thus capable of isolating cells one from another, but cellulose is not attacked by it.

Van Senus believed that the one bacillus destroys certain products of fermentation excreted by *B. Amylobacter,* which inhibit its cellulose-fermenting powers.

I may remark here, that if a sound potato, rhizome, or other underground organ is placed in water and the air exhausted as completely as possible, I almost invariably find its cellulose walls destroyed in a few days by a mixture of bacteria, and with the symptoms found in many kinds of 'wet rot.' There is no reason to believe that these organs would rot if merely wet and not deprived of air, since they lie in ordinary soil—even moist soil—for weeks or months, with plenty of water in their tissues, and respire oxygen, as is well known. The presumption is that the anaërobic conditions set up in the experiment described favour certain forms of soil bacteria, such as Van Senus worked with, and enable them to co-operate in the destruction of the cell walls.

An even more remarkable example is given by Winogradsky, who found that the anaërobic bacterium known as *Clostridium Pasteurianum* is able, if supplied with abundance of dextrose and protected from the access of oxygen, to fix atmospheric nitrogen. In the cultures, and presumably in the soil, the *Clostridium* was found to work when protected by a mantle of aërobic bacteria. In fact, the nitrogen-fixing *Clostridium* was working in the meshes of the oxygen-consuming species, and forming gelatinous flocks like the well-known grains of kephir, or of ginger-beer plant.

Yet another striking instance of symbiotic association has recently been given by Omeliansky. In experiments on nitrification at Bonn, the assertion had been made that the nitrifying organisms, *i.e.* the bacteria known to oxidise ammonia to nitrous acid, and nitrous acid to nitric acid, could be grown and made to do their specific work in media containing proteids or other organic nitrogenous bodies. Now this was directly contradictory of the experience of Warington, Winogradsky, and other workers, who had found that one great peculiarity of these nitrifying organisms is that they refuse to grow on such media; they are incapable of using organic nitrogen. Several workers then showed that the Bonn observers had inadvertently employed mixtures of two or more species, and Omeliansky undertook a critical investigation of the whole subject, and has put forward the following explanation of the tangle.

If *Nitrosomonas*—the bacterium which oxidises ammonia to nitrous acid—and *Nitrobacter*—the bacterium which further oxidises nitrous to nitric acid—be sown together or separately on a medium containing organic nitrogen, no growth or change occurs.

But if a bacterium capable of decomposing the organic nitrogenous medium, *e.g. Bacillus ramosus*, is added to the above-mentioned *Nitrosomonas* and *Nitrobacter*, the associated three organisms are able to carry out all the processes and complete the cycle of nitrification. That is to say, *B. ramosus* breaks down the gelatine and ammonia is formed, this is then oxidised to nitrous acid by *Nitrosomonas*, and the nitrous acid is further oxidised to nitric acid by the *Nitrobacter*.

If *B. ramosus* and *Nitrosomonas* only are sown together, then only nitrous acid is formed, because the latter organism is only capable of carrying the oxidation the one stage.

If *B. ramosus* and *Nitrobacter* only are used, then only ammonia is formed, because the latter organism cannot oxidise ammonia.

If we try to imagine the working of this association of organisms in the soil, and bear in mind the frequent co-existence and action of the de-nitrifying bacteria which Gayon and Dupetit, Giltay and Aberson, Warington and others have familiarised us with, a glimpse is obtained of the very complex symbioses which may be concerned in the circulation of nitrogen in Nature. Moreover, some of these de-nitrifying bacilli appear to be anaërobic, and can only work in the surface soil if protected from the access of oxygen; say, by an associated aërobic bacterium.

Another interesting case is the following. Perdix a few years ago isolated from water an anaërobic bacterium which converts starches into sugars, which with the aid of a yeast can be fermented, the whole process going on in association.

Other cases of symbiotic associations of bacteria exist among the forms concerned in the reductions of sulphates and the oxidation of sulphuretted hydrogen, the iron bacteria, &c.; but I propose to mention only one or two further examples, taken from the true fungi.

Symbiotic associations of fungi are probably common, but only a few cases are as yet established, and these principally among the ferment-fungi.

Van Laer has called attention to the symbiotic co-existence of two yeasts in many beers, explaining certain peculiar after-fermentations as due to the action of one yeast acting on the medium improved for it by the other.

The Japanese have long been in the habit of brewing a peculiar fermented liquor known as rice-wine, or saké. Rice grains are steamed, and when cool are infected with a mould fungus now known as *Aspergillus Oryzæ*. When the rice is quite mouldy, at which time it emits a peculiar odour like that of pineapples, the starch is found to be rapidly turning to sugar, under the action of a diastatic enzyme secreted by the fungus.

This decomposing rice is then placed in water and exposed to the action of a yeast, which rapidly ferments the sugar, and the alcoholic saké results.

So closely is the yeast associated with the *Aspergillus*, that, in practice, the alcoholic fermentation commences soon after the enzyme of the *Aspergillus* begins to hydrolyse the starch of the rice, and for some time a controversy existed as to whether the yeast was not really part of the life-history of the *Aspergillus*. Several observers have now shown, however, that we have here a striking case of symbiosis.

On reviewing these examples, we shall find that very different degrees of association of the organisms are to be met with.

At the one end of the series we find two organisms merely associated for a short time, *e.g.* bacilli and worms, bees and botrytis-spores, and, so far as we may speak of symbiosis at all in these cases, it is merely temporary or disjunctive.

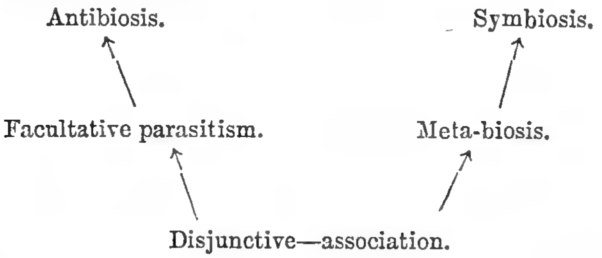
At the other end of the series we have a close permanent combination of the two organisms working in unison, *e.g.* the lichens and Winogradsky's *Closterium* with its protective mantle of aërobic bacteria; also the ginger-beer plant and kephir.

But between these extremes it is possible to find all stages, the halfway house being met with in cases such as the saké ferment, where the *Aspergillus* evidently prepares the way for the *Yeast*.

It has been proposed to apply the term *Metabiosis* to such cases.

It must not be forgotten that there are extremes in the other direction, where one of the two associated organisms is injuring the other, as exemplified by many parasites, but these cases I leave out of account here. This state of affairs has been termed *Antibiosis*.

It seems not impossible that the biological relationships of these cases one to another could be shown thus:—



The Physiology of Symbiosis.

It will be an interesting exercise to see if we can get any further glimpses into the physiology of the phenomenon of Symbiosis.

When we come to enquire as to the processes which lead to enhancement of the functional activity of one organism by another living symbiotically with it, the matter presents many difficulties ; for it is at the outset quite obvious that many things are possible, and soon becomes evident that a tangle of complexities lies before us, as always in the inter-relations between associated biological units. We need go no further than the examination of the possibilities in the inter-relations between a weed and a cultivated plant, or between two trees in a forest, for illustrations of this truth.

Confining attention for the moment to closely associated symbionts, such as those composing a lichen, the ginger-beer plant, or a clump of symbiotic bacteria or fungi, researches have made it practically certain that the provision of definite food-materials by the one symbiont for the other may be an important factor; *e.g.* an alga supplies a fungus with carbohydrates, or a fungus converts starch into the fermentable sugars which the associated yeast needs. In other cases the advantage derived is one of protection from some injurious agent—*e.g.* the aërobic bacterium prevents the access of oxygen to the anaërobic one. But there is evidence which suggests that mere nutrition or protection is not the only or even the principal factor involved. It is well known that the products of fermentative actions are frequently poisons, and we all know of cases where such poisonous excreta of living cells act as stimuli to other living cells, if supplied to them in minimal doses and very gradually: I need only instance the effects of tobacco or alcohol on man, in illustration of this.

Several observers have shown that in presence of a particular food-substance the living cell is stimulated to produce and excrete a particular enzyme, while the substitution of another food stimulates the organism to excrete a totally different enzyme.

Now let us see if there is any evidence to support the hypothesis that some such stimulative action is exerted by one symbiont on another. To a certain extent we find such in the remarkable vigour and large size of the algal cells in a lichen as compared with the same cells living an independent life, and in the persistent zone of brilliant green and often hypertrophied cells of leaves in which certain fungi are living, the gigantic cells of the nodules on leguminous roots in which the bacteroids are living, and many other cases; but since it is impossible to say how far these are cases of merely enhanced nutrition, we will pass them by and seek for other instances.

One of the earliest I can find is Hugo Schulz's demonstration in 1888 that minute quantities of poisons such as corrosive sublimate, iodine, iodide of potassium, bromine, arsenious acid, chromic acid, sodium salicylate, or formic acid, when added to yeast in 10 per cent. grape-sugar solution, immediately raise the fermentative activity of the organism—as measured by the amount of carbon-dioxide evolved. Effront, in 1894, showed that hydrofluoric acid acts similarly on yeasts, butyric ferments, and *mycoderma*, and, later, that the same is true of formaldehyde, salicylic acid, picric acid, &c.

What looks like another case in point is Johannsen's results of experiments with seeds, buds, &c., treated with ether or chloroform: respiration is increased, and the whole course of metabolism so altered that in some cases buds of flowers can be stimulated to open long before their normal period.

The results obtained by Farmer and Waller with carbon-dioxide, which was found to induce an initial acceleration of the movement of the protoplasm in *Elodea*, may be a further instance.

Pfeffer has recently called attention to a still more remarkable instance—that it is possible by etherising the living cells of *Spirogyra* to alter the type of nuclear division from *mitotic* (indirect) to *a-mitotic* (direct). Massart had shown that callus, the hypertrophied tissue developed under stimulation by mites, fungi, exposure to air, &c., is formed of cells which divide with *a-mitotic* nuclear division; and other cases occur. But it is even more to the point for my purpose that Gerassimoff, in Pfeffer's laboratory, found *Spirogyra* driven to *a-mitotic* division by associated bacteria and other organisms, which he regards as a case of symbiosis.

Now it may be regarded as certain that if a cell can be thus stimulated to alter the details of so fundamental and complex a morphological process as its cell-division by the action of associated organisms, the metabolic activities of its protoplasm are being driven into very different channels from the normal, and many physiological processes must be affected.

Of course I am here raising questions which concern the border-line between health and disease, and much investigation is still required as to the meaning of these matters; but I ought to add that according to Pfeffer the etherised cells can be again restored to their normal state if the traces of anæsthetic are washed out, and those familiar with Kleb's experiments on other algæ will appreciate the significance of this one with *Spirogyra.*

However feeble the evidence may be, we can at least say, then, that there is some evidence in support of the hypothesis that one symbiont may stimulate another by excreting some body which acts as an exciting drug to the latter—just as truly as certain drugs act as stimulants to some cell or organ of a higher animal, and no doubt in a fundamentally similar manner. It will be noted that such drugs are frequently excreta from vegetable cells.

But there is another, perhaps more indirect way in which one symbiont may enhance the activity of another. It has long been known that the accumulation of the products of metabolism of a cell tend to inhibit the activity of that cell, and that if by any means we can destroy or remove the metabolite as it is formed, the cell concerned can go on working. Similarly with ferments, and even with enzymes, the accumulation of the products gradually inhibits the action as Tammann showed in the case of amygdalin and emulsin, and Brown and Morris and Lea in the case of starch and diastase, to mention two illustrations only.

Now suppose we have two organisms A and B living in symbiosis, and suppose that A is capable of hydrolysing starch by the excretion of diastase, while B removes the product of hydrolysis, by fermenting the sugar as fast as it is formed; in this case there is every reason to expect that A will complete its hydrolysing action to the utmost, not only because it is of advantage to A to be relieved of the inhibiting sugar, but because the diminution of the sugar reacts as a stimulus to the secretion of more enzyme.

There is yet another point to be considered. Katz, in 1898, published some results confirming in many points the discoveries of Wortmann, Brown and Morris, and others, that fungi, bacteria, embryos, and other enzyme secreting organisms not only vary the extent and kind of enzyme secreted, but can be stimulated to vary the enzyme according to the quantity or quality of food materials at hand.

I think this line of enquiry may lead to results in the present connection, as it is obvious that the products of fermentation of an organism A must be favourable, or without effect, or deleterious to the action of another, B, in its immediate neighbourhood. Moreover, it is shown that a product which is, *per se*, devoid of either favourable or deleterious action, may acquire one or the other if the concentration increases.

Katz regards the action of sugars as not a purely chemical one, but as a physiological stimulus; and without pretending to understand the distinction in detail, we may admit the importance of the experimental facts, and not only seek for, but also hope for, more light.

Here, then, is a brief sketch of some of the salient features of symbiosis, and of some of the physiological factors concerned in the processes; and though it is far from exhaustive, it may serve our purpose to-day of starting a discussion, and of showing some lines along which further investigation is desirable.

Note sur les Fermentations Symbiotiques Industrielles. Par Monsieur le Docteur A. CALMETTE, *Directeur de l'Institut Pasteur de Lille.*

On sait que beaucoup de champignons inférieurs s'accommodent très bien de la vie en symbiose soit avec des bactéries, soit avec d'autres champignons ou avec des algues, soit avec des végétaux ou des animaux supérieurs. On a étudié dans ces derniers temps un très grand nombre d'espèces cryptogamiques parasites. Ces espèces parasites ne nous occuperont pas ici. Nous n'envisagerons que l'étude de quelques phycomycètes et mycomycètes qui vivent ordinairement en saprophytes sur les substances organiques les plus diverses et font subir à celles-ci des transformations que l'homme a pu utiliser pour les besoins de ses industries.

Les champignons qui nous intéressent surtout sont ceux qui fermentent les matières hydrocarbonées, telles que la cellulose, l'amidon, les dextrines, les sucres, les tannins, ou les matières azotées, telles que la caséine du lait.

Ces champignons agissent sur ces substances au moyen des diastases qu'ils sécrètent et qui présentent des propriétés très voisines de celles que possèdent les végétaux supérieurs et les animaux, pour l'assimilation des aliments que ceux-ci puisent dans le monde extérieur.

Chose très remarquable, plusieurs de ces êtres ont la faculté de produire les diastases les plus diverses, suivant la nature des substances qui doivent leur servir d'aliments. C'est ainsi qu'une des mucédinées les plus vulgaires, le *Penicillium glaucum*, est capable de sécréter tantôt de l'amylase, tantôt de la sucrase, si on la fait croître sur des milieux renfermant de l'amidon ou du saccharose, tantôt de la présure et de la caséase, si elle se développe sur du lait.

Dans beaucoup de cas, la croissance de ces végétaux inférieurs et la sécrétion de leurs diastases s'arrêtent dans les milieux nutritifs où ils ont vécu un certain temps, alors même que ces milieux sont loin d'être épuisés, parce que les produits de transformation de la matière organique auxquels ils ont donné naissance deviennent toxiques pour eux-mêmes. On sait par exemple que les Saccharomyces cessent de fermenter le sucre lorsqu'ils se trouvent en présence d'une certaine proportion d'alcool. De même, certains *mucors* et certains *aspergillus* qui hydrolisent énergiquement l'amidon, cessent de saccharifier celui-ci, dès que le milieu dans lequel ils se développent renferme une certaine quantité des produits qu'ils ont fabriqués, sucres, acides ou alcools.

Lorsque ces êtres se développent spontanément dans les milieux organiques fermentescibles—par exemple sur un fragment de pomme de terre placé dans des conditions favorables d'humidité et de température—il arrive souvent que d'autres êtres, bactéries ou moisissures, dont les fonctions sont différentes, ne tardent pas à s'établir à côté d'eux et collaborent aussitôt à l'œuvre de dégradation moléculaire commencée par le premier occupant. Nous verrons, par exemple, la *Sclerotinia libertiana* s'installer tout d'abord et attaquer, grâce à la cytase et à l'acide oxalique qu'elle secrète, la mince enveloppe de cellulose qui entoure les grains d'amidon.

Bientôt, ceux-ci, mis à nu, deviendront une proie facile pour les nombreuses mucédinées saccharifiantes, mucor ou aspergillus, et au fur et à mesure que l'amylase de ces dernières transforme l'amidon en sucre, ce dernier trouve immédiatement d'autres êtres qui s'en emparent, soit pour le brûler, soit pour en faire de l'alcool et de l'acide carbonique. L'alcool lui-même ne tardera pas à rencontrer des cellules de mycodermes ou de myco-levures qui se chargeront de l'oxyder, d'en faire de l'acide acétique, ou tout simplement de l'acide carbonique et de l'eau. Et par cette série de dégradations successives produites par nos champignons inférieurs, le fragment de pomme de terre initial aura complètement disparu.

L'étude scientifique de ces faits devait naturellement suggérer aux biologistes l'idée d'utiliser, en les associant, les propriétés que possèdent certains champignons inférieurs ou certaines bactéries de fermenter les substances hydro-carbonées ou azotées.

Nous n'avions qu'à prendre exemple sur les pratiques de certains peuples de l'Extrême Orient qui utilisent depuis un temps immémorial des moisissures pour fabriquer de l'alcool avec le riz. Les Japonais fabriquent leur *Saké* avec un aspergillus décrit depuis 1879 par Ahlburg sous le nom d'*Eurotium orizoe*; les Chinois et les Javanais préparent leurs eaux-de-vie et leurs vins de riz au moyen d'un mucor, dont les propriétés saccharifiantes très énergiques ont été mises en évidence par moi-même, à Saigon en 1892, puis par Prinsen Geerligs, à Java en 1894.

Ces diverses mucédinées saccharifiantes, aspergillus ou mucor, dont il existe un très grand nombre de variétés, possèdent, pour la plupart, la propriété de fermenter les sucres, lorsqu'elles sont placées dans certaines conditions de vie anaérobie. Toutefois, leurs propriétés fermentatives sont presque toujours beaucoup moins développées que leurs propriétés saccharifiantes, et, lorsqu'elles agissent sur l'amidon pour transformer celui-ci en alcool, elles s'associent toujours spontanément à des levures alcooliques, c'est-à-dire à des saccharomyces vrais.

Ces moisissures s'accommodent parfaitement de la vie symbiotique avec les levures, et si on a soin de les éduquer, de les employer en cultures pures et de ne les mettre en présence de cultures pures de levures que lorsque les mucédinées ont déjà pris possession du milieu et ont commencé leur travail de saccharification, on les utilise dans des conditions beaucoup plus parfaites que ne le font les peuples orientaux qui les emploient. On peut faire en sorte, par exemple, que les saccharomyces s'emparent au fur et à mesure du glucose élaboré par les moisissures, et celles-ci effectuent alors plus activement leur travail parce qu'elles ne sont pas gênées dans leur développement par leurs produits de secrétion. Elles ne cessent de saccharifier l'amidon que lorsque la quantité d'alcool résultant de la fermentation du sucre dans le moût est suffisante pour contrarier leurs sécrétions diastasiques.

La symbiose des mucédinéés saccharifiantes et des levures permet d'effectuer industriellement la fermentation directe de l'amidon des grains ou des pommes de terre et de supprimer à peu près totalement l'emploi du malt ou des acides pour la saccharification en distillerie.

Ce principe de la symbiose s'étendra probablement dans l'avenir à la fabrication de beaucoup d'autres substances que l'industrie prépare aujourd'hui pour ses besoins.

Symbiotic Fermentation: its Chemical Aspects.

By Professor H. E. Armstrong, *F.R.S.*

1. It is open to question whether the establishment of symbiotic relationships involves more than a subdivision of labour—whether the associated organisms combine in carrying the chemical change through any one phase.

2. There is an absence of positive evidence tending to show that the one member of a pair of symbiotic organisms or agents does more than prepare the way for the other by effecting a change which the second is incapable of inducing, leaving it to the second to carry on changes in which the initiating organism plays no part. A rough parallel to the case here contemplated would be that afforded by the occurrence of lactic followed by butyric fermentation under the influence of distinct organisms. These are strictly independent and sequent phenomena, the one change apparently setting in only when the other is complete.

3. In symbiotic fermentation, however, the two sets of changes seem at least to run parallel.

4. It may be a function of the one organism to remove from the sphere of action, as it arises, a product which would tend either to inhibit the change by which it is formed or to promote its reversal.

5. Or the one organism may produce a change which, although minute, is sufficient to place the companion organism under the most favourable conditions. For example, a minute proportion of acid favours the hydrolysis of cane sugar by invertase. Hence it may be supposed that in a neutral or faintly alkaline solution yeast would ferment sugar only slowly, if at all, whilst if associated with an organism capable of producing, say, a minute proportion of lactic acid, it would act rapidly. A case apparently of symbiosis, which possibly comes within this definition, is that referred to by Marshall Ward as studied by Van Senus.

6. Or, again, the one organism may become associated with the hydrolyte, and thus shield or mask a particular 'centre' in it, thereby making it possible for the second organism to actively affect the molecules at other centres. This case corresponds to the removal of a ward from a lock, and the consequent possibility of using a simpler key. What is in some cases a more nearly exact parallel is afforded by the production of glycuronic acid by the oxidation of the compound of glucose with chloral: in glucose, the COH centre is super-attractive to most oxidising agents, but when this centre is masked the attack is transferred to the opposite $CH_2(OH)$ group.

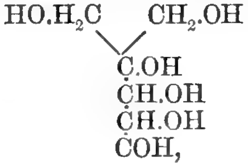
7. Another case is considered subsequently (§ ii.).

8. Fermentation is certainly at bottom a process of *hydrocatalysis*, and it can scarcely be doubted that the function of the enzyme is to introduce water into the circuit of change—in fact, to establish a circuit in which hydrolytic changes can occur, although not of the ordinary kind, but reductive on the one hand and oxidative on the other.

9. Hence we may speak of the substance fermented as the *hydrolyte*, of the ferment as the *hydrolyst*, and of the products of hydrolysis as the *hydroschists*.

10. It is more than probable that the products ordinarily obtained are but end products of a series of changes, and that only some of these are enzymic, whilst others occur, as it were, naturally, and are partly analytic and partly synthetic in character. Thus, in the formation of the inactive amyl alcohol in fusel oil, it may

be supposed that glucose is resolved *by fermentation* into a mixture of glyceraldose and glyceroketose, which spontaneously interact forming a new hexose,



and that this in turn becomes *fermented* to isobutylcarbinol, &c. It is not even known whether fusel oil is a product of fermentation by pure yeast; still less, therefore, can it be decided whether the two successive fermentations here contemplated are the acts of one organism, or of organisms which are in any sense symbiotic. But it seems almost certain that one and the same organism can produce a variety of changes.

11. It is conceivable that two symbiotic organisms may so act that the one produces a substance A, the other a substance B, and that these products interact, forming a third substance; and that the two organisms attack either one and the same substance, or different substances. In such a case the fermentation would be different from that produced by either organism singly. Such would be a case of truest symbiosis.

12. The conversion of lactic into butyric acid, of glycerol into butanol, and the formation of fat are certainly cases of fermentations in which synthetic changes occur, and it may well be apart from enzymic action.

13. There is little doubt that the importance of the part played by synthetic changes in fermentations, especially in the case of nitrogenous compounds, is at present far from being appreciated.

14. But however many steps may be involved in some fermentations, at least the attack on several centres must be simultaneous, and must occur in one and the same circuit, as the change involves expenditure of energy at some centres, and this must be supplied from those others at which energy is developed. A complex carbohydrate molecule undergoing fermentation may, in fact, be compared with a series of voltaic cells of unequal electromotive force in series. It is difficult in any other way to account for the resolution of a single molecule into so many others, such as occurs, for example, in ordinary alcoholic fermentation.

15. Such simultaneous attack is possible, probably because the enzyme is so constituted that it can attach itself at several points along the chain; the hydrolyte, in fact, is comparable with a complex lock, the hydrolyst with a complex key. It is possible thus to picture contact as being established between several more or less distant centres in a complex molecule, and a 'ripple of change' as pervading the system in consequence. Enzymes with restricted powers, such as invertase and diastase, probably can attach themselves only to a single centre, and their action is directly and simply hydrolytic.

16. In some cases, such as the formation of fat, it would seem necessary to suppose that several molecules may become associated together through the agency of the hydrolyst, so that reductive processes may go on almost entirely in the one set; whilst in another corresponding oxidative processes take place, which furnish the energy required to effect the reductions. On the other hand, it is conceivable that oxygen directly intervenes in the formation of fat, and that the process is not merely one of hydrocatalysis.

17. That no very complex mechanism is needed to produce effects such as are believed to be involved in fermentations follows from the fact that dextrose, for example, may be resolved into lactic acid by digestion with alkali and levulose into levulinic acid, $CH_3.CO.CH_2.CH_2.COOH$, by heating it with an acid, the latter being an especially remarkable case.

18. If the phenomena are as suggested, it does not seem probable that true symbiotic fermentation is likely to occur as a consequence of the simultaneous attack of a single molecule by several organisms; rather is it probable that associated molecules undergo change under the influence of a single organism or

agent which determines their association. And hitherto apparently no case has been met with in which a substance has been observed to give way to a pair of organisms, neither of which can attack it singly.

19. The assimilation of nitrogen by plants, which is believed to take place in the symbiotic growths found on the roots of the Leguminosæ, is a phenomenon of which at present no explanation can be given, as this element cannot enter into combination with either hydrogen or oxygen unassisted; its absorption must take place in a circuit in which changes occur from which the necessary energy may be derived. As hydrogen is liberated in many fermentations, it appears not improbable that nitrogen may be brought into circuit by acting as a hydrogen depolariser; one function of the nodule may be to supply carbohydrate, which is fermented by the bacteroid in circuit with the nitrogen.

20. Symbiosis, as distinguished from parasitism, involves the conception not only of the concurrent existence of organisms, but of their useful concurrency; indeed, any other form of symbiosis is difficult to imagine, and *antibiosis* is a contradiction in terms. It is desirable that we should remain satisfied with the term until our knowledge of the actual character of the changes involved in ordinary as well as in symbiotic fermentations is far greater than is now the case: at present it is impossible to draw valid distinctions.

Note.—The explanation of fermentation adopted in this note is given in my address to the Chemical Society in 1895.[1] Green, in his recent work on Enzymes, speaks of Baeyer having put forward, in 1870, the hypothesis that fermentation is due to electric hydrolysis. This is incorrect. Baeyer's paper is entitled 'Ueber die Wasserentziehung und ihre Bedeutung für das Pflanzenleben,' &c. He makes no reference whatever to the manner in which water might be withdrawn, but merely shows that the withdrawal of water and the subsequent addition of its elements in a different order would produce effects such as are observed in fermentations.

Discussion.

Dr. H. Van Laer (Brussels).—Revient sur les communications faites par M. le professeur Marshall Ward et le Dr. Armstrong. Il fait remarquer que l'exemple de vie en commun d'une moisissure et d'une levure, telle qu'on la retrouve dans l'intéressant procédé de fermentation de M. Calmette, ne rentre nullement dans les cas de symbiose, métabiose ou antibiose signalés par M. Marshall Ward.

Il est incontestable que dans cette association de moisissure et de levure celle-ci y trouve tout avantage, puisqu'elle se borne à utiliser le sucre produit par les diastases de la mucédinée. Mais cette dernière ne trouve guère d'avantages dans cette société. Il y a plutôt ici un cas de parasitisme analogue à celui qui se présente lorsque le *Mycoderma cerevisiæ* se trouve en même temps qu'une levure dans un milieu nutritif contenant un sucre (la saccharose ou la maltose, par exemple) que le mycoderme ne peut utiliser.

Il a remarqué que lorsque cet organisme vit en concurrence avec la levure il s'empare d'une portion des monosaccharides qui se forment par l'action des diastases levuriennes sur la maltose ou la saccharose.

Professor R. Warington.—All joint life is based on division of labour. The bricklayer cannot do his work unless the brickmaker supplies bricks, and the brickmaker will cease to work if his bricks are not consumed. We must not argue that there is no combined work because all the agents do not simultaneously attack the same material. There is an evident need, however, of defining the sense in which the term Symbiosis is used: at present it is applied to a number of distinct cases. It will be well to follow Professor Marshall Ward's proposal, and to limit the use of the term to those cases in which each living organism is essentially benefited by the work of its companion, so that joint life is needed for the welfare of both. Cases in which B prepares material for A, but derives no essential benefit from A, should be termed, as Professor Ward suggests, not Symbiosis, but Metabiosis.

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[1] *Trans.* p. 1136.

Mr. Francis Darwin spoke on stimulus as a factor in the problem, and, without dissenting from Professor Ward's view, called attention to a possible difficulty.

Dr. G. Harris Morris said that he was interested in the subject under discussion from the point of view of the so-called symbiotic fermentations, in which moulds and yeasts were concerned. Personally he considered the view of Professor Armstrong, that the first-named organism prepared the way for the second, to be the correct one, and he thought that the results of certain experiments which he hoped to lay before the Section at a later meeting (see p. 710) would support that view. In the fermentations referred to, the function of the mould appeared to be entirely that of secreting diastase, which degraded the starch products and rendered them fermentable by the yeast. The diastase thus secreted could be replaced by malt extract or precipitated diastase with precisely the same result, and although the diastase so secreted or added was undoubtedly stimulated by the fermentative action of the yeast, yet the phenomenon could not be regarded as an instance of true symbiosis. A further proof that the one organism prepared the way for the other was to be found in the fact that in the commercial process which had been mentioned it was found that the best results were obtained when the mould, or diastase secretor, was added twenty-four hours before the yeast or fermentative agent.

The results of the experiments to which he had previously referred showed the supposition that the function of one organism was to remove from the field of action products which inhibited the action of the other to be untenable.

He should also like to correct the view, which appeared to be shared by some who had taken part in the discussion, that because the moulds were only able to produce a comparatively small amount of alcohol, therefore their saccharifying action ceased when the formation of alcohol came to an end. This was by no means the case, as experiment showed that the extent to which degradation of the starch-products had proceeded was by no means indicated by the amount of alcohol formed.

He also could not agree with Professor van Laer in regarding the action of the yeast as that of a parasite, and he did not think that any analogy could be drawn with the action in question and that of *Mycoderma vini*.

[*The President of the Section.*—It is a matter of great difficulty to determine all the actions and reactions of an organism with its environment even when we have to deal with a pure culture living in a medium of the simplest possible composition, but the difficulty is enormously increased when it is a question of two or more organisms, either of which can influence the other in a variety of ways.

If we consider the process of Dr. Calmette for the preparation of alcohol from starch by the metabiotic agencies of a saccharifying Amylomycete or Aspergillus, and a true yeast, we find that the actual amount of hydrolytic action exerted by the first organism when working alone is extremely small, but that the mere presence of a second organism, the yeast, which has the power of fermenting the products of starch-hydrolysis as fast as they are formed, enormously intensifies the initial saccharification. The fact is generally explained by biologists by assuming that the yeast in some mysterious manner *stimulates* the saccharifying organism to secrete a larger amount of diastase. This explanation is a pure assumption which cannot be proved or disproved by direct experiment. We may, however, as Dr. Morris has shown, produce the same effect under conditions where the saccharifying organism is replaced by a small but definite amount of diastase which remains constant throughout the experiment. Now it is impossible to avoid the conclusion that the chemical processes involved are the same in the two cases, and that it is perfectly unnecessary to introduce the explanation of an increased secretion of diastase by stimulation when we are considering the case in which the two metabiotic organisms are concerned.

An extension of similar work, especially on the simultaneous action of mixed enzymes, each one of which is capable of carrying out its own stage of hydrolysis, will, no doubt, ultimately throw considerable light on the metabiotic effect of living organisms. Take, for instance, the case of *diastase* and *glucase*. The former can hydrolyse starch down to maltose but no further, whilst the latter, unable in itself to act on starch, can readily convert maltose into glucose. It is highly probable, if these enzymes were set to work side by side on starch, that the joint hydrolytic effect, measured by the amount of starch which disappears in a given time, would be greater than it would be if the diastase were working alone.

Two possible explanations of the increased effect of the presence of yeast on a trace of diastase naturally suggest themselves. The first is that the hydrolytic process is a reversible one, and is promoted by the rapid removal of the products from the sphere of action, the other being that the small amount of acid produced during the alcoholic fermentation increases the action of the diastase. Dr. Morris has apparently eliminated both these possibilities, in the one case by artificially adding maltose to the solutions, and in the other by the addition of a fermented malt-extract deprived of its living yeast cells.

If, however, it is remembered that maltose, when first formed by diastatic action, unquestionably differs from the optically stable form which has been in solution for some time, and, moreover, that evidence is still wanting as to the relative fermentability of these two forms of maltose, the door is not altogether closed to the possibilities of the phenomena being after all in some way dependent on the prevention of reversal by the rapid removal of the fermentable products of change.] [1]

MONDAY, SEPTEMBER 18.

The following Report and Papers were read:—

1. *Report on the Teaching of Natural Science in Elementary Schools.*

See Reports, p. 359.

2. A Discussion on Atomic Weights was opened by the reading of the following communications:—

Proposed International Committee on Atomic Weights.

By Professor F. W. CLARKE.

(*Letter to* Professor W. A. TILDEN.)

Washington, D.C., July 19, 1899.

Dear Sir,—In response to your letter of June 8, I take pleasure in sending you a statement of my views relative to the proposed International Committee upon Atomic Weights. The suggestions which I have to offer are, however, only my own individual opinions, and are not to be regarded as representing any organisation, or as based upon any definite programme. Still, they may serve as a basis for discussion, and so help to clear a way for progress.

Every chemist who has studied, with any closeness, the determination of atomic weights, has noticed the discordance which exists among the published tables. In many text-books and works of reference tables are given which seem to have been edited with a pair of scissors and a paste-pot, and which show about as much critical acumen in their making up as those useful implements could furnish. Not only are obsolete values found persisting, but values are given which are inconsistent among themselves; and occasionally there is evidence of the most pitiable confusion as to the fundamental standards of reference. One table is based upon the standard of oxygen as 16; another upon oxygen as 15·88, and still others upon the wholly erroneous ratio of 15·96. In one and the same table these several

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[1] Owing to want of time the Conference of the two Sections was closed before the termination of the Discussion. The remarks in square brackets embody the views expressed by the President of Section B at a subsequent date, when Dr. G. H. Morris read his Paper on the 'Combined Action of Diastase and Yeast on Starch-granules.' See p. 710.

standards may simultaneously appear, one atomic weight being referred to one, and another to another; the compiler being quite unconscious of the discrepancy. Tables of atomic weights which were good ten years ago reappear frequently in books of to-day, with no hint that any changes have occurred in any of the data.

In order to remedy, at least in part, this unnecessary confusion in our fundamental constants, the American Chemical Society in 1892 requested me to prepare an annual report upon atomic weights. Each year since I have submitted to the Society such a report (six in all), giving a summary of the determinations made, and a table of values brought down to the date of publication. So far as it went, the work seems to have been useful; but it did not go far enough, and it carried only the authority which might attach to the opinions of a single individual. More criticism, more comparison of views among chemists, was evidently desirable; and the movement in favour of international action seems to be a movement in the proper direction.

In 1898 the subject was taken up independently by the German Chemical Society, which appointed a committee consisting of Landolt, Ostwald, and Seubert. This committee in due time reported a table of atomic weights, recommended the adoption of $O = 16$ as the standard of reference, and suggested that like committees might well be appointed by other societies for purposes of co-operation. Acting upon that suggestion, the American Chemical Society, at its last general meeting, appointed a committee consisting of F. W. Clarke, J. W. Mallet, E. W. Morley, T. W. Richards, and Edgar F. Smith; and that committee has already begun correspondence with the English and German organisations. A number of local societies in various parts of Europe have recommended the use of the table put forth by the German committee; but a full conference of all the parties at interest is yet to be held. Probably an effort will be made to discuss the atomic weight question at the Congress of Chemists in Paris next year; but this proposition is so far only a matter under consideration. At all events, a general international committee might then be most readily brought together; and its recommendations would certainly carry much weight.

What, now, could such a committee accomplish? In what directions should its influence be exerted? These are questions to be answered beforehand, for upon the answers the expediency of definite action must depend. Unless we have a reasonable expectation that something useful can be done, it is not worth while to go any farther.

Two lines of discussion for the proposed committee are self-evident: first, a discussion of the ultimate standard of reference, whether it shall be $O = 16$ or $H = 1$, and upon this question there are legitimate differences of opinion; secondly, a discussion of the existing data, in order to determine the most probable values for the atomic weights, and to get some insight into their relative accuracy. This involves the preparation of a table of atomic weights for practical use, in which some indication shall be given as to the trustworthiness of the individual values. Which figures have been well determined, and which need correction, should be clearly shown, and in that way future investigation would be stimulated. Such a table would call for revision from time to time, perhaps annually, and for this reason the committee should be made a permanent body, to act either by meeting or by correspondence, according to circumstances. Only an international committee could expect to have its findings generally accepted.

Up to this point the work proposed for the committee has already been done, with more or less thoroughness, by the German committee, by Professor Richards, and by myself; so that the ground is pretty well cleared, and the field of action can be seen. But still more is desirable; and just here, I believe, the task of the proposed committee may become most important. Having ascertained the weak points in our system of atomic weights, the next thing to do is to have them strengthened; and to this end the combined influence of a body of trained experts might well be exerted. At present all research in this field of investigation is individual, and consequently the more obvious problems are simultaneously attacked by sometimes several independent workers, while other equally important questions are entirely neglected. A division of the field of labour, and co-operation in research, might easily be brought about; not by any exercise of authority on the part of the committee, but by mutual consent of the investigators, working in conference, and aided by the suggestions which the international body might develop. In short, the committee could not order, but it might persuade; and in this direction its influence ought to be decidedly beneficial. Even if it did no more than to point out the essential problems to be solved, it would fully justify its existence.

There is one more general problem which the proposed committee should consider: that of methods. What are the best experimental methods for the determination of atomic weight ratios, and how shall the data be handled mathematically? On each division of this question there is something to be said. The existing methods, the methods which are commonly employed, are somewhat conventional in their character, and need exhaustive scrutiny. They are not sufficiently varied in their details to eliminate all danger of constant or cumulative errors, and new lines of attack, new points of view, ought to be considered and developed.

At present, the data relative to atomic weights are treated like successive links in a series of chains, each link to be considered separately; while in reality they form an interlacing network of interdependent quantities which should be discussed in some broadly general way.

To illustrate my meaning, let us consider a specific ratio,

$$CaF_2 : CaSO_4,$$

which has been repeatedly measured in order to determine the atomic weight of fluorine. In this case a series of measurements is made, involving of necessity some error which may be great or small. From these data the atomic weight in question is computed, with the assumption that the atomic weights of calcium and sulphur are known. But these antecedent values are themselves in error by small but unknown amounts, and these errors are superimposed upon the experimental error of the ratio itself, so that all three appear in the final result of the calculation. The errors may be compensatory in part, or they may be cumulative; and which is the case we cannot certainly know. In a proper reduction of the data the ratio should contribute to our knowledge of all three of the atomic weights represented, and its error should be distributed among them instead of being piled, with others, upon one. That is, the ratio should not be discussed by itself, but should be combined with other ratios in such a manner that several related atomic weights might be determined simultaneously. This, I believe, will be the method of the future; and ultimately all trustworthy evidence, concerning all atomic weights, will be put into one set of normal equations with simultaneous solution for all. First, the experimental errors will be made as small as possible; after that they will be so uniformly distributed as to become inappreciable. For this procedure the mathematical method is well known, but the existing data are too incomplete for its present application. The final reductions will not be possible for many years to come. Work, comparable with that of Stas and Morley, needs to be done for all the chemical elements, and done with a broad purpose in view; after that the mathematician can contribute his share to the solution of the general problem.

It is greatly to be hoped that at some future time some of the great laboratories may undertake systematic work of the kind I have indicated. The fundamental constants of chemistry are surely of equal importance with the value of the ohm, the form of the earth, or the solar parallax; and institutions like the Reichsanstalt in Berlin, the International Bureau of Weights and Measures at Paris, or the Davy-Faraday laboratory of the Royal Institution, might well contribute to their determination. In this direction an international committee could exert an influence far beyond that of any individual, or even of any one society, but the problems at issue must first be clearly understood and formulated. To clear the ground, to arouse interest, and to stimulate systematic research, are important functions of the proposed body.

Yours very truly,

F. W. CLARKE.

Atomic Weights. *By* Professor W. A. Tilden, *F.R.S.*

The question of atomic weights has two aspects, the theoretical and the practical. For the purposes of theory we require to know the relative values of the atomic weights of all the elements with the utmost possible accuracy, with the object chiefly of explaining observed relations and discovering new ones. The true significance of the periodic scheme of arrangement will never be discovered till the atomic weights of a much larger number of elements are known more correctly than at present. And the employment of numbers which only roughly approximate to the true values for the atomic weights has led in the past to a large amount of speculation and discussion, of which nearly the whole is fruitless, because of necessity successive hypotheses have had to be put aside as knowledge of the subject has advanced, and numbers less inaccurate have been gradually substituted. This is true not only of such crude hypotheses as that of Prout, but of ideas proposed in more recent times concerning the relations of the several series in Mendeléef's table.

Other questions have arisen, such as the possibility of the variation of the atomic weights within certain limits, but they only serve to illustrate the extreme difficulty of the subject in its present position; for while the facts are about equally well known to all chemists who have studied it, they have led some to consider variation possible, while others upon the same evidence are convinced that it is impossible. Unfortunately the settlement of such questions is still far off, for the complete series of determinations of all the elements made with a degree of accuracy comparable with that which has made the work of Stas famous is not to be expected in the present generation.

Another subject which has been reopened by the action of the distinguished Committee of the German Chemical Society relates to the unit to be adopted. The practice which has prevailed universally since the time of Berzelius, that is, for nearly three-quarters of a century, of expressing the atomic weights in terms of hydrogen ($H=1$) is now abandoned by the Committee in favour of the new scale, in which oxygen is the standard and $O=16$. The considerations which have influenced the several members of the Committee are chiefly three, namely, first, the uncertainty still supposed to attach to the ratio $H:O$, though this is now as accurately known as it is likely to be; secondly, the fact that the atomic weights of many elements may be deduced directly from the composition of their compounds with oxygen, but less frequently from compounds with hydrogen; thirdly and chiefly, because the oxygen scale brings many atomic weights very near to whole numbers. It is evident that this consideration is one which concerns alike the analyst, the student, and the investigator in every analytical operation, and in all circumstances which do not involve the discussion of the numerical interrelations of the atomic weights. For that purpose the $H=1$ scale will always be preferable, until an element is discovered having a smaller atomic weight than hydrogen, and of that there is at present no indication so far as terrestrial chemistry is concerned.

On the whole the proposal of the German Chemical Society is probably the best solution of the difficulty. The scale in which $O=16$, however, implies the value 1·01, approximately, for hydrogen; and though it is true that for common analytical use the neglect to recognise this value will not lead to very serious consequences, it must be remembered that an appreciable error will be involved in expressing the composition of compounds which are comparatively rich in hydrogen, such as the chief hydrocarbons and their derivatives. For C_5H_{12}, for example, the percentage of hydrogen is 16·66 or 16·80, according to the value assigned to the atomic weight of hydrogen.

But supposing the $O=16$ scale to be generally adopted, it is still highly desirable that there should be an understanding among the several Chemical Societies, and if possible among the members of these societies, as to the numbers to be chosen for ordinary use. Are we to use 27·1 for Al, 137·4 for Ba, 208·5 for Bi, 79·96 for Br, 35·45 for Cl, 52·1 for Cr, 126·85 for I, 206·9 for Pb, 24·36 for Mg, 200·3 for Hg, 14·04 for N, 194·8 for Pt, 39·15 for K, 23·05 for Na, 32·06 for S &c.,

instead of the nearest whole numbers as has been customary in all these cases, with one exception, namely, chlorine? The temptation will be great, especially when we become aware that in the majority of cases the error introduced will be less than the ordinary experimental error. The example of platinum at once presents itself, without concerning ourselves about the special value for this element used by the potash makers for reasons of their own. But comparing the result of employing the old rounded-off numbers with that of using the more exact values calculated on the $O = 16$ scale, it is interesting to see how little is the effect on the percentage composition of potassium platino-chloride deduced from the formula.

—	Percentages calculated from		Difference
	$K = 39{\cdot}15$, $Pt = 194{\cdot}8$, $Cl = 35{\cdot}45$	$K = 39$, $Pt = 195$, $Cl = 35{\cdot}5$	
Potassium .	16·118	16·049	·069
Platinum .	40·099	40·123	·024
Chlorine .	43·783	43·827	·044
	100·000	99·999	

There are some chemists to whom anything short of scientific accuracy is distasteful. It would be interesting to know whether in their daily work they use, for example, the number 14·04 instead of 14 for nitrogen, and what is the extent of experimental error they admit in analyses of nitrates or ammonia salts, of nitro compounds, or of organic matters by Kjeldahl, or any other recognised process. The composition of nitro-benzene may be used as an illustration. The percentage of N derived from the formula when $C = 12$, $H = 1$, $N = 14$, $O = 16$, is 11·38; while if $C = 12$, $H = 1{\cdot}01$, $N = 14{\cdot}04$, and $O = 16$, the result is 11·40, a difference of ·02 per cent.

It is also usually forgotten that the values arrived at in all the best determinations of atomic weights are obtained under conditions which cannot be observed in daily laboratory practice, the weights, for example, being usually reduced to a vacuum standard. Hence the adoption of the numbers regarded as the most exact does not necessarily contribute to the exactness of ordinary analytical operations, however carefully performed.

A little common sense is required in all such matters, but it should be the common sense of the chemical world, and not the diverse fancies of individuals, and uniformity of practice would tend greatly to the general convenience. The only chance of arriving at such uniformity is to submit the question to discussion first at such meetings as those of the British Association and the Chemical Society, and subsequently at an international gathering such as it is proposed to hold in Paris next year. On such grounds I support cordially the chief proposals brought forward in the communication from Professor F. W. Clarke.

3. *Development of Chemistry in the last Fifteen Years.*
By Professor Geheimrath Dr. A. LADENBURG.

4. *The Chemical Effect on Agricultural Soils of the Salt-water Flood of November* 29, 1897, *on the East Coast. By* T. S. DYMOND, *F.I.C., and* F. HUGHES, *County Technical Laboratories, Chelmsford.*[1]

The fact that on the coast of Essex alone some 30,000 acres of land were flooded during the high tide of November 29, 1897, shows the serious nature of this inundation of salt water. The injurious effect of the salt water on crops is

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[1] The original paper, containing the analytical results and particulars of crops, will be published from the County Technical Laboratories, Chelmsford.

variously stated to last from five to twenty years, and this inquiry was undertaken with a view to advising as to the best means of cultivating the land, and also to determine the amount of salt deposited, the time required for its removal by drainage, and its chemical and physical effects upon the soil constituents, a knowledge of which must be of value in the event of future inundations.

By analysis made after the water had run off, but before an appreciable quantity of rain had fallen, the soil was found to contain 0·2 per cent of salt, or about twenty times the normal quantity. This was insufficient to produce plasmolysis of the root-hairs, and it therefore was not directly injurious to growing crops. Nor was the condition of the soil then impaired; indeed, the addition of salt to soil tends at first to granulate the clay and render it more workable. The immediate injury appeared to be chiefly due to the entire destruction of earth-worms. In the following season (1898) very few crops were worth harvesting.

The soils were re-examined this spring (1899). It was found that nine-tenths of the salt had been washed down by rain and removed by drainage, and that young worms had again made their appearance. The condition of the soil was, however, very unsatisfactory, and while on some farms there was promise of fair crops, on others the crops had failed. When shaken with water the soil is no longer quickly deposited, but remains partially suspended for several weeks, evidence that the clay has become gelatinous. This is also shown by the higher percentage of water of hydration in the air-dried clay from the flooded soil. The retentivity of the soil for water had not become greatly altered, but percolation of water through the flooded soil was just half as rapid as through the unflooded.

These effects appear to be due to the chemical action of the chlorides of the sea-water upon the double silicates of the soil. Analysis of the soil shows that the percentage of lime, magnesia, potash, and soda had been reduced very materially, and this points to the decomposition of the double silicates, the silicate of alumina being left behind in a gelatinous condition.

It is obvious that for the amelioration of the soil attention must be directed to rendering the soil more workable and open, and thus counteracting the effect of the gelatinous clay. Ploughing in green crops or the straw of cereal crops and long manure, and, above all, thorough fallowing, have already proved to be useful. Also, the soil having become impoverished by the action of the salt, dressings of lime and potash manures may be required, lime being especially valuable because of its known effect in granulating clay.

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5. *The Influence of Solvents upon the Optical Activity of Organic Compounds.* *By* WILLIAM JACKSON POPE.

The author traces the variations in the specific rotation of an optically active substance dissolved in various solvents to the degree of association of the active compound; it is shown that the specific rotation of lævotetrahydroquinaldine, a highly associated substance, varies from $[\alpha]_D = -46°$ to $-118°$ in different solvents owing to the varying degree to which the association factor is changed. On the other hand, a substance like lævopinene, which is practically nonassociated in the pure state, alters its specific rotation very slightly when dissolved in different solvents.

Since the specific rotation is so largely dependent upon the association factor, a method can be devised for determining whether a particular optically active substance forms a liquid racemic compound with its optical antipodes. Thus pure lævotetrahydroquinaldine has the specific rotation $[\alpha]_D = -58·12°$, and when dissolved in externally compensated tetrahydroquinaldine as solvent its specific rotation becomes $[\alpha]_D = -58·02°$; this practical identity between the two specific rotations indicates that externally compensated tetrahydroquinaldine is merely a mixture of the two antipodes, each of which retains in the mixture the association factor which it possesses in the pure liquid state. Externally compensated tetrahydroquinaldine is, therefore, not a racemic compound.

6. *A Method for Resolving Racemic Oximes into their Optically Active Components.* By WILLIAM JACKSON POPE.

The author gives a method for resolving very feebly basic racemic substances, such as oximes, into their optically active components. The method consists in forming salts of the feeble base with dextrocamphorsulphonic acid and separating the salt of the dextro-base from that of the lævo-base by fractional crystallisation. In order to demonstrate the efficacy of the method, racemic camphoroxime was resolved into its active components by fractional crystallisation with the equivalent quantity of camphorsulphonic acid; dextrocamphoroxime dextrocamphorsulphonate, $C_{10}H_{16}NOH$, $C_{10}H_{15}OSO_3H$, H_2O, separates first from the acetone or ethereal solution, and when treated with dilute ammonia yields pure dextrocamphoroxime. The more soluble lævocamphoroxime dextrocamphorsulphonate, $C_{10}H_{16}NOH$, $C_{10}H_{15}OSO_3H$, H_2O, remains in the mother liquids, and after appropriate purification yields lævocamphoroxime when treated with ammonia.

TUESDAY, SEPTEMBER 19.

The following Papers were read :—

1. *Phenomena connected with the Drying of Colloids, Mineral and Organic.* By J. H. GLADSTONE, *F.R.S., and* WALTER HIBBERT.

The object of this paper was to draw attention to some peculiarities observed in the drying of colloids—namely, the hydrates of tin, titanium, silica, iron, and alumina, together with gelatine, gum, and albumen.

The mineral colloids when dried from solution approximate very closely to definite hydrates. Through the shrinking caused by the evaporation of the water they crack into non-crystalline blocks, which exhibit a variety of phenomena, such as serrated edges, fringes, contour lines, and internal fissures of a crescent or spiral form.

When the soft material gives off water the surface becomes hard, though the water still continues to find its way through. When the dried surface is tough, as in the case of gelatine, no internal structure is revealed, but where it is hard and brittle, as in the case of titanic hydrate, crescent-shaped cavities and contour lines make their appearance round the region of final attachment.

In the case of the tin hydrate, where the crust is sufficiently strong to resist distortion, cavities make their appearance, generally in the form of regular spirals, often consisting of many convolutions. These spirals, with modifications, are also shown in titanium hydrate, iron oxide, and albumen.

Of the above-mentioned elements, tin, titanium, silicon, and carbon are members of Mendeléeff's fourth group, while iron and alumina form sesquioxides. While there is a close analogy among these organic and mineral colloids, there are modifications which must be ascribed to the chemical nature of the particular hydrate.

2. *The Influence of Acids and of some Salts on the Saccharification of Starch by Malt-Diastase.* By DR. A. FERNBACH.

In a series of papers on 'Invertase,' published in 1889 in the 'Annales de l'Institut Pasteur,' I proved that the slightest variations of acidity or alkalinity have a very great influence on the action of the enzyme. Its action is greatly favoured by the presence of free acid, and for each acid as well as for each sample of invertase there is a definite quantity of acid which appears most favourable to the action.

It was natural to apply these observations to diastatic action, as it has been maintained by different authors that acids favour the saccharification of starch by diastase.

My experiments have led me to a different conclusion. The slightest trace of *free* acid distinctly retards the action of diastase on gelatinised as well as on soluble starch; this applies to all acids. The action is, however, apparent only if both the starch employed and the solution of diastase are absolutely free from salts on which the added acid may act.

If the solution contains such salts, among which the most important are secondary phosphates, which are distinctly unfavourable to diastatic action, the addition of acid is favourable as long as there is no excess over the quantity necessary to transform these salts into primary phosphates. In that case the *acidity* of the liquid increases by addition of acid, but there is no *free* acid present as long as the whole of the secondary salt is not decomposed. The unfavourable action of acid appears as soon as the quantity added is greater than that required for this decomposition.

A distinction must therefore be made between *acidity* and *free acid*, as is proved by the influence of primary phosphates or diastatic action, which salts, although having an acid reaction, are distinctly favourable. This influence of phosphates seems to be specific for salts of this kind.

The same influence of phosphates may be noticed with enzymes other than diastase, and I am at present engaged in investigating this subject farther in conjunction with L. Hubert.

3. *Note on the Combined Action of Diastase and Yeast on Starch-granules.*

By G. Harris Morris, *Ph.D., F.I.C.*

It has long been known that when yeast is allowed to act on a solution of starch-transformation products in the presence of active diastase, the quantity of matter fermented is far in excess of that which can be fermented by the yeast alone; and, furthermore, that when active diastase and yeast are allowed to conjointly act on the so-called stable dextrin, which, under ordinary conditions, is neither degradable by diastase nor fermentable by yeast, it is entirely fermented. The action is apparently analogous to that of *symbiosis*, only, in place of two living organisms being concerned, we have a conjunction of an unorganised enzyme, diastase, and the yeast organism.

Some experiments I was led to make a few years ago showed that a similar action takes place when ungelatinised intact starch granules are submitted to the joint action of diastase and yeast. The experiments were made with barley starch, and were briefly as follows:—

A quantity of the dry starch was shaken continuously with a mixture of cold-water malt extract and water for seventy-two hours.

A similar mixture was made with the addition of a small quantity of yeast, and allowed to stand side by side with the above for the same length of time.

An examination of the two then showed that in the first experiment 22·2 per cent. of the starch had gone into solution, whilst in the second 51·8 per cent. had disappeared. In the former the starch had been converted into *maltose*, and was found in the solution; in the latter, the maltose first formed had been to a very large extent fermented, and existed as alcohol.

It appeared possible that the increased action, when yeast was present, was due to the removal of the soluble product—maltose—from the field of action, thus allowing the diastase to exert a greater activity. In order to determine this, another experiment was made, and two bottles, one containing a mixture of starch, malt extract, and water, the other a mixture of starch, malt extract, and solution of starch transformation-products, were shaken side by side for the same length of time. In each case the amount of starch dissolved was practically identical, thus showing that the soluble products had no retarding action on the diastatic action. Another experiment in which the product of the action of the diastase was removed by dialysis, instead of by fermentation, gave a similar result—the sum of the matter which diffused, and that remaining in the dialyser was the same as that in the mixture where no dialysis was possible.

Other experiments showed that no increased diastatic action took place in the presence of yeast, if the fermentative power of the latter was checked by chloroform, neither was any increase of action observed when the malt extract was fermented and the yeast removed before the starch-granules were added. It appears, therefore, that it is necessary to have both the diastase and the yeast present together in a condition capable of exercising their respective functions, in order to obtain the increased action.

Precipitated diastase acts in the same way as cold-water malt extract.

The combined action of diastase and yeast on starch-granules differs from that of the two on the so-called stable dextrin, since it only takes place on those starches which are attacked in the ungelatinised form by diastase, such as barley or malt starch. The granules of potato starch are not acted on by diastase, even in the presence of yeast.

4. *The Action of Acids on Starch.* *By* G. Harris Morris, *Ph.D., F.I.C.*

Some months ago, H. Johnson[1] published a paper in which he maintains that when starch is hydrolysed by acids only dextrose and dextrin are produced, and that under no conditions is maltose formed in the reaction. He also adopts the view that glucoamylins are formed in the reaction; these substances he regards as molecular aggregates of dextrose and dextrin, similar to amyloins or maltodextrins, but containing the dextrose in place of the maltose group.

This view of the acid hydrolysis of starch is opposed to that previously held by the majority of observers, and is completely at variance with the results obtained by Rolfe and Defren, and the author's.

Johnson states that the properties of the substances intermediate between starch and dextrose can be expressed in terms of dextrin and dextrose, and that when this is done the specific rotatory power calculated for such a mixture agrees with the observed angle for the conversion. He supports this view by giving results obtained with acid starch conversions and with fractions of such conversions obtained by precipitation with alcohol.

Johnson also states that the action of diastase on the products of the acid hydrolysis of starch is very slight, thus further proving the different nature of the products intermediate between dextrin and dextrose from those of conversions with diastase.

The author's experience is, however, directly opposed to that of Johnson. A large number of acid starch conversions, analysed and calculated in the manner described by the latter, gave differences between the observed and calculated specific rotatory powers corresponding to the presence of from 5 to 45 per cent. of maltose. The examination of alcoholic fractions gave similar results, and from the fractions, the analysis of which indicated the presence of considerable percentages of maltose, crystals of undoubted maltosazone were obtained.

The results of the action of malt extract were also entirely different from those obtained by Johnson, the fall in angle on degradation amounting on an average to more than 20° $[\alpha]_D$.

The author's results were obtained from conversions made with different starches and acids, and under varying conditions of temperature and pressure, and in nearly all cases the analytical data, when calculated in the manner indicated above, showed a difference of angles, indicating the presence of maltose.

Several of Rolfe and Defren's results were also calculated in the manner adopted by Johnson, and it was found that they fully confirmed those of the author.

The author also criticised the law regarding the products of acid hydrolysis of starch at which Rolfe and Defren had arrived, and he considered that owing to the method of calculation accepted, further investigation was required before it could be employed.

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[1] *Trans. Chem. Soc.* 1898, pp. 490–502.

From the experience of the author, he is of opinion that the relative amounts of dextrin, dextrose, and maltose present in any given acid conversion of starch depend on the conditions under which the conversion is made, as regards strength of acid, temperature, and pressure, and that it is not possible to predict the relative proportions of the three carbohydrates from the specific rotatory power as is stated by Rolfe and Defren.

5. *The Action of Hydrogen Peroxide on Carbohydrates in the Presence of Ferrous Salts.* *By* R. S. MORRELL *and* J. M. CROFTS.

At the Bristol meeting of the British Association we communicated the results of the oxidation of glucose and levulose by hydrogen peroxide in the presence of ferrous sulphate. The glucose and levulose were oxidised to the same osone, which was identified by the formation of phenyl glucosazone at the ordinary temperature. During the past year we have oxidised in the same way arabinose and galactose.[1] The former sugar yields arabinosone, but galactose has, as yet, furnished no definite results.

We now wish to state some of the results obtained from the oxidation of the glucosone produced when levulose is treated with hydrogen peroxide. The method adopted is to oxidise the glucosone by bromine-water after having first removed as much of the unattacked levulose as possible by fermentation. We obtained the calcium salt of a dibasic acid, which is very soluble in water, reduces Fehling's solution easily, and the analyses point to the calcium salt of a dibasic acid of formula $C_6H_8O_8$. The free acid we have not as yet obtained crystalline. Levulose, by the action of oxidising agents, gives acids containing less than six carbon atoms, but from our results it would seem that the glucosone can be oxidised without destruction of the six-carbon chain.

We have also tried the action of bromine on a solution of glucosone obtained from glucose, after having removed as much of the unaltered glucose as possible, by fermentation with yeast. Unfortunately we have been unable to obtain a pure calcium salt—the analyses indicating the presence of some calcium gluconate.

Besides the oxidation of the glucosone by bromine-water, we have oxidised some of the saccharoses by hydrogen peroxide, namely cane sugar, lactose, and maltose. In the case of cane sugar, the product is merely glucosone, and the yield of osazone is about 30 per cent. of the weight of cane sugar taken—two atoms of oxygen being used in the oxidation. This yield is nearly that obtained when glucose and levulose alone are oxidised. Lactose and maltose both yielded substances which react with phenyl hydrazine acetate in the cold; the yield of osazone, however, was small, and the substance sometimes oily.

6. *Influence of Substitution on Specific Rotation in the Bornylamine Series.* *By* M. O. FORSTER, *Ph.D., D.Sc.*

On replacing an atom of hydrogen belonging to a group attached to asymmetric carbon in an optically active substance, the numerical value of the rotatory power undergoes a change. Hitherto the hydroxylic and carboxylic groups have received most attention, but these radicles contain only one hydrogen atom, and the author has therefore studied the effect produced on the specific rotation of bornylamine by replacing the hydrogen atoms of the amino-group. The following observations have been made:—

1. The specific rotation of bornylamine is largely increased by replacement of a single hydrogen atom in the amino-group by an alkyl radicle, but the increase diminishes in ascending the series of monalkyl bases, of which methylbornylamine has the greatest specific rotatory power.
2. The specific rotation of bornylamine is only slightly increased on replacing

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[1] *C. S. J.* 1899, p. 786.

both hydrogen atoms in the amino-group by the same radicle. The specific rotations of the condensation products of bornylamine with aromatic aldehydes, however, do not exhibit marked approximation to that of the original base, although the compounds in question are represented by the typical formula, $C_{10}H_{17}\cdot N:X$.

3. The specific rotatory power of paranitrobenzylbornylamine approximates more closely to that of benzylbornylamine than does that of the ortho-derivative. Similarly, the specific rotations of paranitro- and parahydroxybenzylidenebornylamines are less divergent from that of benzylidenebornylamine than the corresponding ortho-compounds.

4. Bornylamine and its alkyl derivatives, although strongly dextrorotatory, give rise to benzoyl derivatives which are strongly lævorotatory.

5. The ethyl group increases the dextrorotation of the base in alcohol by 29·2°, whilst the formyl radicle, although of equal mass, converts it into a lævorotation of 42·1°.

6. When an alkyl group replaces a hydrogen atom of the ammonium radicle in the series of alkylbornylammonium iodides, the specific rotatory power of bornylamine hydriodide, instead of undergoing increase in the positive direction, becomes reduced to feeble lævorotation.

A convenient method of preparing methylbornylamine, which may perhaps find application in other groups of primary amines, consists in heating benzylidenebornylamine with methylic iodide, and hydrolysing the resulting methiodide, which is resolved into benzaldehyde and methylbornylamine hydriodide. The remaining derivatives employed in this investigation were prepared by known methods.

7. *New Derivatives from Camphoroxime.*

By M. O. FORSTER, *Ph.D., D.Sc.*

With the object of preparing brominated derivatives of camphoroxime the author has studied the behaviour of this substance towards alkaline hypobromite.

The *compound*, $C_{10}H_{16}NO_2Br$, is obtained by the action of a concentrated ice-cold solution of potassium hypobromite on camphoroxime, dissolved, and in part suspended, in aqueous potash; it crystallises from alcohol in snow-white fern-like aggregates, and melts at 220° to a colourless liquid which immediately decomposes. It is volatile in steam, and sublimes at the temperature of the water-bath, the vapour having an intensely irritating odour; benzene, ether, and petroleum dissolve it with great readiness. The substance is optically active, and gives Liebermann's reaction for nitroso-derivatives; reduction with zinc dust and acetic acid regenerates camphoroxime.

The *compound*, $C_{10}H_{14}NOBr$, produced when the foregoing substance is dissolved in concentrated sulphuric acid, crystallises from alcohol in lustrous transparent prisms, and sublimes in minute needles at the temperature of the water-bath; it shrinks and darkens at about 210°, becoming completely charred at 220°. This derivative is optically inactive, and does not give Liebermann's reaction. Treatment with hot concentrated hydrochloric acid converts it into the *isomeride*, which separates from alcohol in large transparent six-sided crystals, and melts at 240°; the compound does not give Liebermann's reaction, but yields a *benzoyl* derivative, crystallising from alcohol in lustrous scales which melt at 174–176°.

The *nitrile*, $C_8H_{13}\cdot CN$, obtained when either of the compounds, $C_{10}H_{14}NOBr$, is heated with an aqueous 20 per cent. solution of caustic soda, forms a limpid fragrant oil, which boils at 198–199° under 760 mm. pressure; it is feebly dextrorotatory, and a solution in chloroform instantly decolorises bromine. The *amide*, $C_8H_{13}\cdot CONH_2$, occurs as a by-product in the formation of the nitrile, and arises from that substance under the influence of alcoholic potash; it crystallises from light petroleum in white highly lustrous needles, and melts at 90°. The acid, $C_8H_{13}\cdot COOH$, prepared by heating the amide with concentrated hydrochloric acid, is volatile in steam, and readily sublimes in long lustrous needles, melting at 133°; the cold solution in sodium carbonate instantly reduces potassium permanganate, but bromine is not decolorised by a solution of the acid in chloroform. Its behaviour, therefore, resembles that of isolauronolic acid, $C_9H_{14}O_2$, which melts at 135°;[1] the amide of isolauronolic acid, however, is described by Blanc[2] as melting at 129–130°, and the nitrile boils at 205° under 760 mm.

The investigation of the amide and its behaviour on oxidation is being continued.

8. *The Action of Caustic Soda on Benzaldehyde.*
By Dr. C. A. KOHN *and* Dr. W. TRANTOM.

9. *On the Action of Light upon Metallic Silver.*
By Colonel J. WATERHOUSE.

Following on the lines of Moser's thermographic observations, it may be asserted that pure silver is sensitive to light. If cut-out masks be laid upon the surface of silver leaf or foil, or on a daguerreotype plate, and exposed to the sun's rays, a visible image ultimately becomes apparent on the metallic surface. The effect, however, may be got in a very much shorter space of time if the exposed metal be subjected to mercury vapour or developed by immersion in an acid solution of a ferrous salt mixed with nitrate of silver. Clear images, hardly as yet to be called pictures, can thus be obtained of a permanent character, so that it may be possible to work the daguerreotype process without iodising the plate. In fact all photographic phenomena, the invisible developable image, the visible image, reversal, and the effect of pressure marks, can be illustrated on the plain silver surface; this, at least, is a new discovery. Copper also seems to be sensitive in the same way, and doubtless other metals.

10. *Some Experiments to obtain Definite Alloys, if possible, of Cadmium, Zinc, and Magnesium with Platinum and Palladium. By* Professor W. R. E. HODGKINSON, Captain WARING, *R.A.*, *and* Captain DESBOROUGH, *R.A.*, *Ordnance College, Woolwich.*

That platinum alloys with zinc has been noticed by several experimenters—Gmelin-Krant (3), 1193; Gehlen, Fox, Murray, &c., Deville and Debray, 'Ann. Chem. and Phys.' (3), 56, 430; Boussingault, 'Ann. Chem. and Phys.' (3), 53, 429.

Zinc and Platinum.—It is generally stated that the metals unite with energy, and that when the combination is heated until infusible the compound is representable by Pt_2Zn_3.

Deville and Debray, after treating the alloy of Pt and Zn with dilute sulphuric acid, obtained a black powder containing 31 per cent. zinc and a little free platinum.

The method employed has been to submit a weighed amount of platinum to the vapour of the volatile metal, maintaining the platinum or compound formed all the time at a temperature above the boiling-point of the particular volatile metal.

Two plans have been tried: one carrying the vapour with hydrogen; another heating in a vacuum. A very infusible Jena glass tube was employed.

In each case a weighed quantity of platinum[3] (or palladium) was contained in a porcelain boat. Almost touching this was another boat containing the volatile metal in very considerable excess. The region about the two boats was heated very strongly in a powerful combustion furnace, and in the case where hydrogen was used the current of gas passed over the zinc (or other metal) towards the

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[1] Koenigs and Hoerlin, *Ber.* 1893, xxvi. 811; W. H. Perkin, jun., *Trans. Chem. Soc.* 1898, lxxiii. 831.

[2] *Compt. Rend.* 1896, cxxiii. 749.

[3] Very thin foil.

platinum. When heated in vacuum the Sprengel pump was attached at the end nearest the platinum so that the vapour could be drawn over the platinum.

The heating was in each case continued for some hours. After careful cooling the boat with platinum alloy was weighed.

Cadmium.—Vapour carried by hydrogen.

In one experiment ·5832 of platinum absorbed ·6872 of cadmium.

This alloy corresponds almost exactly to the formula $PtCd_2$. It is white and crystalline and very brittle when heated to full redness in a vacuum tube. Scarcely any cadmium sublimed from it. The loss in weight was inappreciable. Its relative weight was found to be 13·53 (at 15°), and the calculated weight for an alloy of this composition is 13·59.

In nitric acid some of the platinum is dissolved along with the cadmium. The same product was given by heating the metals together in a vacuum tube.

Zinc in Hydrogen.—The action was slower than with cadmium.

In one experiment 45·57 per cent. zinc was taken up. $PtZn_2$ requires 40 per cent. Zn. On heating this 45·57 per cent. alloy for two hours in a vacuum tube some zinc distilled off, leaving a residue containing 44 per cent. Zn.

It was now heated until the glass tube began to give way, the pump keeping up a vacuum. The residue after about four hours contained 24·45 per cent. Zn. This is nearly PtZn, which requires 25 per cent. Zn. It seemed hopeless to get more zinc driven off in glass tubes.

The alloy is crystalline and extremely brittle. It dissolves in acids pretty much like the cadmium alloy.

Heated side by side in the vacuum the alloy of PtZn seemed to be formed, but the process was very slow, the zinc vapour not travelling very far.

Magnesium.—This was the most difficult, as at the temperature employed the magnesium vapour is almost entirely absorbed by the glass of the tube and by the porcelain boat.

Some magnesium was distilled in vacuum. This was placed in a porcelain boat lined with MgO. The platinum was placed as close as possible and the whole heated until the magnesium was melted. A gentle current of very dry hydrogen was then kept up for some hours. An extremely friable crystalline alloy was produced. From the amount absorbed it corresponds very nearly to the formula $PtMg_2$.

Palladium.—The experiments with this metal and cadmium and zinc have so far failed to give any result. Very little cadmium seems to be taken up by palladium either when heated in vacuo or in a current of hydrogen. What little is taken up distils away very easily. It is possible to keep a piece of palladium foil for two hours in cadmium vapour without change. There is a little more tendency for zinc to alloy, or be absorbed.

Nickel behaves very like palladium in this respect. Some electro-deposited nickel foil was heated for several hours in cadmium vapour without appreciable change in weight.

These experiments are being repeated.

11. *Action of Acetylic and Benzoylic Chlorides on dried Copper Sulphate. By* Professor W. R. E. Hodgkinson *and* Captain Leahy, *R.A., Ordnance College, Woolwich.*

These experiments were undertaken to ascertain whether there would be any ground for considering copper sulphate monohydrate as an acid body. The ratio of magnesium dissolved to copper deposited from a *solution* of copper sulphate (Clowes) suggested such a nature.

Pure copper sulphate in fine powder was dried for a week at 98° C. An analysis showed that it contained exactly 1 molecule water.

Weighed quantities of this salt were submitted to the action of acetylic chloride, firstly by dissolving the chloride in metaxylene, and agitating this with the fine powder of the copper salt and heating up to about 100° C. As this method was found to produce acet-metaxylene, it was abandoned.

Weighed quantities of the salt were then exposed in shallow platinum trays to the vapour of the chloride. After trying several temperatures with varying results it was found that an evident definite reaction took place when the vapour of the chloride was simply carried over the copper salt by a stream of well-dried CO_2 at the temperature 12°–16° C. Under these circumstances the copper sulphate changed colour from almost white to deep chocolate brown, and hydrogen chloride was evolved. Analyses indicate this product to be a copper sulphate mono-acetate.

On heating the tube containing the tray with salt to about 110° C. the compound evidently decomposed. It became quite white, acetic anhydride was given off, and the residue in the tray was pure $CuSO_4$.

There was distinct evidence that at about 60°–70° C. an intermediate compound was formed from the action of the excess of chloride on the acetate first formed. This appeared to be a compound of the anhydride with the $CuSO_4$. Scarcely a trace of chlorine was retained by the copper salt.

Benzoylic chloride appeared to behave in a perfectly similar manner. The figures obtained are not very close to theory, but scarcely leave any doubt about the composition of the products and the analogy with the acetylic compound.

In one experiment the copper salt absorbed 20·16 per cent. of acetyl. If the reaction proceeded according to $CuSO_4H_2O + CH_3COCl = HCl + CuSO_4CH_3COOH$, the gain in weight should be 23·72 per cent. In another experiment 48·28 per cent. of acetic anhydride was contained. On the assumption that the reaction $CuSO_4CH_3COOH + CH_3COCl = HCl + CuSO_4CH_3COOOC\ CH_3$ took place the gain in weight should be 47·45 per cent. Some similar results were obtained with benzoylic chloride.

The experiments are being continued.

12. *The Reaction between Potassium Cyanide and* 1 : 3 *Dinitro-benzene. By* Professor W. R. E. HODGKINSON *and* Lieutenant W. H. WEBLEY-HOPE, *R.A.*

In the 'Berichte' for 1884 is an abstract[1] of a communication by Lobry de Bruyn on the action of alkaline cyanide on 1 : 3-dinitro-benzene. The result of this action is stated to be an oxyethyl-nitro-benzonitrile, 1 : 2 : 6. Beilstein refers to this abstract in the 'Handbuch.'

The reaction has been tried with a slight modification. In the abstract above cited an alcoholic solution of the dinitro-benzene was treated with the potassium cyanide dissolved in *some* water. We have employed the purest potassium cyanide obtainable, and as nearly absolute alcohol as ordinarily possible.

On digesting for a little time (forty to sixty minutes) on a water-bath the purple-red coloration (*loc. cit.*) was observed, and the final change to a dirty brown. On cooling a considerable crystallisation took place. The solid was separated from the excess of alcohol, and was found to dissolve for the most part in hot water. A small amount of black amorphous substance remained insoluble. On acidifying the solution a brown substance precipitated. It was washed with very dilute acid (H_2SO_4) and then dissolved in hot alcohol, from which crystals deposited on cooling and also on evaporation.

On analysis (nitrogen) figures have been obtained, pointing distinctly to a compound $C_6H_4NO_2CN$. Considerably more than 80 per cent. of the dinitro-benzene employed seems to have been thus converted.

The same body has been obtained with dry methylic alcohol and also with normal propylic alcohol as solvents for the dinitro-benzene.

With acetone and paraldehyde as solvents, beyond the formation of a small amount of very intense colouring matter, very little action seems to have taken

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[1] *Rec. Trav. Chim.* ii. 205–235.

place, for over 90 per cent. of the dinitro-benzene was recovered, and very little cyanide was acted upon.

With an appreciable amount of water present, and ordinary very alkaline cyanide, the reaction probably runs quite differently.

Under our conditions of working we have failed to obtain any sign of an oxyethyl or oxymethyl derivative.

The nitrocyanide or nitrile forms brown needle-shaped crystals from alcohol. It decomposes at about 200°, feebly deflagrating.

It does not seem to hydrolise when boiled with potassium hydrate, or with strong hydrogen chloride.

The work was commenced with a view of employing the oxyethyl-nitro-nitrile as a starting point for another research. It now seems advisable to examine this reaction under several conditions, such as the effect of water and free alkali in the cyanide.

13. *The Presence of Potassium Nitrite in Brown Powder Residue when the Powder is burnt in Air under Ordinary Pressure. By* Mr. SETON, *R.A., and* Mr. STEVENSON, *R.A., Ordnance College, Woolwich.*

Ordinary black powders when burnt in air under ordinary pressure leave a small quantity of residue in which carbonate, sulphate, and sulphide of potassium predominate. Traces only of nitrate and nitrite and other compounds can usually be found. When examined quantitatively, however, the three salts above mentioned together make up some 98 per cent. of the whole. Brown powders burn much more slowly, and in consequence the residue is larger. It is generally white or greyish-white, hygroscopic, and for the most part soluble in water.

Some analyses were made of these brown-powder residues to determine the relation of sulphate to carbonate; no sulphide is, as a rule, present. It was first noticed on acidifying that red fumes were produced. This of course indicated presence of nitrites in more than mere traces.

Several determinations of the amount of nitrite, by permanganate and by the nitrometer, gave about 6 per cent. calculated as KNO_2.

The figures of one complete analysis of residue from SBC are:

Potassium carbonate	61·96
,, sulphate	26·18
,, nitrite	6·17
Silica and other insoluble substances (water)	5·80
	100·11

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION.—SIR ARCHIBALD GEIKIE, D.C.L., D.Sc., F.R.S.

The President delivered the following Address on Saturday, September 16:—

AMONG the many questions of great theoretical importance which have engaged the attention of geologists, none has in late years awakened more interest or aroused livelier controversy than that which deals with Time as an element in geological history. The various schools which have successively arisen—Cataclysmal, Uniformitarian, and Evolutionist—have had each its own views as to the duration of their chronology, as well as to the operations of terrestrial energy. But though holding different opinions, they did not make these differences matter of special controversy among themselves. About thirty years ago, however, they were startled by a bold irruption into their camp from the side of physics. They were then called on to reform their ways, which were declared to be flatly opposed to the teachings of natural philosophy. Since that period the discussion then started regarding the age of the Earth and the value of geological time has continued with varying animation. Evidence of the most multifarious kind has been brought forward, and arguments of widely different degrees of validity have been pressed into service both by geologists and palæontologists on one side, and by physicists on the other. For the last year or two there has been a pause in the controversy, though no general agreement has been arrived at in regard to the matters in dispute. The present interval of comparative quietude seems favourable for a dispassionate review of the debate. I propose, therefore, to take, as perhaps a not inappropriate subject on which to address geologists upon a somewhat international occasion like this present meeting of the British Association at Dover, the question of Geological Time. In offering a brief history of the discussion, I gladly avail myself of the opportunity of enforcing one of the lessons which the discussion has impressed upon my own mind, and to point a moral which, as it seems to me, we geologists may take home to ourselves from a consideration of the whole question. There is, I think, a practical outcome which may be made to issue from the controversy in a combination of sympathy and co-operation among geologists all over the world. A lasting service will be rendered to our science if by well-concerted effort we can place geological dynamics and geological chronology on a broader and firmer basis of actual experiment and measurement than has yet been laid.

To understand aright the origin and progress of the dispute regarding the value of time in geological speculation, we must take note of the attitude maintained towards this subject by some of the early fathers of the science. Among these pioneers none has left his mark more deeply graven on the foundations of modern geology than James Hutton. To him, more than to any other writer of his day, do we owe the doctrine of the high antiquity of our globe. No one before him had ever seen so clearly the abundant and impressive proofs of this remote antiquity recorded in the rocks of the earth's crust. In these rocks he traced the operation of the same slow and quiet processes which he observed to be at work at present in gradually transforming the face of the existing continents. When he stood face to face with the proofs of decay among the mountains, there seems to have arisen uppermost in his mind the thought of the immense succession of ages which these proofs revealed to him. His observant eye enabled him to see 'the operations of the surface wasting the solid body of the globe, and to read the unmeasurable course of time that must have flowed during those amazing operations, which the vulgar do not see, and which the learned seem to see without wonder.'[1] In contemplating the stupendous results achieved by such apparently feeble forces, Hutton felt that one great objection he had to contend with in the reception of his theory, even by the scientific men of his day, lay in the inability or unwillingness of the human mind to admit such large demands as he made on the past. 'What more can we require?' he asks in summing up his conclusions; and he answers the question in these memorable words: 'What more can we require? Nothing but time. It is not any part of the process that will be disputed; but after allowing all the parts, the whole will be denied; and for what?—only because we are not disposed to allow that quantity of time which the ablution of so much wasted mountain might require.'[2]

Far as Hutton could follow the succession of events registered in the rocky crust of the globe, he found himself baffled by the closing in around him of that dark abysm of time into which neither eye nor imagination seemed able to penetrate. He well knew that, behind and beyond the ages recorded in the oldest of the primitive rocks, there must have stretched a vast earlier time, of which no record met his view. He did not attempt to speculate beyond the limits of his evidence. 'I do not pretend,' he said, 'to describe the beginning of things; I take things such as I find them at present, and from these I reason with regard to that which must have been.'[3] In vain could he look, even among the oldest formations, for any sign of the infancy of the planet. He could only detect a repeated series of similar revolutions, the oldest of which was assuredly not the first in the terrestrial history, and he concluded, as 'the result of this physical inquiry, that we find no vestige of a beginning, no prospect of an end.'[4]

This conclusion from strictly geological evidence has been impugned from the side of physics, and, as further developed by Playfair, has been declared to be contradicted by the principles of natural philosophy. But if it be considered on the basis of the evidence on which it was originally propounded, it was absolutely true in Hutton's time and remains true to-day. That able reasoner never claimed that the earth has existed from all eternity, or that it will go on existing for ever. He admitted that it must have had a beginning, but he had been unable to find any vestige of that beginning in the structure of the planet itself. And notwithstanding all the multiplied researches of the century that has passed since the immortal 'Theory of the Earth' was published, no relic of the first condition of our earth has been found. We have speculated much, indeed, on the subject, and our friends the physicists have speculated still more. Some of the speculations do not seem to me more philosophical than many of those of the older cosmogonists. As far as reliable evidence can be drawn from the rocks of the globe itself, we do not seem to be nearer the discovery of the beginning than Hutton was. The most ancient rocks that can be reached are demonstrably not the first-formed of all. They were preceded by others which we know must have existed, though no vestige of them may remain.

It may be further asserted that, while it was Hutton who first impressed on modern geology the conviction that for the adequate comprehension of the past

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[1] *Theory of the Earth*, vol. i. p. 108.

[2] *Op. cit.* vol. ii. p. 329.

[3] *Op. cit.* vol. i. p. 173, *note.*

[4] *Op. cit.* vol. i. p. 200.

history of the earth vast periods of time must be admitted to have elapsed, our debt of obligation to him is increased by the genius with which he linked the passage of these vast periods with the present economy of nature. He first realised the influence of time as a factor in geological dynamics, and first taught the efficacy of the quiet and unobtrusive forces of nature. His predecessors and contemporaries were never tired of invoking the more vigorous manifestations of terrestrial energy. They saw in the composition of the land and in the structure of mountains and valleys memorials of numberless convulsions and cataclysms. In Hutton's philosophy, however, 'it is the little causes, long continued, which are considered as bringing about the greatest changes of the earth.'[1]

And yet, unlike many of those who derived their inspiration from his teaching, but pushed his tenets to extremes which he doubtless never anticipated, he did not look upon time as a kind of scientific fetich, the invocation of which would endow with efficacy even the most trifling phenomena. As if he had foreseen the use that might be made of his doctrine, he uttered this remarkable warning: 'With regard to the effect of time, though the continuance of time may do much in those operations which are extremely slow, where no change, to our observation, had appeared to take place, yet, where it is not in the nature of things to produce the change in question, the unlimited course of time would be no more effectual than the moment by which we measure events in our observations.'[2]

We thus see that in the philosophy of Hutton, out of which so much of modern geology has been developed, the vastness of the antiquity of the globe was deduced from the structure of the terrestrial crust and the slow rate of action of the forces by which the surface of the crust is observed to be modified. But no attempt was made by him to measure that antiquity by any of the chronological standards of human contrivance. He was content to realise for himself and to impress upon others that the history of the earth could not be understood, save by the admission that it occupied prolonged though indeterminate ages in its accomplishment. And assuredly no part of his teaching has been more amply sustained by the subsequent progress of research.

Playfair, from whose admirable 'Illustrations of the Huttonian Theory' most geologists have derived all that they know directly of that theory, went a little further than his friend and master in dealing with the age of the earth. Not restricting himself, as Hutton did, to the testimony of the rocks, which showed neither vestige of a beginning nor prospect of an end, he called in the evidence of the cosmos outside the limits of our planet, and declared that in the firmament also no mark could be discovered of the commencement or termination of the present order, no symptom of infancy or old age, nor any sign by which the future or past duration of the universe might be estimated.[3] He thus advanced beyond the strictly geological basis of reasoning, and committed himself to statements which, like some made also by Hutton, seem to have been suggested by certain deductions of the French mathematicians of his day regarding the stability of the planetary motions. His statements have been disproved by modern physics; distinct evidence, both from the earth and the cosmos, has been brought forward of progress from a beginning which can be conceived, through successive stages to an end which can be foreseen. But the disproof leaves Hutton's doctrine about the vastness of geological time exactly where it was. Surely it was no abuse of language to speak of periods as being vast, which can only be expressed in millions of years.

It is easy to understand how the Uniformitarian school, which sprang from the teaching of Hutton and Playfair, came to believe that the whole of eternity was at the disposal of geologists. In popular estimation, as the ancient science of astronomy was that of infinite distance, so the modern study of geology was the science of infinite time. It must be frankly conceded that geologists, believing themselves unfettered by any limits to their chronology, made ample use of their imagined liberty. Many of them, following the lead of Lyell, to whose writings in other

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[1] *Theory of the Earth*, vol. ii. p. 205.

[2] *Op. cit.* vol. i. p. 44.

[3] *Illustrations of the Huttonian Theory*, § 118.

respects modern geology owes so deep a debt of gratitude, became utterly reckless in their demands for time, demands which even the requirements of their own science, if they had adequately realised them, did not warrant. The older geologists had not attempted to express their vast periods in terms of years. The indefiniteness of their language fitly denoted the absence of any ascertainable limits to the successive ages with which they had to deal. And until some evidence should be discovered whereby these limits might be fixed and measured by human standards, no reproach could justly be brought against the geological terminology. It was far more philosophical to be content, in the meanwhile, with indeterminate expressions, than from data of the weakest or most speculative kind to attempt to measure geological periods by a chronology of years or centuries.

In the year 1862 a wholly new light was thrown on the question of the age of our globe and the duration of geological time by the remarkable paper on the Secular Cooling of the Earth communicated by Lord Kelvin (then Sir William Thomson) to the Royal Society of Edinburgh.[1] In this memoir he first developed his now well-known argument from the observed rate of increase of temperature downwards from the surface of the land. He astonished geologists by announcing to them that some definite limits to the age of our planet might be ascertained, and by declaring his belief that this age must be more than 20 millions, but less than 400 millions of years.

Nearly four years later he emphasised his dissent from what he considered to be the current geological opinions of the day by repeating the same argument in a more pointedly antagonistic form in a paper of only a few sentences, entitled 'The Doctrine of Uniformity in Geology briefly refuted.'[2]

Again, after a further lapse of about two years, when, as President of the Geological Society of Glasgow, it became his duty to give an address, he returned to the same topic and arraigned more boldly and explicitly than ever the geology of the time. He then declared that 'a great reform in geological speculation seems now to have become necessary,' and he went so far as to affirm that 'it is quite certain that a great mistake has been made—that British popular geology at the present time is in direct opposition to the principles of natural philosophy.'[3] In pressing once more the original argument derived from the downward increase of terrestrial temperature, he now reinforced it by two further arguments, the one based on the retardation of the earth's angular velocity by tidal friction, the other on the limitation of the age of the sun.

These three lines of attack remain still those along which the assault from physics is delivered against the strongholds of geology. Lord Kelvin has repeatedly returned to the charge since 1868, his latest contribution to the controversy having been pronounced two years ago.[4] While his physical arguments remain the same, the limits of time which he deduces from them have been successively diminished. The original maximum of 400 millions of years has now been restricted by him to not much more than 20 millions, while Professor Tait grudgingly allows something less than 10 millions.[5]

Soon after the appearance of Lord Kelvin's indictment of modern geology in 1868, the defence of the science was taken up by Huxley, who happened at the time to be President of the Geological Society of London. In his own inimitably brilliant way, half seriously, half playfully, this doughty combatant, with evident relish, tossed the physical arguments to and fro in the eyes of his geological brethren, as a barrister may flourish his brief before a sympathetic jury. He was willing to admit that 'the rapidity of rotation of the earth *may* be diminishing, that the sun *may* be waxing dim, or that the earth itself *may* be cooling.' But he went on to add his suspicion that 'most of us are Gallios, "who care for none of

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[1] *Trans. Roy. Soc. Edin.* vol. xxiii. (1862).

[2] *Proc. Roy. Soc. Edin.* vol. v. p. 512 (Dec. 18, 1865).

[3] *Trans. Geol. Soc. Glasgow*, vol. iii. (February 1868), pp. 1, 16.

[4] 'The Age of the Earth,' being the Annual Address to the Victoria Institute June 2, 1897. *Phil. Mag.* January 1899, p. 66.

[5] *Recent Advances in Physical Science*, p. 174.

these things," being of opinion that, true or fictitious, they have made no practical difference to the earth, during the period of which a record is preserved in stratified deposits.'[1]

For the indifference which their advocate thus professed on their behalf most geologists believed that they had ample justification. The limits within which the physicist would circumscribe the earth's history were so vague, yet so vast, that whether the time allowed were 400 millions or 100 millions of years did not seem to them greatly to matter. After all, it was not the time that chiefly interested them, but the grand succession of events which the time had witnessed. That succession had been established on observations so abundant and so precise that it could withstand attack from any quarter. and it had taken as firm and lasting a place among the solid achievements of science as could be claimed for any physical speculations whatsoever. Whether the time required for the transaction of this marvellous earth-history was some millions of years more or some millions of years less did not seem to the geologists to be a question on which their science stood in antagonism with the principles of natural philosophy, but one which the natural philosophers might be left to settle at their own good pleasure.

For myself, I may be permitted here to say that I have never shared this feeling of indifference and unconcern. As far back as the year 1868, only a month after Lord Kelvin's first presentation of his threefold argument in favour of limiting the age of the earth, I gave in my adhesion to the propriety of restricting the geological demands for time. I then showed that even the phenomena of denudation, which, from the time of Hutton downwards, had been most constantly and confidently appealed to in support of the inconceivably vast antiquity of our globe, might be accounted for, at the present rate of action, within such a period as 100 millions of years.[2] To my mind it has always seemed that whatever tends to give more precision to the chronology of the geologist, and helps him to a clearer conception of the antiquity with which he has to deal, ought to be welcomed by him as a valuable assistance in his inquiries. And I feel sure that this view of the matter has now become general among those engaged in geological research. Frank recognition is made of the influence which Lord Kelvin's persistent attacks have had upon our science. Geologists have been led by his criticisms to revise their chronology. They gratefully acknowledge that to him they owe the introduction of important new lines of investigation, which link the solution of the problems of geology with those of physics. They realise how much he has done to dissipate the former vague conceptions as to the duration of geological history, and even when they emphatically dissent from the greatly restricted bounds within which he would now limit that history, and when they declare their inability to perceive that any reform of their speculations in this subject is needful, or that their science has placed herself in opposition to the principles of physics, they none the less pay their sincere homage to one who has thrown over geology, as over so many other departments of natural knowledge, the clear light of a penetrating and original genius.

When Lord Kelvin first developed his strictures on modern geology he expressed his opposition in the most uncompromising language. In the short paper to which reference has already been made he announced, without hesitation or palliation, that he 'briefly refuted' the doctrine of Uniformitarianism which had been espoused and illustrated by Lyell and a long list of the ablest geologists of the day. The severity of his judgment of British geology was not more marked than was his unqualified reliance on his own methods and results. This confident assurance of a distinguished physicist, together with a formidable array of mathematical formulæ, produced its effect on some geologists and palæontologists who were not Gallios. Thus, even after Huxley's brilliant defence, Darwin could not conceal the deep impression which Lord Kelvin's arguments had made on his mind. In one letter he wrote that the proposed limitation of geological time was one of his

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[1] Presidential Address. *Quart. Journ. Geol. Soc.* 1869.

[2] *Trans. Geol. Soc. Glasgow*, vol. iii. (March 26, 1868), p. 189. Sir W. Thomson acknowledged my adhesion in his reply to Huxley's criticism. *Op. cit.* p. 221.

'sorest troubles.' In another, he pronounced the physicist himself to be 'an odious spectre.'[1]

The same self-confidence of assertion on the part of some, at least, of the disputants on the physical side has continued all through the controversy. Yet when we examine the three great physical arguments in themselves, we find them to rest on assumptions which, though certified as 'probable' or 'very sure,' are nevertheless admittedly assumptions. The conclusions to which these assumptions lead must depend for their validity on the degree of approximation to the truth in the premisses which are postulated.

Now it is interesting to observe that neither the assumptions nor the conclusions drawn from them have commanded universal assent even among physicists themselves. If they were as self-evident as they have been claimed to be, they should at least receive the loyal support of all those whose function it is to pursue and extend the applications of physics. It will be remembered, however, that thirteen years ago Professor George Darwin, who has so often shown his inherited sympathy in geological investigation, devoted his presidential address before the Mathematical Section of this Association to a review of the three famous physical arguments respecting the age of the earth. He summed up his judgment of them in the following words: 'In considering these three arguments I have adduced some reasons against the validity of the first [tidal friction]; and have endeavoured to show that there are elements of uncertainty surrounding the second [secular cooling of the earth]; nevertheless they undoubtedly constitute a contribution of the first importance to physical geology. Whilst, then, we may protest against the precision with which Professor Tait seeks to deduce results from them, we are fully justified in following Sir William Thomson, who says that "the existing state of things on the earth, life on the earth—all geological history showing continuity of life, must be limited within some such period of past time as 100,000,000 years."'[2]

More recently Professor Perry has entered the lists, from the physical side, to challenge the validity of the conclusions so confidently put forward in limitation of the age of the earth. He has boldly impugned each of the three physical arguments. That which is based on tidal retardation, following Mr. Maxwell Close and Professor Darwin, he dismisses as fallacious. In regard to the argument from the secular cooling of the earth, he contends that it is perfectly allowable to assume a much higher conductivity for the interior of the globe, and that this assumption would vastly increase our estimate of the age of the planet. As to the conclusions drawn from the history of the sun, he maintains that, on the one hand, the sun may have been repeatedly fed by infalling meteorites, and that on the other the earth, during former ages, may have had its heat retained by a dense atmospheric envelope. He thinks that 'almost anything is possible as to the present internal state of the earth,' and he concludes in these words: 'To sum up, we can find no published record of any lower maximum age of life on the earth, as calculated by physicists, than 400 millions of years. From the three physical arguments, Lord Kelvin's higher limits are 1,000, 400, and 500 million years. I have shown that we have reasons for believing that the age, from all these, may be very considerably underestimated. It is to be observed that if we exclude everything but the arguments from mere physics, the *probable* age of life on the earth is much less than any of the above estimates; but if the palæontologists have good reasons for demanding much greater times, I see nothing from the physicist's point of view which denies them four times the greatest of these estimates.'[3]

This remarkable admission from a recognised authority on the physical side re-echoes and emphasises the warning pronounced by Professor Darwin in the address already quoted: 'At present our knowledge of a definite limit to geological time has so little precision that we should do wrong to summarily reject any

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[1] Darwin's *Life and Letters*, vol. iii. pp. 115, 146.

[2] *Rep. Brit. Assoc.*, 1886, p. 517.

[3] *Nature*, vol. li. p. 585, April 18, 1895.

theories which appear to demand longer periods of time than those which now appear allowable.'[1]

This 'wrong,' which Professor Darwin so seriously deprecated, has been committed not once, but again and again, in the history of this discussion. Lord Kelvin has never taken any notice of the strong body of evidence adduced by geologists and palæontologists in favour of a much longer antiquity than he is now disposed to allow for the age of the earth. His own three physical arguments have been successively re-stated, with such corrections and modifications as he has found to be necessary, and no doubt further alterations are in store for them. He has cut off slice after slice from the allowance of time which at first he was prepared to grant for the evolution of geological history, his latest pronouncement being that 'it was more than twenty and less than forty million years, and probably much nearer twenty than forty.'[2] But in none of his papers is there an admission that geology and palæontology, though they have again and again raised their voices in protest, have anything to say in the matter that is worthy of consideration.

It is difficult satisfactorily to carry on a discussion in which your opponent entirely ignores your arguments, while you have given the fullest attention to his. In the present instance, geologists have most carefully listened to all that has been brought forward from the physical side. Impressed by the force of the physical reasoning, they no longer believe that they can make any demands they may please on past time. They have been willing to accept Lord Kelvin's original estimate of 100 millions of years as the period within which the history of life upon the planet must be comprised; while some of them have even sought in various ways to reduce that sum nearer to his lower limit. Yet there is undoubtedly a prevalent misgiving, whether in thus seeking to reconcile their requirements with the demands of the physicist they are not tying themselves down within limits of time which on any theory of evolution would have been insufficient for the development of the animal and vegetable kingdoms.

It is unnecessary to recapitulate before this Section of the British Association, even in briefest outline, the reasoning of geologists and palæontologists which leads them to conclude that the history recorded in the crust of the earth must have required for its transaction a much vaster period of time than that to which the physicists would now restrict it.[3] Let me merely remark that the reasoning is essentially based on observations of the present rate of geological and biological changes upon the earth's surface. It is not, of course, maintained that this rate has never varied in the past. But it is the only rate with which we are familiar, which we can watch and in some degree measure, and which, therefore, we can take as a guide towards the comprehension and interpretation of the past history of our planet.

It may be, and has often been, said that the present scale of geological and biological processes cannot be accepted as a reliable measure for the past. Starting from the postulate, which no one will dispute, that the total sum of terrestrial energy was once greater than it is now and has been steadily declining, the physicists have boldly asserted that all kinds of geological action must have been more vigorous and rapid during bygone ages than they are to-day; that volcanoes were more gigantic, earthquakes more frequent and destructive, mountain-upthrows more stupendous, tides and waves more powerful, and commotions of the atmosphere more violent, with more ruinous tempests and heavier rainfall. Assertions of this kind are temptingly plausible and are easily made. But it is not enough that they should be made; they ought to be supported by some kind of evidence

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[1] *Rep. Brit. Assoc.* 1886, p. 518.

[2] 'The Age of the Earth,' Presidential Address to the Victoria Institute for 1897, p. 10; also in *Phil. Mag.* January 1899.

[3] The geological arguments are briefly given in my Presidential Address to the British Association at the Edinburgh Meeting of 1892. The biological arguments were well stated, and in some detail, by Professor Poulton in his Address to the Zoological Section of the Association at the Liverpool Meeting of 1896.

to show that they are founded on actual fact and not on mere theoretical possibility. Such evidence, if it existed, could surely be produced. The chronicle of the earth's history, from a very early period down to the present time, has been legibly written within the sedimentary formations of the terrestrial crust. Let the appeal be made to that register. Does it lend any support to the affirmation that the geological processes are now feebler and slower than they used to be? If it does, the physicists, we might suppose, would gladly bring forward its evidence as irrefragable confirmation of the soundness of their contention. But the geologists have found no such confirmation. On the contrary, they have been unable to discover any indication that the rate of geological causation has ever, on the whole, greatly varied during the time which has elapsed since the deposition of the oldest stratified rocks. They do not assert that there has been no variation, that there have been no periods of greater activity, both hypogene and epigene. But they maintain that the demonstration of the existence of such periods has yet to be made. They most confidently affirm that whatever may have happened in the earliest ages, in the whole vast succession of sedimentary strata nothing has yet been detected which necessarily demands that more violent and rapid action which the physicists suppose to have been the order of nature during the past.

So far as the potent effects of prolonged denudation permit us to judge, the latest mountain-upheavals were at least as stupendous as any of older date whereof the basal relics can yet be detected. They seem, indeed, to have been still more gigantic than those. It may be doubted, for example, whether among the vestiges that remain of Mesozoic or Palæozoic mountain-chains any instance can be found so colossal as those of Tertiary times, such as the Alps. No volcanic eruptions of the older geological periods can compare in extent or volume with those of Tertiary and recent date. The plication and dislocation of the terrestrial crust are proportionately as conspicuously displayed among the younger as among the older formations, though the latter, from their greater antiquity, have suffered during a longer time from the renewed disturbances of successive periods.

As regards evidence of greater violence in the surrounding envelopes of atmosphere and ocean, we seek for it in vain among the stratified rocks. Among the very oldest formations of these islands, the Torridon sandstone of North-West Scotland presents us with a picture of long-continued sedimentation, such as may be seen in progress now round the shores of many a mountain-girdled lake. In that venerable deposit, the enclosed pebbles are not mere angular blocks and chips, swept by a sudden flood or destructive tide from off the surface of the land, and huddled together in confused heaps over the floor of the sea. They have been rounded and polished by the quiet operation of running water, as stones are rounded and polished now in the channels of brooks or on the shores of lake and sea. They have been laid gently down above each other, layer over layer, with fine sand sifted in between them, and this deposition has taken place along shores which, though the waters that washed them have long since disappeared, can still be followed for mile after mile across the mountains and glens of the North-West Highlands. So tranquil were these waters that their gentle currents and oscillations sufficed to ripple the sandy floor, to arrange the sediment in laminæ of current-bedding, and to separate the grains of sand according to their relative densities. We may even now trace the results of these operations in thin darker layers and streaks of magnetic iron, zircon, and other heavy minerals, which have been sorted out from the lighter quartz-grains, as layers of iron-sand may be seen sifted together by the tide along the upper margins of many of our sandy beaches at the present day.

In the same ancient formation there occur also various intercalations of fine muddy sediment, so regular in their thin alternations, and so like those of younger formations, that we cannot but hope and expect that they may eventually yield remains of organisms which, if found, would be the earliest traces of life in Europe.

It is thus abundantly manifest that even in the most ancient of the sedimentary registers of the earth's history, not only is there no evidence of colossal floods, tides and denudation, but there is incontrovertible proof of continuous orderly deposition, such as may be witnessed to-day in any quarter of the globe. The same tale, with endless additional details, is told all through the stratified formations down to those which are in the course of accumulation at the present day.

Not less important than the stratigraphical is the palæontological evidence in favour of the general quietude of the geological processes in the past. The conclusions drawn from the nature and arrangement of the sediments are corroborated and much extended by the structure and manner of entombment of the enclosed organic remains. From the time of the very earliest fossiliferous formations there is nothing to show that either plants or animals have had to contend with physical conditions of environment different, on the whole, from those in which their successors now live. The oldest trees, so far as regards their outer form and internal structure, betoken an atmosphere neither more tempestuous nor obviously more impure than that of to-day. The earliest corals, sponges, crustaceans, mollusks, and arachnids were not more stoutly constructed than those of later times, and are found grouped together among the rocks as they lived and died, with no apparent indication that any violent commotion of the elements tried their strength when living or swept away their remains when dead.

But, undoubtedly, most impressive of all the palæontological data is the testimony borne by the grand succession of organic remains among the stratified rocks as to the vast duration of time required for their evolution. Professor Poulton has treated this branch of the subject with great fulness and ability. We do not know the present average rates of organic variation, but all the available evidence goes to indicate their extreme slowness. They may conceivably have been more rapid in the past, or they may have been liable to fluctuations according to vicissitudes of environment.[1] But those who assert that the rate of biological evolution ever differed materially from what it may now be inferred to be, ought surely to bring forward something more than mere assertion in their support. In the meantime, the most philosophical course is undoubtedly followed by those biologists who in this matter rest their belief on their own experience among recent and fossil organisms.

So cogent do these geological and palæontological arguments appear, to those at least who have taken the trouble to master them, that they are worthy of being employed, not in defence merely, but in attack. It seems to me that they may be used with effect in assailing the stronghold of speculation and assumption in which our physical friends have ensconced themselves and from which, with their feet, as they believe, planted well within the interior of the globe and their heads in the heart of the sun, they view with complete unconcern the efforts made by those who endeavour to gather the truth from the surface and crust of the earth. That portion of the records of terrestrial history which lies open to our investigation has been diligently studied in all parts of the world. A vast body of facts has been gathered together from this extended and combined research. The chronicle registered in the earth's crust, though not complete, is legible and consistent. From the latest to the earliest of its chapters the story is capable of clear and harmonious interpretation by a comparison of its pages with the present condition of things. We know infinitely more of the history of this earth than we do of the history of the sun. Are we then to be told that this knowledge, so patiently accumulated from innumerable observations and so laboriously co-ordinated and classified, is to be held of none account in comparison with the conclusions of physical science in regard to the history of the central luminary of our system? These conclusions are founded on assumptions which may or may not correspond with the truth. They have already undergone revision, and they may be still further modified as our slender knowledge of the sun, and of the details of its history, is increased by future investigation. In the meantime, we decline to accept them as a final pronouncement of science on the subject. We place over against them the evidence

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[1] See an interesting and suggestive paper by Professor Le Conte on 'Critical Periods in the History of the Earth,' *Bull. Dept. Geology, University of California*, vol. i. (1895), p. 313; also one by Professor Chamberlin on 'The Ulterior Basis of Time-divisions and the Classification of Geological History,' *Journal of Geology*, vol. vi. (1898), p. 449.

of geology and palæontology, and affirm that unless the deductions we draw from that evidence can be disproved, we are entitled to maintain them as entirely borne out by the testimony of the rocks.

Until, therefore, it can be shown that geologists and palæontologists have misinterpreted their records, they are surely well within their logical rights in claiming as much time for the history of this earth as the vast body of evidence accumulated by them demands. So far as I have been able to form an opinion, one hundred millions of years would suffice for that portion of the history which is registered in the stratified rocks of the crust. But if the palæontologists find such a period too narrow for their requirements, I can see no reason on the geological side why they should not be at liberty to enlarge it as far as they may find to be needful for the evolution of organised existence on the globe. As I have already remarked, it is not the length of time which interests us so much as the determination of the relative chronology of the events which were transacted within that time. As to the general succession of these events, there can be no dispute. We have traced its stages from the bottom of the oldest rocks up to the surface of the present continents and the floor of the present seas. We know that these stages have followed each other in orderly advance, and that geological time, whatever limits may be assigned to it, has sufficed for the passage of the long stately procession.

We may, therefore, well leave the dispute about the age of the earth to the decision of the future. In so doing, however, I should be glad if we could carry away from it something of greater service to science than the consciousness of having striven our best in a barren controversy, wherein concession has all to be on one side and the selection of arguments entirely on the other. During these years of prolonged debate I have often been painfully conscious that in this subject, as in so many others throughout the geological domain, the want of accurate numerical data is a serious hindrance to the progress of our science. Heartily do I acknowledge that much has been done in the way of measurements and experiments for the purpose of providing a foundation for estimates and deductions. But infinitely more remains to be accomplished. The field of investigation is almost boundless, for there is hardly a department of geological dynamics over which it does not extend. The range of experimental geology must be widely enlarged, until every process susceptible of illustration or measurement by artificial means has been investigated. Field-observation needs to be supplemented where possible by instrumental determinations, so as to be made more precise and accurate, and more capable of furnishing reliable numerical statistics for practical as well as theoretical deductions.

The subject is too vast for adequate treatment here. But let me illustrate my meaning by selecting a few instances where the adoption of these more rigid methods of inquiry might powerfully assist us in dealing with the rates of geological processes and the value of geological time. Take, for example, the wide range of lines of investigation embraced under the head of Denudation. So voluminous a series of observations has been made in this subject, and so ample is the literature devoted to it, that no department of geology, it might be thought, has been more abundantly and successfully explored. Yet if we look through the pile of memoirs, articles, and books, we cannot but be struck with the predominant vagueness of their statements, and with the general absence of such numerical data determined by accurate, systematic, and prolonged measurement as would alone furnish a satisfactory basis for computations of the rate at which denudation takes place. Some instrumental observations of the greatest value have indeed been made, but, for the most part, observations of this kind have been too meagre and desultory.

A little consideration will show that in all branches of the investigation of denudation opportunities present themselves on every side of testing, by accurate instrumental observation and measurement, the rate at which some of the most universal processes in the geological *régime* of our globe are carried on.

It has long been a commonplace of geology that the amount of the material removed in suspension and solution by rivers furnishes a clue to the rate of denudation of the regions drained by the rivers. But how unequal in value, and generally how insufficient in precision, are the observations on this topic! A few rivers have been more or less systematically examined, some widely varying results have been obtained from the observations, and while enough has been obtained to show the interest and importance of the method of research, no adequate supply of materials has been gathered for the purposes of accurate deduction and generalisation. What we need is a carefully organised series of observations carried out on a uniform plan, over a sufficient number of years, not for one river only, but for all the important rivers of a country, and indeed for all the greater rivers of each continent. We ought to know as accurately as possible the extent of the drainage-area of each river, the relations of river-discharge to rainfall and to other meteorological as well as topographical conditions; the variation in the proportions of mechanical and chemical impurities in the river-water according to geological formations, form of the ground, season of the year and climate. The whole geological *régime* of each river should be thoroughly studied. The admirable report of Messrs. Humphreys and Abbot on the 'Physics and Hydraulics of the Mississippi,' published in 1861, might well serve as a model for imitation, though these observers necessarily occupied themselves with some questions which are not specially geological and did not enter into others on which, as geologists, we should now gladly have further information.

Again, the action of Glaciers has still less been subjected to prolonged and systematic observation. The few data already obtained are so vague that we may be said to be still entirely ignorant of the rate at which glaciers are wearing down their channels and contributing to the denudation of the land.

The whole of this inquiry is eminently suitable for combined research. Each stream or glacier, or each well-marked section of one, might become the special inquiry of a single observer, who would soon develop a paternal interest in his valley and vie with his colleagues of other valleys in the fulness and accuracy of his records.

Nor is our information respecting the operations of the Sea much more precise. Even in an island like Great Britain, where the waves and tides effect so much change within the space of a human lifetime, the estimates of the rate of advance or retreat of the shore-line are based for the most part on no accurate determinations. It is satisfactory to be able to announce that the Council of this Association has formed a Committee for the purpose of obtaining full and accurate information regarding alterations of our coasts, and that with the sanction of the Lords of the Admiralty the co-operation of the Coast-guard throughout the three kingdoms has been secured. We may therefore hope to be eventually in possession of trustworthy statistics on this interesting subject.

The disintegration of the surface of the land by the combined agency of the Subaërial forces of decay is a problem which has been much studied, but in regard to whose varying rates of advance not much has been definitely ascertained. The meteorological conditions under which it takes place differ materially according to latitude and climate, and doubtless its progress is equally variable. An obvious and useful source of information in regard to atmospheric denudations is to be found in the decay of the material of buildings of which the time of erection is known, and in dated tombstones. Twenty years ago I called attention to the rate at which marble gives way in such a moist climate as ours, and cited the effects of subaërial waste as these can be measured on the monuments of our graveyards and cemeteries.[1] I would urge upon town-geologists, and those in the country who have no opportunities of venturing far afield, that they may do good service by careful scrutiny of ancient buildings and monuments. In the churchyards they will find much to occupy and interest them, not, however, like Old Mortality, in repairing the tombstones, but in tracing the ravages of the weather upon them, and in obtaining definite measures of the rate of their decay.

The conditions under which subaërial disintegration is effected in arid climates, and the rate of its advance, are still less known, seeing that most of our information is derived from the chance observations of passing travellers. Yet this branch

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[1] *Proc. Roy. Soc. Edin.* vol. x. (1879–80), p. 518.

of the subject is not without importance in relation to the denudation not only of the existing terrestrial surface but of the lands of former periods, for there is evidence of more than one arid epoch in geological history. Here, again, a diligent examination of ancient buildings and monuments might afford some, at least, of the required data. In such a country as Egypt, for instance, it might eventually be possible to determine from a large series of observations what has been the average rate of surface-disintegration of the various kinds of stone employed in human constructions that have been freely exposed to the air for several thousand years.

Closely linked with the question of denudation is that of the Deposition of the material worn away from the surface of the land. The total amount of sediment laid down must equal the amount of material abstracted, save in so far as the soluble portions of that material are retained in solution in the sea. But we have still much to learn as to the conditions, and especially as to the rate, of sedimentation. Nor does there appear to be much hope of any considerable increase to our knowledge until the subject is taken up in earnest as one demanding and justifying a prolonged series of well-planned and carefully executed observations. We have yet to discover the different rates of deposit, under the varying conditions in which it is carried on in lakes, estuaries, and the sea. What, for instance, would be a fair average for the rate at which the lakes of each country of Europe are now being silted up? If this rate were ascertained, and if the amount of material already deposited in these basins were determined, we should be in possession of data for estimating not only the probable time when the lakes will disappear, but also the approximate date at which they came into existence.

But it is not merely in regard to epigene changes that further more extended and concerted observation is needed. Even among Subterranean movements there are some which might be watched and recorded with far more care and continuity than have ever been attempted. The researches of Professor George Darwin and others have shown how constant are the tremors, minute but measurable, to which the crust of the earth is subject.[1] Do these phenomena indicate displacements of the crust, and, if so, what in the lapse of a century is their cumulative effect on the surface of the land?

More momentous in their consequences are the disturbances which traverse Mountain-chains and find their most violent expression in shocks of Earthquake. The effects of such shocks have been studied and recorded in many parts of the world, but their cause is still little understood. Are the disturbances due to a continuation of the same operation which at first gave birth to the mountains? Should they be regarded as symptoms of growth or of collapse? Are they accompanied with even the slightest amount of elevation or depression? We cannot tell. But these questions are probably susceptible of some more or less definite answer. It might be possible, for instance, to determine with extreme precision the heights above a given datum of various fixed points along such a chain as the Alps, and by a series of minutely accurate measurements to detect any upward or downward deviation from these heights. It is quite conceivable that throughout the whole historical period some deviation of this kind has been going on, though so slowly, or by such slight increments at each period of renewal, as to escape ordinary observation. We might thus learn whether, after an Alpine earthquake, an appreciable difference of level is anywhere discoverable, whether the Alps as a great mountain-chain are still growing or are now subsiding, and we might be able to ascertain the rate of the movement. Although changes of this nature may have been too slight during human experience to be ordinarily appreciable, their very insignificance seems to me to supply a strong reason why they should be sought for and carefully measured. They would not tell us, indeed, whether a mountain-chain was called into being in one gigantic convulsion, or was raised at wide intervals by successive uplifts, or was slowly elevated by one prolonged and continuous movement. But they might furnish us with suggestive information as to the rate at which upheaval or depression of the terrestrial crust is now going on.

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[1] *Report Brit. Assoc.* 1882, p. 95.

The vexed questions of the origin of Raised Beaches and Sunk Forests might in like manner be elucidated by well-devised measurements. It is astonishing upon what loose and unreliable evidence the elevation or depression of coast-lines has often been asserted. On shores where proofs of a recent change of level are observable it would not be difficult to establish by accurate observation whether any such movements are taking place now, and, if they are, to determine their rate. The old attempts of this kind along the coasts of Scandinavia might be resumed with far more precision and on a much more extended scale. Methods of instrumental research have been vastly improved since the days of Celsius and Linnæus. Mere eye-observations would not supply sufficiently accurate results. When the datum-line has been determined with rigorous accuracy, the minutest changes of level, such as would be wholly inappreciable to the senses, might be detected and recorded. If such a system of watch were maintained along coasts where there is reason to believe that some rise or fall of land is taking place, it would be possible to follow the progress of the movement and to determine its rate.

But I must not dwell longer on examples of the advantages which geology would gain from a far more general and systematic adoption of methods of experiment and measurement in elucidation of the problems of the science. I have referred to a few of those which have a more special bearing on the question of geological time, but it is obvious that the same methods might be extended into almost every branch of geological dynamics. While we gladly and gratefully recognise the large amount of admirable work that has already been done by the adoption of these practical methods, from the time of Hall, the founder of experimental geology, down to our own day, we cannot but feel that our very appreciation of the gain which the science has thus derived increases the desire to see the practice still further multiplied and extended. I am confident that it is in this direction more than in any other that the next great advances of geology are to be anticipated.

While much may be done by individual students, it is less to their single efforts than to the combined investigations of many fellow-workers that I look most hopefully for the accumulation of data towards the determination of the present rate of geological changes. I would, therefore, commend this subject to the geologists of this and other countries as one in which individual, national, and international co-operation might well be enlisted. We already possess an institution which seems well adapted to undertake and control an enterprise of the kind suggested. The International Geological Congress, which brings together our associates from all parts of the globe, would confer a lasting benefit on the science if it could organise a system of combined observation in any single one of the departments of inquiry which I have indicated or in any other which might be selected. We need not at first be too ambitious. The simplest, easiest, and least costly series of observations might be chosen for a beginning. The work might be distributed among the different countries represented in the Congress. Each nation would be entirely free in its selection of subjects for investigation, and would have the stimulus of co-operation with other nations in its work. The Congress will hold its triennial gathering next year in Paris, and if such an organisation of research as I have suggested could then be inaugurated a great impetus would thereby be given to geological research, and France, again become the birthplace of another scientific movement, would acquire a fresh claim to the admiration and gratitude of geologists in every part of the globe.

THURSDAY, SEPTEMBER 14.

The following Papers and Reports were read:—

1. *On the Relation between the Dover and Franco-Belgian Coal Basins.*
By ROBERT ETHERIDGE, *F.R.S.*

That the history of the stratified rocks of the south-east of England, and South-eastern Kent in particular, is in a fair way of being determined there is little doubt, this being mainly accomplished through the numerous trials by boring at sites selected where the probability of the continuity of the Coal Measures may be determined, westward, or beyond Dover, towards the South Somerset coalfield or southern end of the Bristol coal basin.

The physical identity of the coal-bearing district of Southern Somerset on the west with the coalfields of Northern France and Belgium to the east was recognised as far back as 1826, as well as the fact that the Coal Measures and their associated or accompanying coals lie deeply buried under a variable thickness of Cretaceous and Tertiary rocks.

It now remains to practically trace and extend the Belgian and French coalfields further west from Dover, which it is believed will ultimately prove to constitute a continuous chain of isolated coal basins extending to the northern side of the Mendip Hills to join the exposed coalfield of Nettlebridge and Vobster south of the Radstock and Farrington basins.

The Dover boring, carried down to the depth of 2,225 feet, has shown that the deeper coals are of the same character as the rich bituminous coals of Mons and Bruay, but thicker; the four lower seams at Dover unitedly measure 12 feet. The extent of the unexplored area between Dover and the Great Western coal track, originally included in the South Wales, Somerset and Gloucester, or Bristol coalfield, is about 160 miles.

The upper series or the Radstock and Farrington basins, which lie above or rest upon the thick Pennant sandstones, contain the thin but finest bituminous coals, which appear upon analysis to correspond chemically with the coals at Dover and those of the French and Belgian basins, especially those of Mons and Valenciennes.

The lower coals proved at Dover appeared to be of as high a class as the Radstock, and also will compare with the thirty-seven samples of Welsh coals which were analysed by Sir H. De la Beche and Dr. Lyon Playfair in 1850.

—	The 4 lower seams of the Dover Coal	37 Samples of South Wales Coal required for the Navy
Carbon . .	83·80	83·78
Hydrogen . .	4·65	4·79
Nitrogen . .	·97	·98
Oxygen . .	3·23	4·15
Heating power .	14·858 units	14·858 units

Comparison with 53 samples of the midland and north country coals suited for the Royal Navy, and analysed by the same two gentlemen in 1850, is even closer and more favourable :—

—	Coal from the Dover boring	Newcastle	Derby and Yorkshire	Lancashire
		18 Samples	7 Samples	28 Samples
Carbon . .	83·80	82·12	79·68	77·90
Hydrogen .	4·65	5·31	4·94	5·32
Nitrogen .	·97	4·94	1·41	1·30
Oxygen . .	3·23	5·69	10·28	9·53
Heating power	14·867	14·820	13·860	13·19

The coal at Dover is uniformly good, pure, and clean throughout the twelve seams which were penetrated in a thickness of 1,054 feet, the four-foot seam being at present the thickest. The borehole was carried down 105 feet below the four-foot to test the continuity of the Coal Measures still remaining to be proved. The most easterly of the eight coal basins, that of the Ruhr, gives names to the second largest and most productive coalfield in Germany, ranging 60 miles from west to east, with a breadth of 25 miles or 1,500 square miles.

This area is partly Westphalian and east of the Rhine, followed west by the coalfields of Aix-la-Chapelle and Liège; the great east and west fields of Hainaut, comprising Namur, Charleroi, and Mons; then succeeded west by the prolific coalfield of Valenciennes, in the Pas-de-Calais.

That these coal basins were originally connected, and extended from the Rhine and Eastern Belgium to Somersetshire immediately north of the Mendip Hills, is now admitted.

Their mean thickness, where taken in their most complete series, shows similar results, as given in the following table:—

Mean Thickness of the Five Great Coalfields.

South Wales	Bristol Somerset (South)	Hainaut, Charleroi, and Mons	Liège	Westphalia
10,000 ft.	8,400 ft.	9,400 ft.	7,600 ft.	7,218 ft.

It is important to notice also in tabular form the number of coal-seams and the workable thickness of the same.

—	South Wales	Bristol Somerset (South)	Hainaut, Charleroi, and Mons	Liège	Westphalia
Number of seams of coal	75	55	110	85	117
Total thickness of workable coal	120 ft.	98 ft.	230 ft.	212 ft.	294 ft.

One probable cause of the greater amount of coal in these Continental coalfields as compared with the two British areas where the Pennant is only developed, as in the South Wales and the Bristol coal-basins, arises from the fact that the so-called *Pennant Rock,* which is from 2,000 feet to 3,000 feet thick in the Bristol and South Wales coalfields, and containing but little coal, is replaced by the more productive Coal Measures, with workable coal, in Belgium and North France.

Again, the general characters of the groups of coal seams have often a distinctive element amongst themselves, such similarity being maintained in all essential points throughout Belgium, North France, and Britain; this persistence of the same physical character both in South Wales, Somerset, and Gloucestershire is a condition most important to note; and although the South Wales coalfield is separated from the Bristol basin by 30 miles, yet in the mass and general structure they show strongly marked and definite physical features and relations.

Table of Comparison between the Two Basins.

	Coal Measures of South Wales			Coal Measures of the Bristol Coal basin	
Upper	Sandstones and shales with 26 seams of coal	3,400 ft. thick	Upper	Sandstones and shales with 18 seams of coal	2,600 ft. thick
Middle	Pennant Sandstone Rock with 15 coal seams	3,260 ft. thick	Middle	Pennant Rock Sandstone with 4 or 5 seams of coal	3,000 ft. thick
Lower	Shales and sandstones and ironstone with 34 seams	400–1,400 ft. thick	Lower	Shales and sandstones with ironstone and 28 seams of coal	2,800 ft. thick
		8,060 ft.			8,400 ft.

The coal basins of Belgium and France owe their origin or geological and geographical position to the one great line or axis of disturbance which can be traced from the south of Ireland to Frome (Somersetshire) through the Pembroke, South Wales, and southern end of the Somersetshire coalfield, and parallel to the disturbed axis of the Mendip Hills, to Mells, Elm, Nunney, and Frome, then lost under the unconformable overlap of the Jurassic and Cretaceous strata of Wilts, Hants, Sussex, and South-east Kent, until again revealed and determined through the two, if not three, deep and remarkable borings, that of West Brabourne, 5 miles east of Ashford, to the depth of 2,003 feet. The partly completed and important boring at Ropersole, south of Barham, 1,773 feet 6 inches, and the pioneer borehole by Mr. F. Brady at Great Fall, west of Dover, in 1892, to the depth of 2,225 feet, and now the site of the two deep coalpits, immediately west of the Shakespeare Tunnel. Mr. Brady's trial proved the thickness of the overlying Jurassic and Cretaceous rocks to be 1,112 feet, touching the true Coal Measures at 1,113 feet, terminating with the four-foot seam of coal at 2,225 feet, but the floor of the Dover Coal Measures is yet unknown.

In Belgium and North France the Carboniferous rocks have been persistently and practically followed along a given line, but in England the Coal Measures of Gloucestershire and Somersetshire have not been traced eastwards, or beyond the well-defined eastern escarpment of the Bristol and Somerset coalfield, ranging from north to south from Tortworth to Frome, or from the eastern end of the Mendip range beyond Frome.

We now know without doubt the range and thicknesss of the Jurassic rocks below the overlying Cretaceous series in South-east Kent at Brabourne, Ropersole, and Dover, where the most complete succession has been determined, and a *complete series* of the cores preserved, from the top of the Gault to the base of the Lower Lias inclusive, from the Brabourne borehole, and a Triassic conglomerate new to this area, and also the French and Belgian line of coal basins.

Comparative Thickness between the Brabourne Boring and that of Dover.

Brabourne[1]		Ft.	in.	Dover (Mr. F. Brady, C.E.)		
Creta-ceous 708 ft.	Gault . . .	72	6	182 ft.	Grey Chalk and Chalk Marl Chloritic Marl	Cretaceous 544 ft.
	Neocomian .	231	0			
	Weald Clay .	198	0			
	Hastings beds .	206	6	121 ft.	Gault.	
Jurassic 1,165 ft. 10 in.	Portland Oolite .	14	0	241 ft.	Lower Greensand, Wealden and Hastings Beds	
	Kimmeridge Clay	242	0			
	Corallian . .	305	0			
	Oxfordian . .	243	0	613 ft.	Upper, Middle, and Lower Oolites with Lias at the bottom	Jurassic 613 ft.
	Bathonian . .	189	1			
	Middle Lias .	74	8			
	Lower Lias .	98	1			
Triassic 48 ft. 4 in.	Triassic Conglomerates	48	4	1157 ft.	Coal Measures with eight workable seams containing 16 feet of bright bituminous coal	Palæozoic Coal Measures
		1936	2			
Palæozoic 88·5 ft.	Palæozoic Rock unknown	88	5			
		2024	7			

There can be little doubt as to the value of the Dover or South-eastern Kent coal basin, with its present known or determined resources; when we consider the great capacity of the French, Belgian, and Westphalian coalfields, with their numerous and successful workings, and the determined and scientific way in which their wealth has been, and is now being developed, at times under great difficulties, we

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[1] Five miles east of Ashford.

cannot doubt the westerly continuity of these Continental coalfields with their vast wealth of fuel.

It is, however, by trial only that this important problem or question of value can be solved, and we are now obtaining much insight into the intimate geological structure of the coal-bearing rocks of the south-east of England, and Kent in particular; neither can we doubt the Continental relationship established between Eastern France and Belgium with ourselves, with regard to the solution of so large a problem as the westerly extension of their coalfields, and coals under the Straits of Dover to meet the new enterprise at Dover, established upon and through the practical knowledge obtained from the great works in the Borinage and the wealthy coalfields of Hainaut.

This naturally gives rise to the significant question, Are the coals at Dover, as compared with the great and prolific coalfields of France and Belgium, within the depth and capacity at which coal-mining can be carried on at a profit?

The eight workable seams at Dover commence at 1,113 feet from the surface, the Coal Measures being proved to be 782 feet thick with 16 feet of workable coal, the lowest or four-foot seam being reached at 2,225 feet 6 inches; this is well within the limit of practical working—many of the important coal pits in this country are worked at much greater depths, ranging from 2,800 feet to over 3,000 feet.

The Royal Commission of 1871, under the presidency of the Duke of Argyll, appointed 'to look into the question of several matters relating to our coal in the United Kingdom,' fixed the limit of safe working at 4,000 feet, on account of the underground temperature at that depth being 98° or blood heat, hence the legal limit of practical working to that depth.

Connection through the palæozoic rocks of France and Belgium with those of the same age in South-east Kent has now been well determined; the 22 miles of what is now sea has been, and probably will again be, dry and continuous land. We may now regard this, for want of under-water testing, as probably one of the north and south trough-like or transverse fractures occurring along or between the severed coal basins between Calais and Westphalia and the valley of the Rhine, notably those of Liège, Mons, Bristol and South Wales, &c.

The interest and value attached to the discovery of coal at Dover is both national and scientific; it is as much Continental as British—North France, Belgium, and Western Germany have each and all been closely and physically united to us by a series of now disunited yet connected and rich coal basins, occupying the extended line between Dover and the Rhine valley marked and distinguished by the great works at Valenciennes, Mons, Charleroi, Liège, and the Prussian province of Westphalia.

We must now bridge the Dover Straits and include the 22 miles of water, as covering an additional and buried coalfield, the westerly termination of which is now being practically tested, by the great undertaking beneath the far-famed cliffs west of Dover, and I doubt not of its westerly development and continuity to the northern side of the Mendip Hills, or to the exposed coalfield of Nettlebridge, Holcombe, and Vobster, and this with ultimate success under our four great masters—Patience, Perseverance, Money, and Time.

2. *On the South-Eastern Coalfield.*

By Professor W. BOYD DAWKINS, *M.A., F.R.S.*

The discovery of a coalfield in 1890 at Dover, in a boring at the foot of the Shakespeare Cliff, has been already brought before the British Association by the author at Cardiff in 1892, and is so well known that it is unnecessary to enter into details other than the following. The carboniferous shales and sandstones contain twelve seams of coal, amounting to a total thickness of 23 feet 5 inches. These occur at a depth of 1,100 feet 6 inches below Ordnance datum, and have been penetrated to a depth of 1,064 feet 6 inches, or 2,177 feet 6 inches from the surface. They are identical, as I have shown elsewhere,[1] with

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[1] *Proc. Royal Inst.*, June 6, 1890; *Trans. Manchester Geol. Soc.*, xxii., Feb. 2, 1894; xxv., Feb. 9, 1897.

the rich and valuable coalfields of Somersetshire on the west, and of France and Belgium on the east. This discovery is of great practical value, as it will probably result in the same development in Kent of industries and manufactures which has taken place where the coal has been worked, under the same conditions, under the Cretaceous and Jurassic rocks in France and Belgium. It is of equally great theoretical value, as it proves up to the hilt the truth of Godwin-Austen's view, published in 1858, that the coal measures lie buried underneath the newer rocks in South-eastern England.

After the boring was completed in 1893 the discovery lay dormant until in 1897 the Kent Collieries Corporation began to sink shafts on the site of the boring, and to put down boreholes at Brabourne and Pluckley, in the Weald of Kent, to verify the range of the coal measures in the property which they held under lease.

The Mid-Kent Coal Syndicate also put down a boring at Penshurst, and the Kent Coal Exploration Company began work in various parts of eastern Kent. The borings of the two latter undertakings have been carried on under my supervision, and none of them, as yet, is completed. They, nevertheless, throw important light on the range of the coal measures in South-eastern England, and are not unworthy of being brought before this meeting of the British Association.

The first boring to be noticed is at Ropersole, a spot near the highway between Dover and Canterbury—eight miles from Dover, at 400 feet above O.D.—the surface being composed of Upper Chalk, with a thin stratum of Clay-with-Flints. It was begun at the close of 1897, and has at the present time pierced the strata to a depth of 1,773 feet 7 inches.

It is being carried out under the able superintendence of Mr. James Newton, resident engineer, with the calyx drill, with the occasional use of a diamond crown for the lower and harder rocks. The result in both cases is a solid core. The section is as follows:

Ropersole, 400 *O.D.*

—	Thickness		Below Ordnance datum	
	feet	in.	feet	in.
Upper Cretaceous	953	0	553	0
Upper Chalk	480	0	80	0
Middle Chalk	118	0	198	0
Lower Grey Chalk	220	0	418	0
Glauconitic Marl	16	0	434	0
Gault	119	0	553	0
Neocomian	72	0	625	0
Lower Greensand	51	0	604	0
Atherfield Clay	21	0	625	0
Purbeck-Wealden Beds	55	0	680	0
Oolitic	472	0	1,152	0
Kimmeridge Clay (?)	10	0	690	0
Corallian	157	0	847	0
Oxfordian, Callovian	142	0	989	0
Bathonian	164	0	1,153	0
Liassic	27	9	1,180	9
Upper Lias (?)	3	0	1,156	0
Middle Lias	24	9	1,180	9
Coal Measures	192	10	1,373	7
Shales and Underclays	69	3	1,250	0
First Coal	0	9	1,250	9
Shales and Underclays	50	6	1,301	3
Second Coal	0	6	1,301	9
Shales and Underclays	22	3	1,324	0
Micaceous Sandstones	49	7	1,377	7

The coal measures contain the usual carboniferous plants—Sigillaria, Lepidodendron, and ferns, and the usual Stigmarian roots and rootlets, and, like those which we struck in the borehole at Dover, are probably horizontal. The coal is bright and blazing, and breaks up into little cubes, but slightly deformed by pressure into the lozenge-shape. In this respect it agrees with the coals of Dover, and like them shows no sign of crushing. The horizontality of the beds in both these cases may be accounted for by the boreholes happening to strike the bottom of a carboniferous synclinal fold. This conclusion, viewed in the light of the coalfields of France and Belgium on the one hand, and of Somerset on the other, is more probable than the view that they extend horizontally over a very large area.

It is strengthened by the fact that the rocks, probably Devonian, struck at the bottom of the borehole at Brabourne, some few miles to the west, are inclined at a high angle. They here are a portion of an anticline which is probably related to the coal measures above them, as the Devonian axis of the Mendip Hills is related to the syncline of the Somerset coalfield.

In my opinion the coal measures of Ropersole are a portion of the same series as those at Dover. Here, as at Dover, the question of seams of coal resolves itself probably into a question of sinking deeper. Here only two unimportant seams have been met with in a thickness of 197 feet. There twelve seams were penetrated in a thickness of 1,054 feet 6 inches, the thickest 4-feet seam being at the bottom.

The Ropersole boring establishes the fact that the Dover coal measures extend northwards for a distance of eight miles and beyond in the direction of Canterbury.

It remains now to see how far the range of the South-eastern coalfield has been proved by other borings. None of the three others which are now being carried on by the Kent Coal Exploration Company at Ottinge, Hothfield, and Old Soar to the north of Tonbridge has been carried deep enough to give any evidence. We are, however, indebted to Mr. Etheridge[1] for conclusive proof that its south-western boundary does not extend as far to the south-west as Brabourne. Here a fine-grained grey argillaceous sandstone, in my opinion Devonian, was struck in a boring at a depth of 1,921 feet 5 inches from the surface, the strata being inclined at a high angle, and being covered by a red dolomitic conglomerate of Triassic age, just as similar rocks occur in the central axis of the Mendip Hills. This boring has verified the exact position of the Pembroke-Mendip anticlinal fold, which I mapped in 1894.[2] It ranges in a north-west and south-easterly direction close under the line of the Chalk downs from Folkestone to Wye, a few miles to the north of the theoretical line of my map, and forms the southern boundary of the South-eastern coalfield. In Somersetshire it emerges from beneath the Triassic and Jurassic strata in the Mendip Hills, and in Northern France along the low hills sweeping from Hardinghen past Ferques in the direction of Cape Gris Nez, where, as in the Mendip range, it is traversed by many faults.

The coal measures set in in Kent at a sufficient distance to the north-east of Brabourne to allow of the presence of the Carboniferous Limestone and Millstone Grit. These probably dip at the same high angle as the Devonian below. Their south-western boundary can only be accurately defined by further borings such as that which we are now carrying on at Ottinge, about two and a half miles to the north-east of the scarp of the Downs, and six miles to the south-west of Ropersole. Their range to the north and the east still remains to be proved. They are, however, continued under the Channel, and have been proved by the boring at Calais in 1850 as well as those carried out in 1898 at Strouannes near Wissant. In this district they are clearly shown by other borings to be faulted into the Devonian and other pre-coal-measure rocks.

The thickness and value of this South-eastern coalfield can only be estimated by the exposed coalfields of Northern France and Belgium, and of Somerset. That of Liège is 7,600 feet thick and contains eighty-five seams, presenting an

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[1] Brit. Assoc. Bristol Meeting, 1898.

[2] The Probable Range of the Coal Measures in Southern England. *Trans. Federated Institution of Mining Engineers*, vol. vi. Map.

aggregate thickness of 212 feet of workable coal. That of Mons is 9,400 feet with 110 seams yielding 250 feet of coal. In Somersetshire the coalfield is 8,400 feet thick, the seams are fifty-five in number, and yield 120 feet of available coal. It is obvious from these figures that the possibilities of the South-eastern coalfield are very great, although it still remains to be proved how far these great thicknesses of rock have been denuded in Kent before the deposition of the Triassic and Jurassic rocks.

The upper denuded surface of the South-eastern field was struck at Ropersole at a depth of 1,373 feet 7 inches below Ordnance datum, and at Dover at 1,100 feet 6 inches. If the rocks which have to be traversed above O.D. be added, the resulting figures of about 1,600 feet necessary to sink from the surface are well within the depth to which coal is now being worked at a profit in England and in France and Belgium. The coal is well within the 4,000-feet limit laid down by the Coal Commission of 1872.

The strata overlying the coal measures at Ropersole and Dover present points of great geological interest bearing on the geographical conditions under which they were formed, as may be seen from the following table:—

Table of Comparative Thicknesses of Neocomian and Jurassic Rocks at Dover and Ropersole.

—	Dover	Ropersole
	ft. in.	ft. in.
Neocomian	124 8	72 0
Purbeck-Wealden	94 6	55 0
Oolitic	634 10	472 0
Liassic		27 9

All these rocks are thinning off to the northwards against the carboniferous and pre-carboniferous rocks, which form the 'axis of Artois' of Godwin-Austen, as he foresaw in 1858 that they must thin off in South-eastern England. South and west of the meridian of Dover they thicken very rapidly, the Neocomians being 244 feet, the Purbeck-Wealden of Kent and Sussex being not much less than 2,000 feet thick, and the Jurassic rocks of considerable though unknown thickness. In the Netherfield boring, near Battle in the Hastings district, the Upper and Middle Oolites are proved to be more than 1,700 feet thick.

The evidence of the other boreholes under my supervision proves that the thickening of the Neocomian, Purbeck-Wealden, and Upper Jurassic strata to the south of the downs between Folkestone and Tonbridge is very considerable. It is summed up in the following table:—

—	Ottinge	Hothfield	Old Soar	Penshurst
Neocomian	246	180 +	? 50	—
Purbeck-Wealden	146	593	650	1,511
Portlandian	—	—	—	—
Kimmeridge Clay	—	—	—	356 +

The Purbeck-Wealden beds also show a considerable thickening to the west, if the boring at Ottinge be compared with that of Penshurst, near Tonbridge, where the boring began low down in the Ashdown Sand, the lowest member but one of the group.

It remains for us to sum up the results of these borings, which are likely to effect the same economic revolution in Kent as was brought about in France by the extension of the coalfield of Valenciennes and Mons, about ninety-five miles to the west of its original outcrop at the surface, and to within some thirty miles of Calais. The coalfield has been proved at Dover. Its range for eight miles to the north has been also proved at Ropersole. Its southern boundary, as yet ill-defined, is marked by the Pembroke-Mendip anticline, ranging under the southern scarp of the chalk downs. Its range in other directions is unknown, and awaits further investigation. To the south of this anticline the palæozoic floor is probably composed of pre-coal-measure rocks. If, however, the coal measures do occur, they are buried under such great thicknesses of superincumbent rock—largely sands and loams full of water—that it will be difficult to work them. We know now by experiment not only where to seek, but also where it is advisable not to seek for the coal measures. The difficult problem of the buried coal measures in South-eastern England, now being worked out by private enterprise, is likely to add greatly to the resources of this country, as it has already added to the wealth of geological knowledge.

3. *Note on a Boring through the Chalk and Gault near Dieppe.*
By A. J. Jukes-Browne, *B.A., F.G.S.*

The following particulars of a boring for water made at Puys, near Dieppe, in 1898, have been communicated to me by Messrs. Le Grand & Sutcliff, the site of the boring being about 45 feet above the sea, and not more than 50 yards from high-water mark.

—	Metres	Feet
Chalk without flints	156	511½
Greensand and sandy clay	2	6½
Gault clay	42	137¾
Black sand and pyrites passing down into clean quartzose sand	11½	37¾
Total	211½	693½

The 'chalk without flints' will correspond to our Lower and Middle Chalk, and must include chalk which, on the English side, generally contains a few flints. The two metres of greensand and sandy clay at the base of this is probably what is generally known in England as Chloritic Marl, the zone of *Stauronema Carteri*, which is 15 feet thick at Folkestone, but less beneath Dover.

No sandy beds referable to 'Upper Greensand' are recorded, and the Gault seems to be entirely represented by clay, as at Folkestone and Dover. The black sand with pyrites should doubtless be regarded as the basement bed of the Gault, but the clean quartzose sand below is probably the equivalent of the highest part of the Vectian or Lower Greensand.

A good supply of water was found in these sands, rising to 12 feet above the surface of the ground.

From this boring it would appear that the Folkestone and Wissant facies of the Gault extends southward as far as Dieppe, a distance of about 52 miles.

4. *Some Recent Work among the Upper Carboniferous Rocks of North Staffordshire, and its bearing on concealed Coal-fields. By* Walcot Gibson, *F.G.S.*

[Communicated by permission of the Director-General of the Geological Survey.]

There is every reason to believe that in the near future the supplies of coal lying beneath the Red Rocks of the Midland counties will have to be relied upon to meet the increasing demand.

Workable seams of coal have been met with at reasonable depths beneath the Red Rocks surrounding the South Staffordshire coalfield, but there remain large areas lying between the known coalfields of Shropshire, North Staffordshire, and Nottinghamshire, which have not at present been explored. Within this region, as shown on the published maps of the Geological Survey, there are considerable areas of so-called Permian rocks, which recent investigations have proved to be conformable to the upper coal-measures, and to contain a coal-measure flora. Thus Mr. T. C. Cantrill has shown that in the forest of Wyre the so-called Permian rocks contain thin coal-seams and bands of Spirorbis limestone.[1]

Exceptional facilities afforded by numerous marl- and brick-pits and other artificial and natural exposures in North Staffordshire have enabled Mr. C. B. Wedd and myself to make out the following definite stratigraphical sequence in the Upper Carboniferous Rocks:—

(4) *Keele Sandstone Series.*—Red sandstones and marls, calcareous breccias, fossiliferous (Entomostracan) limestones; thickness, 700 feet, summit nowhere seen. (= Permian of older observers.)

(3) *Newcastle-under-Lyme Series.*—Grey sandstones, marls, and shales, with four thin coals. Two bands of fossiliferous limestone (Entomostracan) form the base. Thickness, 250 to 300 feet.

(2) *Etruria Marl Series.*—Red and mottled marls, with thin bands of coarse green grits near the summit and base. Thickness, 700 to 800 feet.

(1) *Black Band Series.*—Grey and mottled marls, the grey marl predominating; bands of ironstone with Entomostraca, *Anthracomya*, Fish-remains; occasional bands of grit sometimes 30 feet thick; several thin coals; numerous zones of limestone and shales with Entomostraca. A band of limestone, constant in position (36 to 40 feet) above the Bassey Mine ironstone, forms the base. Thickness, about 250 feet.

Variability in the character of the deposits of the coal-measures is universal, so that it is hardly to be expected that this sequence will be recognisable in its entirety over the whole Midland area; but there can be no doubt that it is an important point to find out which of these divisions occurs at the surface in the areas at present regarded as Permian or as upper coal-measures on the published maps.

Already the determination of the successive divisions above noted has had important industrial bearings. The fact that the Newcastle limestone lies at the base of grey measures intercalated between an upper group of red strata (the Keele series) and a lower group of red strata (the Etruria marls) has enabled me to detect true upper coal-measures in Keele Park, Shutlanehead, and to the west of Leycett. Moreover, there seems to be little doubt that the coal-measures of the Pottery Coalfield lie not far from the surface under Little Madeley and Craddocks Moss. Evidence has been obtained that the strata on the north-west side of the North Staffordshire anticline do not uninterruptedly descend beneath red rocks (so-called Permian) to the west of Leycett, but rise locally westward under Hayes. The effect of this change of inclination is to bring to the surface strata which lie considerably below the unproductive red series, and to bring the principal coals and ironstones within reach further west than might have been expected.[2]

It follows that a thorough and complete examination of the exposed coalfields of the Midland counties and of the bordering New Red Rocks will be of the highest importance in determining at what depth the productive measures lie beneath the great central tracts of the Midland counties.

5. *Report on the Drift Sections at Moel Tryfaen.* See Reports, p. 414.

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[1] *Quart. Journ. Geol. Soc.*, vol. li., 1895, p. 528.

[2] See *Summary of Progress of the Geological Survey of the United Kingdom for* 1898, p. 123.

6. *Note on Barium Sulphate in the Bunter Sandstone of North Staffordshire. By* C. B. WEDD, *B.A., F.G.S.*

[Communicated by permission of the Director-General of the Geological Survey.]

Special attention has been directed by Professor F. Clowes to the deposition of barium sulphate as a cementing material of Triassic sandstone near Nottingham, and he has mentioned numerous places, on the authority of Mr. J. Lomas, where the same mineral has been observed in Triassic rocks.[1]

It may be interesting to record another locality. In a cutting of the North Staffordshire Railway (Audley Branch), three quarters of a mile south of Alsager Road (Talke) Station, a section of Bunter sandstone in Merelake Hill shows the cross-like marks common in the Keuper sandstone of Cheshire and Staffordshire, and due to barium sulphate crystals. A partial analysis, made by my friend Mr. R. Hornby, of the Red Bunter sandstone of Merelake Hill, showed a considerable quantity of barium sulphate. Occasional veins filling joints consist of baryto-celestite, which may also be seen in other sections of the Bunter of Merelake Hill.

7. *Report on Seismological Investigations.* See Reports, p. 161.

8. *Interim Report on the Structure of Crystals.*

9. *Report on Life-Zones in British Carboniferous Rocks.* See Reports, p. 371.

FRIDAY, SEPTEMBER 15.

The following Papers and Reports were read:—

1. *The Photo-micrography of Opaque Objects as applied to the Delineation of the Minute Structure of Fossils. By* Dr. ARTHUR ROWE, F.G.S.

The object of the paper is not to enter into minute technical details of the process, but rather to demonstrate upon the screen the scope and limitations of the photo-micrography of opaque objects. A contrast was drawn between the technique employed in the case of transparent and opaque objects, and it was pointed out that, simple as are the broad principles of the latter, the application of these principles is a very difficult and tedious matter. Allusion was made to the methods used by the author, and the advantages of various lenses and illuminants were discussed.

The author stated that incandescent gas had proved quite satisfactory in his hands, and that it had been used throughout all his experiments. It was pointed out that rapid exposure was no object, and that it was useful to have a light which, while sufficiently white and powerful for all purposes, gave one ample margin wherewith to vary exposures, and that the real difficulty lay not so much in the choice of an illuminant as in the way in which it was managed. The lighting of an object would always be a somewhat tedious process, and each specimen had to be treated on its merits.

The limitations to the power of a lens were mentioned, and it was stated that it was impossible to expect any lens to focus details lying on separate horizontal planes. An instance of this difficulty was furnished by the ambulacral grooves of

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[1] *Proc. Roy. Soc.*, vol. lxiv. p. 374. References to previous papers are given in this article.

Micraster, and the author demonstrated the methods employed to retain the accuracy of detail, and yet to convey the impression of the depth of the ambulacra.

Allusion was made to the weariness of eye and brain caused by the frequent use of a hand-lens, and a contrast noted between this course and the use of photo-micrographic prints for obtaining broad and detailed observations of small objects. It was pointed out that with the aid of photographic prints the palæontologist and the artist could meet on level terms, and that the draughtsman would by this means be enabled to see the value of minute detail as plainly as the trained observer. Further, such was the excellence of the results obtained, that the assistance of an artist could in most instances be dispensed with altogether, and the photographs rendered in collotype and autotype. A proof of the latter assertion was afforded by showing numerous silver-prints of Bryozoa and sea-urchins, and by the set of collotype plates which illustrated the author's recent paper on the genus Micraster.[1]

The question of expense is an important one, for in the paper mentioned six hundred negatives were taken to illustrate the details of the test, and it is obvious that the cost of employing an artist to make drawings of even a portion of these details would be prohibitive.

The demonstration was illustrated by fifty lantern-slides of sea-urchins, Bryozoa, Brachiopoda, and Foraminifera, and care was taken to show examples which would bring out the shortcomings as well as the advantages of the process.

2. *Water-zones: Their Influence on the Situation and Growth of Concretions.* *By* G. Abbott, *M.R.C.S.*

Many hold the theory that concretions are due to the presence of organic remains, and apparently claim that some centre is necessary for their formation. The author thinks that many may be otherwise explained, and calls attention to the effects produced by the rain-water which passes into and saturates a rock-structure. He has noticed on surfaces of sections and of walls of buildings that as soon as percolation has come to an end in beds which are horizontal, or nearly so, the water breaks up into horizontal lines or water-zones, and subsequently these lines are broken up into moist patches of unequal length, extending across a section in definite lines, as illustrated by the photographs which he exhibits.

Hence the soluble substances of the rock, especially lime, iron, and silica, will be brought by the saturation water into positions favourable for the growth of crystalline and amorphous masses, and these substances as evaporation goes on must be redeposited in new situations, which may or may not coincide with the position of fossils. The space through which the dissolved substances may travel before being deposited has not been determined, but in many cases one or two feet seem to be sufficient.

The author has observed these zones of moisture both on sandstone and limestone, and thinks it possible that the selective work may go on in the same way in clay. Many disconnected facts relating to concretionary growth appear to be explicable in this manner, but further inquiry will be necessary to decide what are the special influences at work regulating the growth and deciding the form, and whether the concretion shall be amorphous or crystalline.

3. *Tubular and Concentric Concretions.* *By* George Abbott, *M.R.C.S.*

After excluding stalactites and pseudomorphs from the list of tubular concretionary bodies there yet remain a remarkable series of rings and cylinders which afford no obvious explanation of their existence. They consist chiefly of lime, silica, and iron, and no other substances appear to possess this peculiar property.

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[1] *Q.J.G.S.* Aug. 1899, vol. lv.

It seems also to be a rule for these bodies to occasionally exhibit concentric arrangement. A recent instance of this re-deposit of material is very frequent in weathered mortar, whether used as a cement for sandstone, limestone, or igneous rocks. So far, I have never failed to discover examples of this in whatever town or village I have searched. Both in dolomite and oolite beds, at Fulwell, Cresswell Crags, and Isle of Portland, tubes and channels, often concentrically arranged, are to be met with quite distinct from ordinary drainage channels. These are probably due to the same influence, a hydrostatic or mechanical one, which causes the segregation in the mixture of sand and lime used as mortar. The cone-in-cone rings seen in coal from Merthyr Tydvil may be due to the same selective power or growth, for, from an analysis made for me by Mr. E. T. Andrews, they contain lime and alumina in about equal parts.

Both flint paramoudra and the flint circles near Cromer should, in my opinion, come under this division of concretionary bodies and no longer be supposed to be fossil sponges.

Beekite, the geodes from Uruguay, and the variety of agate with 'eyes,' afford innumerable examples of annular formation, differing in arrangement from the mortar only by the smaller size of the circles. Both chalcedony and opal must be recognised as possessing this power to produce circles and 'fortifications' on *flat* surfaces quite irrespective of the contour lines of the cavities in which the agates are formed.

Iron cylinders in the Folkestone beds of the Lower Greensand exist in large numbers as single tubes, clusters, and concentric tubes. As yet, I believe, no one has found any sign of organic remains in association with them. In all probability they are due, like the other instances mentioned, to some special arrangement or concentration of solutions in the beds. They are met with to a smaller extent in the Trias, near Exeter, the Wealden of the south-east of England and other rock beds. They give little, perhaps no evidence of pressure, and are generally found in horizontal positions, so cannot be supposed to be stalactitic.

The actual cause or origin of these formations is not very clear. We may call it segregation, but this does not carry us far. Whilst further study may add to our knowledge of the influences which favour their growth, we may be just as ignorant as to why they grow as the crystallographers are of the similar processes in crystals. I surmise, however, that we shall ultimately find that some hydrostatic influence will explain much that is at present both mysterious and perplexing.

4. *On Photographs of Sandstone Pipes in the Carboniferous Limestone at Dwlbau Point, East Anglesey.* By EDWARD GREENLY.

At Dwlbau Point, Red Wharf Bay, certain beds in the Carboniferous Limestone are traversed by remarkable funnel-shaped pipes filled with fine hard sandstone. The sandstone filling the pipes can be seen to be continuous with that of overlying sandstone beds, from the lower side of which the pipes pass down into an underlying limestone. Most of the pipes are about six feet wide at the top, and have been followed to a depth of some six or seven feet. There are, however, smaller ones; and one much larger is seen in section to a depth of twelve or fifteen feet. The sandstone of the pipes is bedded, and there appears also to be a concentric structure. It is obvious that they are due to contemporaneous erosion, though of an exceptional kind.

The photographs show pipes in various stages of denudation, some standing up four or five feet from the surface of the foreshore.

5. *Glaciation of Dwlbau Point, East Anglesey.* By EDWARD GREENLY.

The surface of the limestone at Dwlbau Point is magnificently ice-worn, the general direction of the striæ being N.N.E.–S.S.W., and the moutonnée surface facing N.N.E. On the sides, however, of the funnel-shaped pit surrounding one of the sandstone pipes the striæ are deflected, and sweep round, till on its landward or S.S.W. side they are running as much as 20° N. of W. This is on a convex surface of limestone, forming the side of a moat-like depression, about a foot wide at the top and the same deep, running round the mass of sandstone filling the pipe. A short distance away, a low face of limestone is not merely furrowed, but undercut. It is smoothed and striated in the usual manner, and is undercut some two or three inches, the overhanging surface being as much as 15°, and in parts even 30° from the vertical. It would seem that these effects must have been produced by an agent which moulded itself like a plastic body to the face of the rock. The ice-worn surfaces are overlaid by about ten feet of reddish boulder clay, poor in stones.

6. *On the Glacial Drainage of Yorkshire. By* Percy F. Kendall, *F.G.S.*

The author referred to the effects produced when the edge of a glacier or ice-sheet obstructed the rivers of the adjacent country, ponding up the water to produce a lake, whose overflow was carried over into some neighbouring valley as a river. Sometimes the overflow would cross the main watershed, while at other times it would pass into some minor valley of the same slope. In this way single lakes or chains of lakes are formed, discharging by valleys cutting across spurs and ridges. Where lakes of this description existed during the Glacial Period their traces may be left after the withdrawal of the ice in the form of beach lines, silt deposits, deltas of inflowing streams, and abandoned overflow channels. In the famous Glenroy lakes the beaches and deltas are the noticeable features, but in Yorkshire the author has relied chiefly upon the streamless river valleys marking the overflow, though other indications often exist. These valleys present marked features. They are deep, sharply cut, and the character of their windings shows that they were occupied by large rivers. Moreover they often trench flat plateaux, from which they received no commensurable tributaries, and cut completely through main watersheds or projecting spurs.

The author describes the distribution of the ancient glaciers of Yorkshire, showing that while the Pennine Valleys were occupied by separate ice streams the Vale of York was covered by a great glacier. The edge of the Scandinavian ice-sheet abutted upon the whole coast line, and pressed against the northern face of the Cleveland Hills. The whole drainage of the district was obstructed, and Mr. Strangways long ago recognised that the Vale of Pickering was converted into a lake which drained backward across the natural watershed, which became trenched by the beautiful gorge of the Derwent at Castle Howard. The author's investigations showed that Newtondale was the overflow of another great lake in Eskdale, but a lobe of the Scandinavian ice-sheet crossed the Cleveland watershed near Egton, and stood against the hills above Grosmont, which was severed by two streamless gorges forming a connection between the main lake and a lesser one at Goathland. Lakelets fringed the edge of the ice along the outer face of the Cleveland Hills from Swainby to Stonegate, and for the most part drained one into another until some overflow into Eskdale was encountered. As the ice shrank by the series of stages new channels were cut at lower level across the spurs, and in some cases water flowed round the end of a lobe of ice as it stood against the slope of the hills, and thus curious 'in and out' valleys were cut, as near Freeborough. Robin Hood's Bay was drained by four successive outlets which cut through the amphitheatre of hills, and which are splendidly shown on the road from Scarborough to Whitby. The beaches of the old lakes were seldom visible, for the outlets, being cut through very soft rocks, were lowered too rapidly for well-defined beaches to be formed, but gravel deltas, where the overflow of one lake entered the quiet waters of another, were of frequent occurrence, the largest being that on which the town of Pickering is built. The floor deposits of the lakes are also well seen. On the western side of the Vale of York, near Ripon, the features are somewhat different. The lateral moraine of a great glacier is clearly traceable extending from Kirkby Malzeard to Nidd Hall. As the glacier advanced the eastward-flowing streams were successively ponded up into lakes, which overflowed each into its neighbour on the south, and finally out into the Vale of York. On the retreat of the ice some of the streams fell back through gaps in the moraine into the old valleys, leaving the extramorainic channels as practically dry gorges. One of these, Cayton Gill, was three miles long, and its excavation involved the removal by stream action of nearly three million tons of rock.

7. *On the Origin of Lateral Moraines and Rock Trains.*
By J. LOMAS, *A.R.C.S., F.G.S.*

In dealing with the accumulations of fragmentary materials associated with glaciers it is necessary to distinguish between deposits which are stationary and the *débris* riding on, or moving with the ice.

The latter, reviving a term used by Rendu, will be referred to as 'rock trains,' and the meaning of 'moraines' will be restricted to stationary deposits, either lateral or terminal.

Lateral moraines are not necessary adjuncts to glaciers. Their distribution, which appears capricious, really conforms to a well-defined law. In glaciers with a straight course, they are feebly, if at all, developed, whereas those moving through winding channels have lateral moraines developed in their concave bends. The *débris* carried by a glacier either in the ice or on the surface gradually works towards the side in such places where motion is retarded and carrying power reduced. In this respect they conform exactly to the action of rivers which deposit material in their inner bends.

Rock trains may appear suddenly in the middle of a glacier or at the junction of two streams. The first are undoubtedly caused by the erosion of sub-glacial spurs or crags. Those formed at the point of union of two glaciers are usually regarded as being formed by the joining together of two lateral rock trains.

There are cases, however, where rock trains are formed at the junctions of glaciers, and no lateral rock trains fringe the tributary glaciers. In front of the rocky islands or spurs which separate the glaciers at the point of confluence, a hollow is always seen in which a lakelet often exists. This is the counterpart of the hollow on the down-stream side of a river after passing under a bridge supported by piers.

Objects carried by rivers tend to accumulate in this hollow, and may linger there a long time before they join the main current and get carried away.

Thus rock trains may be formed by *débris* being thrust out of glaciers at similar places where motion is small. In these instances the fragments are probably torn off under the ice from the flanks of the dividing spurs, and they may be compared with those originating in the middle of a glacier.

8. *Note on the Origin of Flint.* *By* PROFESSOR W. J. SOLLAS, *F.R.S.*

The first stage was the conversion of the calcareous remains of the organisms of the chalk into silica. The siliceous foraminifera and coccolithes so produced were cemented by a deposition of silica into white flint, and this by a further deposit of silica became converted into black flint, just as snow might be transformed into compact ice. This had been shown by the author in 1880. The source of the silica might be looked for in the remains of siliceous organisms such as sponge spicules, and Professor Sollas said he was now able to bring positive proof of the original existence of abundant spicules in the chalk which were now represented by hollow casts to the extent sometimes of 3 per cent. of the rock.

9. *Calcareous Confetti and Oolitic Structure.* *By* H. J. JOHNSTON-LAVIS, *M.D., D.Ch., F.G.S.*

The older geologists, unaided by the microscope, considered oolitic granules as concretionary bodies, as they did also pisolites and other spherical bodies found in sedimentary deposits.

Recently an author has attempted to overthrow the physico-chemical origin and replace it by a vital one.

Some granules in certain so-called oolitic rocks have been shown to be of undoubted organic origin.

The present paper is an attempt to compare these granules with identical concretions the origin of which is known, and the formation of which can be observed in progress.

The microscopic sections shown are a series from specimens kindly collected from the vicinity of Cheltenham by Mr. Gray, and for comparison are several sections of somewhat similar structures, found at the present day, unquestionably inorganic.

The true oolites and pisolites are seen to be concentric grains and masses of very variable dimensions in which three grades of crystallisation can be seen.

In one, fragments of rock, shell, or other organic remains have been enveloped in crystalline calcite minutely saccharoidal in structure.

In another similar nuclei have been enveloped in very distinctly marked concentric bands of radiating needle-like or fibrous calcite.

In a third, the enveloping material is finely granular, dirty, with the concentric bands very imperfectly marked.

All these gradate into each other, and, what is more, alternate with each other in the same grain or pisolite. We have here nothing more than the varying conditions of slowness, turbidity, and movement of the water or other solution in which they were formed.

In studying oolites, the first question which arises is whether these structures were formed coincident with the deposit or as a secondary structure set up subsequently. The author thinks that the former is the true state of things.

Accepting as granted that oolitic and pisolitic structures were coincident with the formation of the deposit in which we find them, the conditions necessary are nuclei, a solution of bicarbonate of lime, and gentle motion.

In the first specimens shown was a section of a calcareous granule from the galleries of La Gardette mine near Bourg d'Oisans. The galleries have been abandoned for some years, and the calcareous water dropping from the roof has formed small pools in which granules of rock are churned up as each drop falls, and receives an infinitesimal coating of carbonate of lime. This process is a fairly rapid one, as the mine has not been abandoned for many years, and yet very thick crusts may often be found. Another specimen is from a gallery of quite modern date, cut into the side of Monte-Somma to catch the Olivella spring, and here we find the same rapid deposition of the concentric crystalline layers identical and often more perfect than in ordinary oolitic grains. The third and most striking examples are similar confetti from the mines of Laurium (Greece), where in small pools in the ancient galleries the most beautiful highly polished examples have been found.

So far all of these are formed in very shallow pools of calcareous water, or have not even been immersed but only moistened by the liquid. The process is identical with the method adopted for depositing sugar from its solution in water in the manufacture of sugared almonds, 'cannon balls,' and other varieties of confetti, the only difference being the separation in the former case of the lime by loss of CO_2; in the second, the evaporation in the rolling pans of the water by heat.

The formation of confetti when completely immersed occurs in the mineral water springs at the mud volcanoes of Paterno in Sicily. There, traversing fissures in a basalt, are springs of water supersaturated with CO_2 and a large quantity of bicarbonate of lime. These gush out with considerable violence, and keep in constant movement the grains of basalt or other solid loose fragments, as we frequently see in any spring. This supersaturated water reaches the surface under decreased pressure, much of the CO_2 escapes, and a deposit of $CaCO_3$ takes place on the walls of the fissure and on the grains that are being constantly churned up in the unstable solution. The specimens exhibited show examples of the great perfection of this concretionary structure, which is identical with that of stalactites and stalagmites, and being on a microscopic scale the author suggests the term 'micro-stalagmitic' to indicate this structure.

Such structures are not limited to those formed from carbonate of lime. Urinary concretions of uric acid, urates, oxalate of lime, often show this structure to perfection.

Sea-water as a solvent of carbonate of lime and a retainer of CO_2 is still much of a problem, notwithstanding many researches. As a general statement, deep-sea water may be said to contain more of these materials than surface-water, because it is under greater pressure and cooler. With currents setting from great depths to more shallow regions, the water will rise in temperature and diminish in pressure, and so lose its bicarbonate of lime. Now we know that oolitic rocks were chiefly shallow water and shore deposits, and here we have all the elements favourable to the formation of oolites—namely, supersaturation of water by lime bicarbonate and constant rolling movement. Another and perhaps equally important source must be the innumerable calcareous springs from land drainage issuing all over the sea-bottom for miles from the shore, churning up sand and depositing their burden of calcite at the same time.

10. *Report on the Tyn Newydd Caves.* See Reports, p. 406.

11. *Report on Fossil Phyllopoda.* See Reports, p. 403.

SATURDAY, SEPTEMBER 16.

The President's Address was delivered. See p. 718.

MONDAY, SEPTEMBER 18.

The following Papers and Report were read :—

1. *Homotaxy and Contemporaneity. By* Professor W. J. SOLLAS, *F.R.S.*

On the occasion of the centenary of William Smith's great discovery of the identification of strata by fossil remains, which formed the basis of historical geology, attention might fitly be called to the triumphs of the last two decades which had been achieved by its means. The study of the distribution of zonal fossils had unexpectedly vindicated the old-fashioned notion of the contemporaneous formation of similar stratified systems over great parts of the world, and no one could any longer assert that the Silurian system in Europe might possibly be contemporaneous with the Devonian in America. The distribution of Ammonites in the Cretaceous zones of Europe, America, and Pondicherry could be shown to prove that the difference in age of the same zone in different localities was not equal to the whole time required for a species to migrate from one place to another, but to the difference in the times occupied by Pacific species in passing to Europe, and Atlantic species in passing to Asia. Further, the lapse of time during migration or transport was a vanishing quantity in comparison with the long periods occupied in the evolution of species. The results of recent work had been to inspire geologists with renewed confidence in the accuracy and logical basis of their methods.

2. *Note on the Surface of the Mount Sorrel Granite.*
By W. W. WATTS, *M.A., F.G.S.*

It has long been known that, when first exposed in the quarries, the granite of Mount Sorrel exhibits a smoothed, grooved, and slightly terraced aspect. As the surface, when first discovered, was covered with boulder-clay, it has been concluded that it was produced by glaciation. The writer has long had doubts with regard to this interpretation, and recent excavations near Mount Sorrel have thrown a new light on the phenomenon. At Hawkley Wood and Nunckley Hill similar but smaller surfaces have recently been exposed which are covered by undisturbed Keuper Marl, while another surface, exposed at Nunckley Hill, has boulder-clay abutting on it. Thus the grooving, terracing, and smoothing, like so much of the scenery in Charnwood Forest, was originated in Triassic times, though locally it may have been somewhat modified by glaciation. One loose block of granite, apparently removed in baring the surface of the rock, presents characteristic fluting and glazing like that due to the action of wind. The writer wishes to thank Mr. R. F. Martin for calling his attention to these newly exposed surfaces.

3. *On the Origin of Chondritic Meteorites.—By* Professor A. RENARD.

4. *On Coast Erosion.* *By* Captain McDAKIN.

The district dealt with is the coast from Deal to Dover, Folkestone and Sandgate.

The Six-Inch Ordnance Survey, 1877, is taken as the standard. Several noted falls are mentioned.

The comparatively slow action of the unaided sea, ascertained by boring holes in the cliffs, has been recorded.

The more rapid effect, where the waves are charged with a small quantity of shingle, and the absolute barrier thrown up by the sea when it forms large banks of shingle.

The important part played by the springs is dwelt upon as one of the chief causes constantly at work.

The disintegratory power of the frosts and the accumulation of water on the hollow surfaces of the usual pervious chalk, due to the freezing of the otherwise porous surface.

The moisture-absorbing power of the chalk, which amounts in many instances, especially in that of the Upper Chalk, to over 20 per cent.

The compression of air in the joints and fissures of the rocks by an incurving, on-rushing wave, are all factors influencing the coast erosion.

The writer is of opinion that although the falls of the cliff amount to thousands of tons, the area lost has not been great in historic times, for the Roman lighthouse at Dover Castle, and the foundations of a similar structure on the western heights, show that their position with regard to the coast is very much the same now that it was nearly two thousand years ago.

The more rapid destruction of the Dover cliffs within the last fifty years is curiously due to those structures that might be supposed to protect the coast, the breakwaters at Dover and Folkestone, which intercept the shingle that would otherwise form a natural protection to the coast.

5. *On Coast Erosion.* *By* G. DOWKER, *F.G.S.*

The author has, during the past several years, recorded the coast erosion in Kent with Captain McDakin, of Dover, and in this paper continues these observations from Walmer, on the south of Kent, to Whitstable on the north. The following particulars are given:—The progress of the northward drifting of the beaches from the south along the coast from Deal to Ramsgate, and on the north of Kent their drifting from Margate to Whitstable.

The changes in the direction of the mouth of the Stour, and the resultant action of the same in the rapid erosion of the cliffs at Pegwell Bay; illustrating these changes with sketches taken at different times during the last forty years, and with reference to the Ordnance maps. The rate of erosion of the chalk of Thanet is herein discussed, and also the permanence of certain submarine shoals and sand and gravel banks in the coast-line near Ramsgate.

The effects of erosion in the jointing and faulting of the Thanet Cliff and fall of the cliff and its removal by natural and artificial causes.

Especial results of the abnormal high tide of November 29, 1897, with the north-east gale that accompanied it.

The Whitstable bank, known as the 'Street,' is described, and the change in its character during the last ten years recorded.

Finally, the author discusses the probable oscillations in the level of the land and the total result, being subsidences since the Roman occupation of Britain.

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6. *Preliminary Report on Observations of Coast Erosion by the Coastguard.*

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7. *On Photographs of Wave Phenomena.*

By VAUGHAN CORNISH, *M.Sc.* (*Vict.*), *F.R.G.S.*, *F.C.S.*

PART I.—*What is a Wave?*

The connotation of the word 'wave,' which is becoming customary from the special aspects of waves most studied in physics, is that of transmission of energy in a pulse-like manner, attention being concentrated on a process and diverted from the thing produced. This is well enough *e.g.* in the physical study of light, where the structures produced are obliterated almost as soon as formed; but it is not the right point of view in geology, where the structure frequently outlasts the process, and the process of production is by no means always a pulse-like transmission of energy. The primary and principal meaning of 'wave' (noun) in our language[1] is properly associated with (1) up and down motion, (2) with a systematically corrugated surface, an onward rushing mound of water; the notion of pulse transmission comes in but slightly.

The most fruitful source of the waves which constitute geological structures is the relative motion of two bodies which yield viscously at their common surface. An undulating interface is an almost invariable result of such movements, whether of a lighter air over a heavier, giving clouds in parallel bars, or sometimes a mackerel sky; or of atmosphere and non-rigid parts of the lithosphere, giving blown-sand ripples, sand dunes, or waves of drifted snow; or hydrosphere and non-rigid parts of lithosphere, giving ripple-mark of the seashore, tidal ripple-mark of estuaries, sand banks, ripple-drift, 'sand reefs,' &c.; or between parts of the lithosphere, when the relative movement is slow enough to allow them to behave viscously. In this case of slow wave formation, pulse-transmission may be present, but difficult to observe directly. Moreover, the structures are often studied in the 'fossil' state, *e.g.* rock-folds, when no longer part of the living rock.

Sudden interruption of such slow wave-making (*e.g.* fold passing into fault, the wave 'breaking') brings out elastic effects, and waves such as those of earthquake shock become possible, in which the pulse-transmission-of-energy-aspect of waves

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[1] See Johnson's *Dictionary of the English Language* (Latham, 1870); W. W. Skeat, *An Etymological Dictionary of the English Language*, 1898; J. Bosworth, *A Dictionary of the Anglo-Saxon Language*, 1838, and as edited by A. N. Toller, 1892; and Cruden's *Concordance of the Old and New Testament.*

is prominent, but which, apparently, do comparatively little towards the building of permanent waves.

In some cases (*e.g.* lava flow) where plastic material flows over a bed which behaves in a rigid manner, the *free* surface of the upper moving viscous body is thrown into waves which are analogous to the characteristic water-waves of shallow streams.

The author has proposed the term Kumatology (κῦμα, a wave) for the co-ordinate study of the waves of the Atmosphere, Hydrosphere, and Lithosphere.

PART II.—*Description of Illustrative Photographs.*

1. Rock-waves, from a specimen in the Geological Museum, Jermyn Street.
2. Ditto.
3. Lava-waves, Vesuvius.
4. Mud-wave over a stone, section on road up Vesuvius.
5. Rippled sand of definite wave-length left after a thunderstorm, Branksome, Dorset.
6. Supposed imprint of skin of fossil fish, from a piece of sandstone in the British Museum of Natural History, Cromwell Road, the form being that given by the rippling of sand by two simultaneous sets of waves.
7. Supposed fossil nests of tadpoles, from a piece of sandstone in the same museum, being the form given by the rippling of sand by three simultaneous sets of waves.
8. Ripples of blown sand, Branksome, Dorset.
9. Ripples of blown sand, Ismailia.
10. A desert sand-dune in its steepest, or spraying, form, south side of Lake Timsah.
11. Sand naturally assorted in a desert dune, from a sample collected by the author at Ismailia. (Micro-photograph slide made for the author by Newton.)
12. Small dunes on a sandy foreland of the Nile, forming a train of waves, looking up-wind.

The following photographs illustrate the sorting and sizing of materials by the waves of the sea:—

13. Mixed detritus, east of Chesil Beach.
14. A photographic field of pebbles lying on the Chesil Beach.
15. Seven sets of pebbles collected by the author on the Chesil Beach, arranged and photographed so as to show the gradation of sizes from end to end of the beach.

16, 17, and 18. The sorting of shingle from sand by waves, and the consequent formation of 'chevrons' of shingle on the beach at Branksome.

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8. *The Eruption of Vesuvius of* 1898. *By* TEMPEST ANDERSON, *M.D., B.Sc.*

The author stayed about a week at the Hermitage on Vesuvius, in September, 1898, when the eruption was about at its height.

A lava cone has been thrown up at the entrance of the Atrio del Cavallo, the slopes of which reach to the foot of Somma on the west side, the cone of Vesuvius on the east, and nearly to the Hill of the observatory on the S.W., and a prolongation of the latter, the Crocella, described as of great beauty, has been entirely covered up. The eruption has been going on gently in this locality for about two years, but has never been very active. Small streams of lava have been almost constantly poured out, but they have all cooled and solidified before reaching the foot of the mountain, and consequently have assumed the form of a cone rather than a large sheet.

The lava in the early part of the eruption had been of the corded variety. In September 1898, that which was being poured out was scoriaceous.

Lantern photographs from negatives by the author were exhibited, some of which have been reproduced in the 'Alpine Journal, May 1899.

9. *Investigation of the Underground Waters of Craven. The Sources of the Aire. By* PERCY F. KENDALL, *F.G.S.*

10. *The Recent Eruption of Etna. By* Professor GIOVANNI PLATANIA.

The eruptions of Etna from the central crater are less frequent than in the case of Vesuvius. The last great eruption was in 1892, when 2,470 million cubic feet of lava was poured forth from a crater on the southern flank. On July 19 a Plinian eruption occurred in the central crater, during which a great number of ejected blocks of old lava were scattered round the crater to a distance of over 4,000 feet. Some of the blocks damaged the roof of the Observatory. It is suggested that this Plinian eruption is a symptom of an impending lava eruption, which will produce a rift in continuation of that of 1892 in the Valle del Bove.

TUESDAY, SEPTEMBER 19.

The following Papers and Reports were read:—

1. *The Geological Conditions of a Tunnel under the Straits of Dover. By* Professor W. BOYD DAWKINS, *M.A., F.R.S.*

In 1882 the physical structure of the cliffs on the English and French sides of the Straits was brought by the author before the British Association. Since that time the question of a tunnel has been relegated to a future more or less remote, while many new facts have been ascertained. It is not, therefore, inopportune to recur to the subject, which has a special interest for the place of our present meeting.

The rocks exposed in the cliffs between Folkestone and St. Margaret's, and measured for the purposes of the proposed tunnel, are as follows, in descending order:—

			Thickness. English Feet.
Upper.	VI.	St. Margaret's Chalk	280
	V.	Nodular Chalk with flints	100
	IV.	Chalk with few flints	100
Middle.	III.	Lower White Chalk with Nodular layers without flints	145
Lower.	II.	Grey Chalk and Chalk Marl No. II. of Price	225
	I.	Glauconitic Marl, No. I. of Price	3

Gault.

The Gault, a stiff blue impervious clay, forms a low line of cliffs on the west side of Eastwear Bay, and disappears beneath low-water mark, opposite the western end of the Abbotscliffe. It occurs in St. Margaret's Bay in Sir John Hawkshaw's boring at a depth of 536 feet below O.D.

The Glauconitic Marl, No. I., a clayey calcareous deposit, generally impervious, but sometimes so full of grains of glauconite and sand as to be pervious, overlies the Gault and passes into the chalk marl, underlying the Lower Grey Chalk, No. II. This sets in in the cliff traversed by the Folkestone Tunnel at 360 feet above O.D., and descends to Ordnance datum, a little to the east of Shakespeare's Cliff. It constitutes the base of the cliff from Abbotscliffe as far as that point.

From this point as far as the west base of Eastcliffe, the cliffs are composed of the Middle Chalk Nodular, and White, No. III., rising on the west to 490 + O.D., and plunging down to the east to a depth of 180 − O.D. at St. Margaret's. At its base is a hard nodular iron-stained layer, the Grit-bed of Price, forming a conspicuous band in the English and French cliffs. The three upper members of the section constitute the Upper Chalk, out of which the cliffs between Dover and St. Margaret's have been carved.

All these strata dip steadily to the east at an inclination of about 1 in 72.

On the French side, in the cliffs between St. Pot and Sangatte, the Lower and Middle Chalk of the English section emerge from the sea with physical characters the same, and the thickness practically also the same. They dip also to the east, but at a higher angle.

The French survey of the sea bottom in the Straits for the purposes of the proposed tunnel proves that the Lower and Middle Chalk are perfectly continuous and constitute the sea floor, the sea in the line of the tunnel being 192 feet in depth at the deepest point.

It is obvious that the geological structure of the Straits of Dover offers great facilities for the construction of a tunnel, which would descend at an inclination of 1 in 70 or 80 on the English, sweep under the Channel and rise with the strata on the French side, if it can be made in an impervious stratum which cannot be traversed by the sea water under high pressure. The only stratum satisfying this condition is the Lower Grey Chalk, and especially the lower and more clayey horizon overlying the Glauconitic Marl.

A careful examination also of the cliffs proved that the faults, mostly small and insignificant, do not become water passages at this place in the section, because they become blocked with clay. There are no springs at this horizon in either the English or the French cliffs.

These considerations led the Channel Tunnel Companies to sink the shafts at the Shakespeare Cliff and at Sangatte down to this horizon, and to make their drifts on the English side 2,300 yards long, and on the French more than a mile, passing diagonally away from the shore under the sea. The selection is amply justified by their experience. On the English side the faults visible in the Shakespeare Cliff were traversed, and yielded a slight oozing of water, which was stopped by rings of iron tubing. These rings were afterwards removed and the faults were found to be perfectly water-tight. The water in the French shaft comes from the fault intersected at a point considerably above the level of the drift, which here also traversed small water-tight faults.

The chalk is here soft enough to be easily cut by Colonel Beaumont's machine, and hard enough to stand without lining. Five years' exposure has not sensibly affected the surface of the drift, which remains as fresh as the day when it was made. The geological conditions are therefore peculiarly favourable for the construction of a submarine tunnel at the bottom of the Chalk, and do not present any engineering difficulty.

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2. *On a Proposed New Classification of the Pliocene Deposits of the East of England. By* F. W. Harmer, F.G.S.

The term Red Crag, including, as it does, beds differing considerably in age, is vague and, when we attempt to correlate the East-Anglian deposits with those of other countries, inconvenient; the Scaldisien zone of Belgium, with its southern fauna, for example, representing one part of it, and the Amstelien of Holland, in which northern and even arctic mollusca are common, another.

It seems desirable, therefore, while retaining it for general use, to adopt for its various horizons some more definite and distinctive names.

The upper Crag deposits arrange themselves geographically, in horizontal rather than in vertical sequence, assuming always a more recent as well as a more boreal character as we trace them from south to north. They are the littoral accumulations of a sea which was from time to time retreating in a northerly direction.

The classification now proposed, which is based on palæontological evidence, is as follows:—

	Older Pliocene.	
Lenhamian	Lenham beds (Zone of *Arca diluvii*)	Diestien sands. Waenrode ?
	Newer Pliocene.	
Gedgravian	Coralline Crag	Zone à *Isocardia cor.*
Waltonian	Essex Crag (Zone of *Neptunea contraria*)	
Walton horizon	Scaldisien.	
Oakley „	Poederlien.	
Newbournian	Red Crag of Newbourn, Sutton, and Waldringfield	Amstelien
Butleyan	Red Crag of Butley and Bawdsey (Zone of *Cardium groenlandicum*)	
Icenian		
Lower horizon	Norwich Crag, Southern district.	
Upper „	„ „ Northern district. (Zone of *Astarte borealis*).	
Chillesfordian	(Estuarine) Chillesford Clay and Sands.	
Weybournian	Crag of Weybourne and Belaugh (Zone of *Tellina balthica*) Forest bed (so-called) series.	

An analysis of the characteristic mollusca of the different divisions respectively of the Crag here suggested shows a gradual diminution of the percentages of extinct and southern forms, and a gradual increase in northern and recent species. The difference between the Gedgravian (Coralline Crag) and Waltonian is shown to be less than has been supposed, and the former is here grouped as Newer instead of as Older Pliocene, as hitherto.

The Crag of Little Oakley, near Harwich, from which the author has recently obtained nearly 300 species of mollusca, belongs to an horizon different from anything previously described, and serves to bridge over the interval between the Crag of Walton-on-the-Naze and that of Suffolk. Its fauna closely resembles that of Walton, but contains some boreal and arctic species unknown from that place, including *Neptunea antiqua* (dextral), *N. carinata*, and *N. despecta*, and represents the period when northern forms were first beginning to establish themselves in the Crag basin. It is approximately and partly equivalent to the Poederlien zone of Belgian geologists.

The Red Crag beds, the fossils of which are, with few exceptions, the drifted and stratified shells of dead mollusca, seem to have been deposited either against the shore, or in shallow water in proximity to it, in land-locked bays or inlets. The position which these inlets successively occupied was from time to time shifted towards the north, in consequence of the upheaval of the southern part of the Crag area, described by the author in a former paper.[1] These inlets were silted up, one after another, by masses of shelly sand, but as far as the evidence goes the beds composing the different zones do not overlap. The Waltonian deposits are confined to the county of Essex, the Newbournian occupying the district to the north of the river Stour, and the Butleyan beds occurring along a narrow belt extending northwards from Bawdsey at the mouth of the river Deben. The Icenian deposits, which are found only to the north of Aldeburgh, are shown by their molluscan fauna to belong to a period considerably more recent than any part of

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[1] *Quarterly Journal Geol. Soc.*, vol. lii. p. 773, 1896.

the Red Crag. They cover an area 45 miles by 20 in extreme breadth, and in one place are nearly 150 feet in thickness, but they are not anywhere known to be underlaid by beds of Red Crag age. In the northern part of the Icenian area *Astarte borealis* occurs, and this species seems to mark a slightly more recent horizon of this zone. The Weybournian Crag, containing *Tellina balthica*, is only known to the north of Norwich, and extends from thence to the Cromer coast. The author now believes that these latter beds are distinct from, and of older date than, the Westleton shingle of Prestwich.

3. *The Meteorological Conditions of North-Western Europe, during the Pliocene and Glacial Periods.* *By* F. W. Harmer, *F.G.S.*

No satisfactory explanation has yet been offered as to the conditions under which originated the great sheets of shelly sand known to geologists as the Upper Crag, the littoral deposits of the North Sea in Pliocene times, which contain everywhere (over an area in East Anglia more than sixty miles in length) the dead shells of mollusca in the most extraordinary profusion. No such accumulations are now taking place on the shores of Norfolk and Suffolk, although molluscan life is more or less abundant in the adjoining seas. On the coast of Holland, on the contrary, dead shells are exceedingly common.

The occurrence of such *débris* is local rather than general, and seems to be due sometimes to currents, but more frequently to the action of stormy winds, which agitate the sea bottom to a greater or less depth. An examination of the daily weather charts issued by the Meteorological Office shows that movement of dead shells towards the shore at any place is for the most part in the direction of the gales which may there be prevalent. At present the cyclonic disturbances, to which East-Anglian storms are due, pass as a rule with their centres to the north-west of that district; and hence south-westerly and westerly gales are there common, and shelly *débris* is driven on to the shores of Holland, and not on to those of the east of England. It would seem, therefore, that during the Pliocene epoch, strong winds from the east must have prevailed in the Crag area. At an early stage of the Red Crag period, mollusca now confined to the Arctic Circle had begun to establish themselves in the Crag basin, so that the glaciation of Scandinavia, attended with anticyclonic conditions over that country, had probably then commenced. At present, when Scandinavia is anticyclonic, storm centres may be diverted from their usual course towards the south, as was the case, for example, in October 1898, causing south-easterly and easterly gales, with rough sea, on the eastern coasts of England. It is suggested that such conditions may have frequently prevailed there during the Crag period.

The meteorological conditions of the northern hemisphere during the Glacial epoch must have been widely different from those of our own time. At present the accumulation of ice sheets in the Arctic regions is local rather than general; Greenland, for example, being glaciated, while the north of Scandinavia enjoys a milder climate. The latter is due partly to the Gulf Stream, but partly also to the prevalence of south-westerly winds, caused by the relative positions occupied by areas of high and low pressure. Nansen states that a constant area of high pressure now exists over Greenland, and that the winds blow outwards from that country in all directions. Similar conditions probably obtained during the Glacial period over the great ice sheet of northern Europe, producing the most far-reaching changes on the climate of different parts of the northern hemisphere; and this may, to some extent, explain the local character of the accumulation of great masses of snow and ice during that epoch.

4. *On some Palæolithic Implements of North Kent.* *By* the Rev. J. M. Mello, *M.A.*, *F.G.S.*

There is evidence from the abundance of flint implements that the prehistoric population of Kent must have been considerable. Implements are found at all levels up to 600 feet, and great interest is attached to the high level or plateau group as affording traces of man's presence before the formation of the existing river systems.

The implements of the plateau and hill drift are extremely rude, and bear evidence of rough usage and transportation; while they differ in type from those of later Palæolithic times.

A large collection recently formed by Mr. R. Jones, of East Wickham, contains many interesting examples, which were exhibited by the author. Amongst the localities from which these have been derived are Swanscombe, Milton Street, Ash, Darent, Crayford, &c., and also a remarkable series found at Rainham, a new locality, here at only about 20 feet above high-water mark. A large number of Palæolithic implements were found on the surface, but they appear to have been derived from an old gravel; they are for the most part deeply stained white or yellow, and are highly patinated, whilst also showing signs of considerable wear on their worked edges. The question is, Have they been brought down to this low level from the high-level drifts of the Medway Valley?

5. *Report on Photographs of Geological Interest.* See Reports, p. 377.

6. *Report on Irish Elk Remains in the Isle of Man.* See Reports, p. 376.

7. *Report on the Flora and Fauna of the Interglacial Beds in Canada.* See Reports, p. 411.

WEDNESDAY, SEPTEMBER 20.

The following Papers and Reports were read:—

1. *Sigmoidal Curves.—By* MARIA M. GORDON, *D.Sc.*

The phenomena of crust-torsion are produced when the wave-forms existing in an already folded region are altered as a result of the superposition of a new series of folds. Let a unit-area of rectangular folds be taken as a type, where two anticlines and an intervening trough in east and west direction have been crossed by two anticlines and an intervening trough in north and south direction. Then the cross-arches are four in number, and are areas of uprise limiting obliquely an inner cross-trough, which represents a common reciprocal area of depression. The new anticlines east and west of the trough are areas of uprise, while north and south of the trough the old anticlines are broken by local areas of depression.

The redistribution of the wave-forms in the area determines several distinct centres towards which crust-creep sets in, and the conflicting nature of the combined horizontal and vertical pressures in relation to the separate centres produces torsional phenomena. The inner trough is an area of involution, into which the higher horizons of rock sink and are carried obliquely downward, while each of the four cross-arches are areas of evolution where the compensatory opposite movements of torsion carry the lower horizons of rock or molten material from below the crust obliquely upward. 'Streaming' of the rock-particles is associated with this circulatory system of crust-movement.

'S'-folds gradually take shape around the cross-arches, and as these are specially liable to be fractured in their most warped, 'middle limb' portions, limiting-faults tend to form in oblique directions and to become continuous with north and south faults between the simple lateral arches and the reciprocal troughs. The outcrop of the fault-zone in the unit-area, therefore, describes characteristic sigmoidal curves, the same curves practically which would be followed by the outcrop of intermediate horizons of the crust in any ground-plan of the unit-area of torsion.

Among the tectonic phenomena which may be demonstrated in a unit-area of torsion are the arrangement of the horizons of the stratigraphical succession in elliptical whorls set at right angles, the formation of crust-folds in opposite or sometimes intersecting arcs, and of faults in 'fault-polygons' and 'bundles,' the cross-transferences of rock-material, the fan-structure of cross-arches, and the disposition of consolidated fault-rock in sigmoidal bands. These phenomena become much more complicated when the unit-area is considered as part of a much larger area of torsion, since the varying magnitudes and varying shapes of the wave-forms in a large region of cross-arches and troughs necessarily cause all kinds of local structural peculiarities.

Sigmoidal curves limit the great mountain-masses and troughs of the Alpine system, and are associated there (*ex.* Prättigau, Salzkammergut, &c.) with all the above-mentioned phenomena of crust-torsion. What is designated a Central Massive or a major Trough in the Alpine mountain system really represents a very large wave-form, which bears upon its surface a number of smaller wave-forms represented by the subordinate cross-arches and covered troughs in each great Massive or Trough.

2. *Adjourned Discussion on Wave Phenomena.* See p. 748.

3. *Report on the Ossiferous Caves at Uphill.* See Reports, p. 402.

4. *Report on Erratic Blocks of the British Isles.* See Reports, p. 398.

5. *On the Subdivisions of the Carboniferous System in certain portions of Nova Scotia. By* H. M. Ami, *M.A., F.G.S., of the Geological Survey of Canada.*

Considerable discussion has arisen of late in Canada regarding certain sediments, near the summit of the Palæozoic columns. No doubt exists as to the proper and natural succession, but whether the red sandstones and shales and conglomerates of the Union formation, and the grey and dark carbonaceous shales and sandstones of the Riversdale formation of Pictou, Colchester and Cumberland counties of Nova Scotia should be classed as Carboniferous or Devonian was the problem which presented itself to Canadian geologists.

From a careful collection of palæontological material in the formations in question, the writer has been able to satisfy himself that the Union and Riversdale strata hold a flora and a fauna which in every essential feature are truly Carboniferous. The plants obtained were submitted both to Professor David White of Washington, and to Mr. Kidston of Stirling, Scotland, and they both recognise a distinctly Carboniferous flora.

The Ostracoda were examined by Professor T. Rupert Jones, F.R.S., who reports that the forms have a decidedly Carboniferous facies. The wing of a large neuropterous insect is referred to a Carboniferous genus by Professor Charles Brongniart. Reptilian and fish remains, tracks and trails of the former all serve to point to post-Devonian times.

To assign such a fauna and a flora as are found in the Union and Riversdale formations of Nova Scotia to the Devonian period would be contrary to the consensus of opinion and generally accepted inferences of the leading geologists in the world, and contrary to the principles of classification.

The various life-zones of these two formations, as well as the characters of the sediments due to the conditions in which they were deposited, serve to unite them in every respect with the similar sediments which went on in the Millstone Grit and the Coal Measures in later Carboniferous times.

These two terrigenous formations—the Union and Riversdale—are separated from the Millstone Grit and Coal Measures of the same district by a series of limestones of marine origin, associated with certain sandstones and mudstones, which point to a period of subsidence when the Carboniferous sea encroached upon the land and deposited limestones, holding abundance of the remains of the sea life of those days. The shallow water, estuarine and terrigenous characters of the Union and Riversdale formations (eo-Carboniferous) caused by the conditions of deposition had ceased for a period, and when the marine conditions which followed had ceased, the former conditions recurred, and similar shallow water, estuarine and terrigenous deposits, were deposited, and constituted the Millstone Grit and productive Coal Measures of the Springhill, Pictou, and Joggins coalfields. For these reasons these two eo-Carboniferous formations are so classed.

In the study of the succession and classification of the fossiliferous and associated strata in certain portions of Nova Scotia, together with the life-zones they contain, it has been deemed necessary at the present stage of our study to introduce certain names to describe better the various formations under discussion, and the following synoptical table may serve to present them in a condensed manner:—

	Southern areas	Northern areas
	Pleistocene[1]	Pleistocene[1]
	Unconformity	*Unconformity*
Neo-Carboniferous		Cape John sandstones. Pictou freestones. Smelt Brook shales, &c. Small's Brook (Spirorbis) limestones. New Glasgow conglomerates.
		Unconformity
Meso-Carboniferous	Coal Measures (Stellarton). Millstone Grit (Westville).	Millstone Grit.
	Unconformity.	*Unconformity* (?)
	Hopewell and Windsor.	
	Unconformity.	
Eo-Carboniferous	Union. Riversdale.	

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6. *Report on the Registration of Type Specimens.* See Reports, p. 405.

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[1] Of course, not included in Carboniferous, but introduced to show field relations and succession.

SECTION D.—ZOOLOGY.

PRESIDENT OF THE SECTION—ADAM SEDGWICK, M.A., F.R.S.

THURSDAY, SEPTEMBER 14.

The President delivered the following Address:

Variation and some Phenomena connected with Reproduction and Sex.

IN the following address an attempt is made to treat the facts of variation and heredity without any theoretical preconceptions. The ground covered has already been made familiar to us by the writings of Darwin, Spencer, Galton, Weismann, Romanes, and others. I have not thought it advisable to discuss the theories of my predecessors, not from a want of appreciation of their value, but because I was anxious to look at the facts themselves and to submit them to an examination which should be as free as possible from all theoretical bias.

Zoology is the science which deals with animals. Knowledge regarding animals is, for convenience of study, classified into several main branches, amongst the most important of which may be mentioned: (1) the study of structure; (2) the study of the functions of the parts or organs; (3) the arrangement of animals in a system of classification; (4) the past history of animals; (5) the relations of animals to their environment; (6) the distribution of animals on the earth's surface. That part of the Science of Zoology which deals with the functions of organs, particularly of the organs of the higher animals, is frequently spoken of as Physiology, and separated more or less sharply from the rest of Zoology under that heading. So strong is the line of cleavage between the work of the Physiologist and that of other Zoologists, that this Association has thought it advisable to establish a special Section for the discussion of physiological subjects, leaving the rest of Zoology to the consideration of the old-established Section, D. In calling attention to this fact, I do not for one moment wish to question the advisability of the course of action which the Association has taken. The Science of Physiology in its modern aspects includes a vast body of facts of great importance and great interest which no doubt require separate treatment. But what I do wish to point out is that it is quite impossible for us here to abrogate all our functions as physiologists. Some of the most important problems of the physiological side of Zoology still remain within the purview of this Section.

For instance, the important and far-reaching problems connected with reproduction and variation are very largely left to this Section, and that large group of intricate and almost entirely physiological phenomena connected with the adaptations of organisms to their environment are dealt with almost exclusively here. Indeed, we may go further, and say that apart altogether from practical questions of convenience, which make it desirable to separate a part of physiological work from the Zoological Section, it is, as a matter of fact, impossible to divorce the intelligent study of structure from that of function. The two are indissolubly connected together. The differentiation of structure involves the differentiation of function, and the differentiation of function that of structure. The conceptions of structure and function are as closely associated as those of matter and force. A zoologist who confined himself to the study of the structure of organisms, and paid no attention to the functions of the parts, would be as absurd a person as a philologist who studied the structure of words and took no account of their meaning. In the early part of this century, when the subject matter of zoology was not so vast as it is at present, this aspect of the case was fully recognised, and one of the greatest zoologists of the century, whether considered from the point of view of modern anatomy, or of modern physiology, was Professor of Anatomy and Physiology at the University of Berlin.

Having said that much as to the various aspects of living Nature, of natural history, if you like, which it falls within the province of this Section to deal with, I may now proceed to the subject of my address. And when I mention to you what that subject is, you will be able to make some allowance for the somewhat commonplace remarks with which I have treated you. For that subject, though it has its important morphological aspects, is in the main a physiological one; at any rate, no study which does not take account of the physiological aspect of it can ever hope to satisfy the intellect of man. The subject, then, to which I wish to draw your attention at the outset of our proceedings, is the great subject of Variation of Organisms.

As every one knows, there is a vast number of different kinds of organisms. Each kind constitutes a species, and consists of an assemblage of individuals which resemble one another more closely than they do other animals, which transmit their characteristics in reproduction and which habitually live and breed together. But the members of a species, though resembling one another more closely than they resemble the members of other species, are not absolutely alike. They present differences, differences which make themselves apparent even in members of the same family, *i.e.* in the offspring of the same parents. It is these differences to which we apply the term *variation*. The immense importance of the study of variations may be judged from the fact that, according to the generally received evolution theory of Darwin, it is to them that the whole of the variety of living and extinct organisms is due. Without variation there could have been no progress, no evolution in the structure of organisms. If offspring had always exactly resembled their parents and presented no points of difference, each succeeding generation would have resembled those previously existing, and no change, whether backwards or forwards, could have occurred. This phenomenon of genetic variation forms the bedrock upon which all theories of evolution must rest, and it is only by a study of variations, of their nature and cause, that we can ever hope to obtain any real insight into the actual way in which evolution has taken place. Notwithstanding its importance, the subject is one which has scarcely received from zoologists the attention which it merits.

Though much has been written on the causes of variation, too little attention has of late years been paid to the phenomenon. Since the publication of Darwin's great work on the 'Variation of Animals and Plants under Domestication,' there have been but few books of first-rate importance dealing with the subject. The most important of these is Mr. William Bateson's work, entitled 'Materials for the Study of Variation.' I have no hesitation in saying that I regard this work as a most important contribution to the literature of the Evolution theory. In it attention is called, with that emphasis which the subject demands, to the supreme importance of the actual study of variation to the evolutionist, and a systematic attempt is made to classify variations as they occur in Nature. In preparing this book Mr. Bateson has performed a very real service to zoology, not the least part of which is that he has made a most effective protest against that looseness of speculative reasoning which, since the publication of the 'Origin of Species,' has marred the pages of so many zoological writers.

The Variations of Organisms may be grouped under two heads, according to their nature and source: (1) There are those variations which appear to have no relation to the external conditions, for they take place when these remain unchanged, *e.g.* in members of the same litter; they are inherent in the constitution of the individual. These we shall call constitutional variations, or, as their appearance seems nearly always to be connected with reproduction, they may be called *genetic* (congenital, blastogenic) *variations.* (2) The second kind of variations are those which are caused by the direct action of external conditions. These variations constitute the so-called *acquired characters.*

My first object is to consider these two kinds of variations, their nature, their causes, and their results on subsequent generations, and to inquire whether there are any fundamental differences between them. In this connection it is of particular importance that we should inquire whether acquired modifications are transmitted in reproduction. As is well known, there are two schools of thought holding directly opposite views as to this matter. The one of these schools—the so-called Lamarckian school—holds that they may be transmitted as such in reproduction; the other school, on the other hand, maintains that acquired modifications affect only the individual concerned, and are not handed on as such in reproduction. That the decision of the matter is not only theoretically important, but also practically, is evident, for upon it depends the answer to the question whether mental or other facilities acquired by the laborious exercise of the individual are ever transmitted to the offspring—whether the facility which the individual acquires in resisting temptation makes it any easier for the offspring to do the same, whether the effects of education are cumulative in successive generations. To put the matter as Francis Galton has put it, is nature stronger than nurture, or nurture than nature?

We have then two kinds of variation to consider: (1) genetic variation, (2) acquired modification. It is the former of these—namely, genetic variation—with which I wish primarily to deal. Let us examine more fully the mode of its occurrence.

Genetic Variation.

Organised beings present, as you are aware, two main kinds of reproduction, the sexual and the asexual. These two kinds of reproduction present certain differences, of which the most important, and the only one which concerns us now, is the fact that genetic variation is essentially associated with sexual reproduction, and is rarely, if ever, found in asexual reproduction. In other words, whereas the offspring resulting from asexual reproduction as a rule exactly resemble the parent, they are always different from the parents in sexual reproduction. I am aware that I am treading on disputed ground. You will observe that I do not make the assertion that asexually produced offspring *always* exactly resemble the parent, and never present genetic variations. To say that would be going too far in the present state of our knowledge. Therefore I have put the matter less strongly, and merely assert that whereas asexual reproduction is on the whole characterised by identity between the offspring and the parent, sexual reproduction is always characterised by differences more or less marked between the two; and I reserve the question as to whether genetic variations are ever found in asexual reproduction for later consideration.

This modified form of the statement will, I think, be admitted on all hands, but before going on I will illustrate my meaning by reference to actual examples.

Asexual reproduction is a phenomenon comparatively rare in the animal kingdom, and when it does occur it is exceedingly difficult to investigate from this particular point of view. In the vegetable kingdom, on the other hand, it is quite common. All, or almost all, plants possess this power, and in a very great many of them the result of its exercise can be fully followed out, and contrasted with that of sexual reproduction. Let us follow it out in the potato-plant. The potato can and does normally propagate itself asexually by means of its underground tubers. As you will know, if you take one of these and plant it, it gives rise to a plant exactly resembling the parent. If the tuber (seed as it is sometimes erroneously called) be that of the Magnum Bonum, it gives rise to a plant with foliage, flowers, and tubers of the Magnum Bonum variety; if it be of the Snowdrop, the foliage, flowers, habit, and tubers are totally different from the Magnum Bonum, and are easily identified as Snowdrops. In this way a favourable variety of potato can be reproduced to almost any extent with all its peculiarities of earliness or lateness, pastiness or mealiness, power of resisting disease, and so forth. By asexual reproduction the exact facsimile of the parent may always be obtained, provided the conditions remain the same.

Now let us turn to the results of sexual reproduction—the seeds, *i.e.* the real seeds, which as you know are produced in the flowers, are the means by which sexual reproduction is effected. They are produced in great quantity by most plants, and when placed in the ground under the proper conditions they germinate and produce plants. But these plants do not resemble the parent. Try the seed of the Magnum Bonum potato, and raise plants from it. Do you think that any of them will be the Magnum Bonum with all its properties of keeping, resisting disease, and so forth? Not a bit of it. The probability is, that not one of your seedling plants will exactly reproduce the parents; they will all be different. Again, take the apple; if you sow the seed of the Blenheim Orange and raise young apple-trees, you will not get a Blenheim Orange. All your plants will be different, and probably not one will give you apples with the peculiar excellence of the parent. If you want to propagate your Blenheim Orange and increase the number of your trees, you must proceed by grafting or by striking cuttings, which are the methods by which such a tree may be asexually reproduced. And so on. Examples might be multiplied indefinitely. Every horticulturist knows that variety characterises seedlings, *i.e.* sexual offspring, whereas identity is found in slips, grafts, and offsets, *i.e.* in asexual offspring; and that if you want to get a new plant you must sow seeds, while if you want to increase your stock of an old one you must strike cuttings, plant tubers, or proceed in some analogous manner.

An apparent exception to this rule is afforded by so-called bud variation, but it is not certain that this is really an exception. In so far as these bud variations are not of the nature of acquired variations produced by a change of external conditions, and disappearing as soon as the old conditions are renewed, they are probably stages in the growth and development of the organism. That is to say, they are of the same nature as those peculiarities in animals which appear at a particular time of life, such as a single lock of hair of a different colour from the rest of the hair,[1] the change in colour of hair with growth,[2] the appearance of insanity or of epilepsy at a particular age. There is nothing more remarkable in a single bud on a tree departing from the usual character at a particular time of life, than in a particular hair of a mammal doing the same thing.

We have seen that, speaking broadly, genetic variation is connected with sexual reproduction, and it becomes necessary to examine this mode of reproduction a little more fully. What is the essence of sexual reproduction, and how does it differ from asexual? What I am now going to say applies generally to the phenomenon whether it occurs in plants or animals. Sexual reproduction is generally carried on by the co-operation of two distinct individuals—these are called the male and female respectively. They produce, by a process of unequal fission which takes place at a part of their body called the reproductive gland, a small living organism called the reproductive cell. The reproductive cell produced by the male is called in animals the spermatozoon, and is different in form from the corresponding cell produced by the female, and called in animals the ovum. The object with which these two organisms are produced is to fuse with one another and give rise to one resultant uninucleated organism or cell, which we may call the *zygote*. This process of fusion between the two kinds of reproductive cells, which are termed *gametes*, is called conjugation. The difference in structure between the male and female gamete is a matter of secondary importance only, and is connected with the primary function of

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[1] Darwin, *Variation*, vol. i. p. 449.

[2] As an example I may refer to the Himalayan rabbit; Darwin, *Variation*, vol. i. p. 114.

coming into contact and fusing. The same may be said with regard to the so-called sexual differences of the parents of the two kinds of gametes, and to the powerful instincts which regulate their action. The conjugation of the male and female gamete, or the fertilisation of the ovum, as it is sometimes called, consists in the fusion of two distinct masses of protoplasm which are nearly always produced by different individuals. In the case of hermaphrodites, the term applied to organisms which produce both male and female gametes in the same individual, there is generally some arrangement which tends to prevent the male gamete from conjugating with the female gamete of the same parent; but this phenomenon is not absolutely excluded, and takes place as a normal phenomenon in many plants and possibly in some animals.

This fusion of the protoplasm of the two gametes gives us a uninucleated organism— for the fusion of the nuclei of the two gametes seems to be an essential part of the process—in which the potencies of the two gametes are blended. The *zygote*, as the mass formed of the fused gametes is called, is formed by the combination of two individualities, and is therefore essentially a new individuality, the characters of which will be different from the characters of both of the parents. This fact, which is not apparent in the zygote when first established, because the parts are hardly distinguishable by our senses, becomes obvious as soon as organs, with the appearance of which we are familiar, are formed. As a general rule this cannot be said to have occurred until what we call maturity has been nearly reached, because we are not familiar enough with the features of immature organisms to detect individual differences. But you may rest assured that such differences exist at all stages of growth from that of the uninucleated zygote till death. How the characters of the two parents will combine in the zygote it is impossible to predict, and the result is never the same even though the conjugations have been between gametes of identical origin. There may be an almost perfect mixture, the blending extending to even quite minute details; or the characters of the one parent may predominate—be prepotent, as we call it—over those of the other; or they may blend in such a way that the zygote offers characters found in neither parent. Or, finally, the features of one parent may come out at one stage of growth, those of the other at another stage. But, however the characters may blend, the product never exactly resembles the parents. The extent to which it differs from them is the measure of the variation.

To resume, it will be observed that in the method of reproduction sometimes called sexual, two distinct processes occur. One of these is the real reproductive act, which consists in the production by fission of uninuclear individuals called gametes; the second is the fusion of the gametes to form the zygote. The gametes are of two kinds, and the reason of there being two kinds is intelligible when we consider the parts they have to play. The male gamete is nearly always endowed with locomotive power, and the female gamete is stored with food material to be used by the zygote in the first stages of growth. The destiny of these two uninucleated organisms is to fuse with one another, and so to give rise to a zygote which ultimately assumes the typical form of the species. As a general rule the gametes have but a limited duration[1] of life unless they conjugate, and this is quite intelligible when we remember that they have no organs, *e.g.* digestive organs, suitable for the maintenance of life. It is rarely found that they have the power of assuming the form of their parent, unless they conjugate. This never happens in the case of the male gamete (at any rate in animals), and only rarely in that of the female. When it occurs—that is to say, when the ovum develops without conjugation—we call the phenomenon parthenogenesis. Parthenogenesis is found more commonly in Arthropods than in other groups, but it may be more common than is supposed.[2]

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[1] Under favourable conditions they may live a considerable time—*e.g.* the spermatozoon of certain ants, which are stated by Sir John Lubbock to live in some cases for seven years.

[2] It may be mentioned as a curious fact that parthenogenesis is rarely found in the higher plants, and, as I have said, is not known for the male gamete among animals.

In sexual reproduction then, in addition to the real reproductive act, which is the division by fission of the parent into two unequal parts, the one of which continues to be called the parent, while the other is the gamete, there is the subsequent conjugation process. It is to this conjugation process that that important concomitant of sexual reproduction must be attributed, namely genetic variation. We have thus traced genetic variation to its lair. We have seen that it is due to the formation of a new individuality by the fusion of two distinct individualities. We have also seen that in the higher animals it is always associated with the reproductive act.

Let us now take a wider survey and endeavour to ascertain whether this most important process, a process upon which depends the improvement as well as the degradation of races, ever takes place independently of the reproductive act. In the Metazoa, to which for our present purpose I allude under the term higher animals, conjugation never takes place except in connection with reproduction. It is impossible from the nature of the process that it should do so, as I hope to explain later on. But among the Protozoa, the simplest of all animals, it is conceivable that conjugation might take place apart from reproduction, and as a matter of fact it does do so. Let us now examine a case in which this occurs. Amongst the free-swimming ciliated Infusoria it frequently happens that two individuals become applied together, and that the protoplasm of their bodies becomes continuous. They remain in this condition of fusion for some days, retaining however their external form and not undergoing complete fusion. While the continuity lasts there is an exchange of living substance between the two bodies, in which exchange a bit of the nucleus of each participates. It thus happens that at the end of conjugation, when the two animals separate, they are both different from what they were at the commencement; each has received protoplasm and a nucleus from its fellow, and the introduced nucleus fuses, as we know, with the nucleus which has not moved. It would therefore appear that all the essential features of the conjugation process, as we learnt them in the case of the conjugation of the gametes in the Metazoa, are present, and it is impossible to doubt that we have here an essentially similar phenomenon. The phenomenon differs, however, from the conjugation first described in this interesting and important respect, that the two animals separate and resume their ordinary life. It is true that their constitution must have been profoundly changed, but they retain their general form. I say that the constitution of the exconjugates, as we may call them after they are separated, must be different from what it was before conjugation, but so far as I know no difference in structure corresponding with this difference in constitution has been recorded. I feel no sort of doubt, however, that structural differences, *i.e.* variations, will be detected when the exconjugates are closely scrutinised and compared with the animals before conjugation, and I would suggest that definite observations be made with a view to testing the point. Here then we have a case of conjugation entirely dissociated from reproduction. Other cases of a similar character are known among the Protozoa, though as a general rule the fusion between the conjugating organisms is complete and permanent. Among plants conjugation is generally associated with reproduction, but not always; for in certain fungi[1] fusion of hyphæ and consequent intermingling of protoplasm occurs, and is not followed by any form of reproduction. Among bacteria alone, so far as I know, has the phenomenon of conjugation never been observed.

To sum up, we have seen that the phenomenon of conjugation is very widely distributed. Excluding the bacteria, there is reason to believe that it forms a part of the vital phenomena of all organisms. Its essential features are a mixture and fusion of the protoplasm of two different organisms, accompanied by a fusion of their nuclei. It results in the formation of a new individuality, which differs from the individualities of both the conjugating organisms. This difference manifests itself in differences in habit, constitution, form, and structure; such differences constituting what we have called genetic variations.

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[1] It must be mentioned, however, that in the case of these fungi the fusion of nuclei has not been observed, nor has it been noticed whether the habit, structure, or constitution of the conjugating plants is altered after the fusion.

The conjugation of the ovum and spermatozoon in the higher animals, and the corresponding process in the higher plants, are special cases of this conjugation, in which special conjugating individuals are produced, the ordinary individuals being physically incapable of the process. The phenomenon of sex, with all its associated complications, which is so characteristic of the higher animals and plants, is merely a device to ensure the coming together of the two gametes. In the lower animals it is possible for the ordinary organism to conjugate; consequently the phenomenon does not form the precursor of developmental change, and is in no way associated with reproduction. Indeed, in such cases it is often the opposite of reproduction, inasmuch as it brings about a reduction in the number of individuals, two separate individuals fusing to form one.

Acquired Characters.

We now come to the consideration of the second kind of variations—namely, those which owe their origin to the direct action of external agencies upon the particular organism which shows the variation; or, as Darwin puts it, to the definite action of external conditions These are the variations which I have called acquired variations or acquired characters. This is not a good name for them, but at the present moment, when I am about to submit them to a critical examination, I do not know of any other which could be suitably applied. Later on, when I sum up the various effects of the direct action of external agencies upon the organism, I may be able to use a more suitable term.

The main peculiarities of acquired variations are two in number: (*a*) they make their appearance as soon as the organism is submitted to the changed conditions; (*b*) speaking generally they are more or less the same in all the individuals of the species acted upon. As examples of this kind of variations, I may mention the effect of the sun upon the skin of the white man; the Porto Santo rabbit, an individual of which recovered the proper colour of its fur in four years under the English climate;[1] the change of *Artemia salina* to *Artemia milhausenii*; the increase in size of muscles as the result of exercise; and the development of any special facility in the central nervous system. Among plants, variations of this kind are very easily acquired, by altering the soil and climate to which the individuals are submitted. So common are they, that it is quite possible that a large number of species are really based upon characters of this kind; characters which are produced solely by the external conditions, and which frequently disappear when the old conditions are reverted to.

With regard to these variations, we want to ask the following question: Do they ever last after the producing cause of them is removed, and are they transmitted in reproduction? In a great number of cases they either cease when the cause which has produced them is removed, or if they last the life of the individual they are not transmitted in reproduction. But is this always the case? That is the important question we now have to consider.

But before doing so let us inquire what acquired characters really are. The so-called adults of all animals have, as part of their birthright, a certain plasticity in their capacity of reacting to external influences; they all have a certain power of acquiring bodily and mental characters under the influence of appropriate stimuli. This power varies in degree and in quality in different species. In plants, for instance, it is mainly displayed in habit of growth, form of foliage, &c.; in man in mental acquirements, and so on. But however it is displayed, it is this property of organisms which permits of the acquisition of those modifications of structure which have been so widely discussed as *acquired* characters. Now this power, when closely considered, is in reality only a portion of that capacity for development which all organisms possess, and with which they become endowed at the act of conjugation. A newly formed zygote possesses a certain number of hidden properties which are not able to manifest themselves unless it is submitted to certain external stimuli. It is these stimuli which constitute the external conditions of existence, and the properties of the organism which are

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[1] Darwin, *Variation*, ed. 2, vol. i. p. 119.

only displayed under their influence are what we call acquired characters. They are acquired in response to the external stimuli.

It would appear, then, that every feature which successively appears in an organism in the march from the uninucleated zygote to death is an acquired character. At first the stimuli which are necessary are quite simple, being little more than appropriate heat and moisture; later on they become more complicated, until finally, when the developmental period is over and the mature life begins, the necessary conditions attain their greatest complexity, and their fulfilment constitutes what we call in the higher animals education. Education is nothing more than the response of the nearly mature organism to external stimuli, the penultimate response of the zygote to external stimuli, the ultimate being those of senile decay, which end in natural death. Acquired properties, it will be seen, are really stages in the developmental history. They differ in the complexity of the stimulus required to bring them out. For instance, the segmentation of the egg requires little more than heat and moisture, the walking of the chick the stimulus of light and sound and gravity, the evolutions of an acrobat the same in greater complexity, and lastly the action of a statesman requires the stimulation of almost every sense in the greatest complexity. Moreover, not only are there differences in the complexity of the stimulus required, but also in the rapidity with which the organism reacts to it. The chick undergoes its whole embryonic development in three weeks, a man in nine months; the chick develops its walking mechanism in a few minutes, while a man requires twelve months or more to effect the same end. Chickens are much cleverer than human beings in this respect. There is the same kind of difference between them that there is between the power of learning displayed by a Macaulay and that displayed by a stupid child.

An instinct is nothing more than an internal mechanism which is developed with great rapidity in response to an appropriate stimulus. It is difficult for us to understand instincts, because with us almost all developmental processes are extremely slow and gradual. This particularly applies to the development of those nervous mechanisms, the working of which we call reason.

Within certain limits the external conditions may vary without harming the organism, but such variations are generally accompanied by variations in the form in which the properties of the zygote are displayed. If the variations of the conditions are too great, their action upon the organism is injurious, and results in abortions or death. And in no case can the external conditions call out properties with which the zygote was not endowed at the act of conjugation.

It would thus appear that acquired characters are merely phases of development; they are the manifestations of the properties of the zygote, and are called forth only under appropriate stimulation; moreover, they are capable of varying within certain limits, according to the nature of the stimulus, and it is to these variations that the term 'acquired character' has been ordinarily applied.

A genetic character, on the other hand, is the possibility of acquiring a certain feature under the influence of a certain stimulus; it is not the feature itself—that is an acquired character—but it is the possibility of producing the feature. Now as the possibility of producing the feature can only be proved to exist by actually producing it, the term 'genetic character' is frequently applied to the feature itself, which is, as we have seen, an acquired character. In consequence of this fact, that we can only determine genetic characters by examining acquired characters, a certain amount of confusion may easily arise, and has indeed often arisen, in dealing with this subject. This can be avoided by remembering that in describing genetic characters account must always be taken of the conditions. For example, the white fur of the Arctic hare is an acquired character, acquired in response to a certain stimulus; while the power of so responding to the particular stimulus when applied at the correct time is a genetic character. Thus a genetic character is a character which depends upon the nature of the organism, while an acquired character depends on the nature of the stimulus.

If we imagine a zygote to be a machine capable of working out certain results on material supplied to it, then we should properly apply the term 'genetic character' to the features of the machinery itself, and the words 'acquired character' to the results achieved by its working. These clearly will depend primarily on the structure of the machinery, and secondarily upon the material and energy supplied to it—that is to say, upon the way in which it is worked.

Variations in genetic characters are variations in the machinery of different zygotes—that is to say, in the constitution—while variations in acquired characters are variations in the results of the working of one zygote according to the conditions under which it is worked.

For instance, let us take the case of those twins which arise by the division of one zygote, and are consequently identical in genetic characters, *i.e.* in constitution. If they are submitted to different conditions, they will develop differences which will depend entirely upon the conditions and the time of life when the differentiation in the conditions occurred. These differences then will be a function of the external conditions, *i.e.* of the manner in which the machinery is worked, and constitute what we call variation in acquired characters.

Are Acquired Characters Transmissible as such in Reproduction?

To return to our question, are the so-called acquired characters ever transmitted in reproduction? Let us consider what this question means in the light of the preceding discussion. Acquired characters are features which arise in the zygote in response to external stimuli. Now the zygote at its first establishment has none of the characters which are subsequently acquired. All it has is the power of acquiring them. Clearly, then, acquired characters are not transmitted. The power of producing them is all that can be transmitted; and this power resides in the reproductive organs and in the gametes to which the reproductive organs give rise, so that the question must be put in another form. Is it possible by submitting an organism to a certain set of conditions, and thus causing it to acquire certain characters, so to modify its reproductive organs that the same characters will appear in its offspring as the result of the application of a different and simpler stimulus?

For instance, the power of reading conferred by education, the hardness of the hands and increased size of the muscles produced by manual labour: is it possible that these characters, now produced by complex external stimuli applied at a particular period of life, should ever in future ages be produced by the simpler stimuli found within the uterus, so that a man may be born able to read or write, or with hands horny and hard like those of a navvy?

In trying to find an answer to this question let us first of all look into the probabilities of the case, to see if we can relate the question to any other class of phenomena about which we have, or think we have, definite knowledge.

When an organism is affected by external agents the action may apply to the whole organisation or principally to one organ. Let us take a case in which one organ only appears to be affected, *e.g.* the enlargement by exercise of the right arm of a man. Now, although in this case it is only the muscles of the arm which appear at first sight to be affected, we must not forget that the organs of the body are correlated with one another, and an alteration of one will produce an alteration in others. By exercise of the right arm the muscles of that arm are obviously enlarged, but other changes not so obvious must also have taken place. The bones to which the muscles are attached will be altered; the blood-vessels supplying the muscles will be enlarged, and the nerves which act upon the muscles, and probably the part of the central nervous system from which they proceed, will also be altered. These are some of the more obvious correlated changes which will have occurred; no doubt there will have been others—indeed it is not perhaps too much to say that all the organs of the body will have reacted to the enlargement of the arm—but the effect on organs not in functional correlation with the muscles of the right arm will be imperceptible, and may be neglected. Thus the colour of the hair, the length and character of the alimentary canal, size of the leg muscles, the renal organs, &c., will not show appreciable alteration. Above all, the other arm will not be affected, or if it is affected the alteration will be so slight as not to be noticeable. Now, we know that homologous parts, whether symmetrically homologous or serially so, are in some kind of close connection. For instance, when one member of an homologous series varies, it is commonly found that other members of the same series will also vary. Yet in spite of this connection which exists between the right and left arms and between the right arm and right leg, there is no similar alteration either in the left arm or in the right leg. Now, if parts which from these facts we may suppose to be in some connection are not affected, how can we expect the reproductive organs not only to be modified, but also to be so modified that the germs which are about to be budded off from them will be so affected as to produce exactly the same character—in this case enlarged muscle, &c.—without the application of the same stimulus, viz. exercise? Thus, while I freely admit that every alteration of an organ in response to external agents will react through the whole organisation, affecting each organ in functional correlation with the affected organ in a way which will depend upon the function of the correlated organ, and possibly other organs not in functional correlation in an indefinite way and to a slight extent, yet I maintain that it is very hard to believe that it will have such a sharp and precise effect upon every spermatozoon and ovum subsequently produced that not merely will these products be altered generally in all their properties, but that one particular part of them—and that part of them always the same—will be so altered that the organisms which develop from them will be able to present the same modification on the application of a different stimulus. It is inconceivable; unless, indeed, we suppose that the very molecules of the incipient organs in the germ are more closely correlated with corresponding parts of the parent body than are the homologous parts of the parent body with one another.

Now, to prove the existence of such a remarkable and intimate correlation would surely require the very strongest and most conclusive evidence. Is there any such strong evidence? I think I may fairly answer this question in the negative. The evidence which has been brought forward in favour of the so-called inheritance of acquired characters is far from conclusive. That such evidence[1] exists I do not deny, but it is all, or almost all, capable of receiving other interpretations.

Effect of Changed Conditions upon the Reproductive Organs.

On the other hand, all the certain evidence we have concerning what happens when the reproductive organs are affected, either directly or by correlation, by a change of conditions—and, as we have seen above, they must be affected if there is to be any change in the offspring—tends to show that there is not any relation between the effect produced on the parent and that appearing in the offspring.

The only means of judging whether the reproductive organs are affected by external conditions is by observing any change which may occur in their function. Now, only two such physiological effects of a change of conditions are certainly known; these are (1) the production of sterility or of partial sterility; (2) the production of an increased but indefinite variability in the offspring. With regard to the first of these effects: One of the most common, or at any rate one of the most noticeable alterations in an organism, effected by change in the external conditions, is an alteration of the reproductive system, an alteration of such a kind that organisms which had previously freely interbred with one another are no longer able to do so. One of the most common results of removing organisms from their natural surroundings is to induce sterility or partial sterility. There is no reason to doubt that this sterility or tendency to sterility is, broadly speaking, due to an affection of the reproductive system. In the case of the higher animals, it may in some cases be due to an action upon the instincts, but in the lower animals and in plants we can hardly doubt that it is due to a direct action upon the reproductive organs. Indeed in plants these organs are often visibly affected. Among animals, however, there does not appear to be any satis-

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[1] For a good statement and discussion of the evidence in favour of this view, see Romanes's *Darwin and after Darwin*, vol. ii. chaps. 3 and 4.

factory evidence on the point, and it is not known what organs are affected, whether it is the actual gametes, or the reproductive glands, or some of the other organs concerned.[1]

The other result of changed conditions which is certainly known is to induce an increased amount of variability of the genetic kind, though not immediately, often indeed not until after the lapse of some generations. On this point Darwin says: 'Universal experience shows us that when new flowers are first introduced into our gardens they do not vary; but ultimately all, with the rarest exceptions, vary to a greater or less extent' ('Variation,' ii. p. 249).[2] With regard to the variability thus induced, it is to be noticed that it is not confined to any particular organ, nor does it show itself in any particular way. On the contrary, the whole organisation is affected, and the variations are quite indefinite.

To sum up the argument as it at present stands: (1) a change in conditions cannot affect the next generation unless the reproductive organs are affected; (2) from a consideration of the facts of the case, it is almost inconceivable that the effect produced upon any organ of a given organism by a change of conditions should so modify the reproductive organs of that organism as to lead to a corresponding modification in the offspring without the latter being exposed to the same conditions; (3) the only effects, which are certainly known, of changed conditions upon the reproductive organs are (*a*) the production of sterility; (*b*) an increase in genetic variability.

As far then as our certain knowledge goes, it would appear that a change of conditions may have one or both of the following effects:—

(1) A definite change, of the same character or nearly so, in all the individuals acted upon. Such changes may be adaptive or non-adaptive, but they are not permanent, lasting only so long as the change of conditions, or at most during the life of the individual acted upon. They are not transmitted in reproduction, and do not appear in the offspring unless it is submitted to the same conditions. These variations are the direct result of the action of the environment upon the individual, with the exception of the reproductive organs.

(2) Increase in the variations of the genetic kind. These are seen not in the generation[3] first submitted to the changed condition, but in the next or some subsequent generations. The effect is produced through the reproductive organs. These variations are non-adaptive, and different in each individual.

If the reproductive organs are affected we get an increase in the variations of the genetic kind. These, we have seen, are usually of an indefinite character; they are different in every case, and their nature cannot be predicted from experience. But we still have to ask: Is this a universal rule? Does it never happen that a change of conditions so affects the reproductive organs as to produce a definite non-adaptive change of the same character or nearly so in all the descendants of the individual acted upon? This is the most obscure question connected with the study of variations. If such changes occur, they might be cumulative, being increased in amount by the continued action of the conditions. They would be non-adaptive, their nature depending on the constitution of the reproductive cells and having no functional relation to the original stimulus.

As possible examples of such variation, I may recall those variations referred to by Darwin as 'fluctuating variations which sooner or later become constant

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[1] The exact cause of this sterility in the higher animals is a point which specially needs investigation.

[2] The phenomenon of increased variability following upon change of conditions has most often been observed when the change has been from a state of nature to a state of cultivation. Hence the conclusion has been drawn that the kind of change involved in domestication alone induces variation. But there is no evidence in favour of this view. The evidence shows that change of conditions in itself may induce greater variability.

[3] No doubt the individuals of the generation first submitted to the changed conditions would be affected as regards their reproductive organs, which would be altered in structure, but this has not been made out, though there are indications of such an effect in certain plants, *vide* Appendix.

through the nature of the organism and of surrounding conditions, but not through natural selection' ('Origin,' ed. 6, p. 176); to the variations in turkeys and ducks which take place as the result of domestication ('Variation,' ii. p. 250); to those variations which Darwin had in his mind when he wrote the following sentence ('Origin,' p. 72): 'There can be little doubt that the tendency to vary in the same manner has often been so strong that all the individuals of the same species have been similarly modified without the aid of selection.'

It is, however, as I have said, extremely doubtful if variations of this kind really occur. The appearance of them may be caused by the combination of the two other kinds of variation. In all cases which might be cited in support of their occurrence, there are the following doubtful elements: (1) no clear statement as to whether the variations showed themselves in the individuals first acted upon; (2) no history of the organisms when transported back to the old conditions.

Moreover, a general consideration of the facts of the case renders it improbable that such similar and definite genetic variations should often occur, at any rate in sexual reproduction. For although the effect upon the reproductive organs may possibly be almost the same in nearly all the individuals acted upon, it must not be forgotten that the reproductive elements have to combine in the act of conjugation, and that it is the essence of this act to produce products which differ in every case.

Effect of Changed Conditions in Asexual Reproduction.

This brings us to the consideration of the question reserved on p. 3: Are genetic variations ever found in asexual reproduction?

If the views expressed in the earlier part of this Address are correct, it would seem to follow that genetic variations are variations in the actual constitution, and are inseparably connected with the act of conjugation. The act of conjugation gives us a new constitution, a new individuality, and it is the characters of this new individual in so far as they differ from the characters of the parents which constitute what we have called genetic variations. According to this the answer to our question would be that genetic variations cannot occur in asexual reproduction, and that if any indefinite variability recalling genetic variability makes its appearance[1] it must be part of the genetic variability and directly traceable to the zygote from which the asexual generations started.

But if genetic variability is not found in asexual reproduction the question still remains, can the other kind of variations—namely, those due to the direct action of external forces upon the organism—be transmitted in asexual reproduction? Now we have already seen that the effect of external agencies acting upon the organism must be regarded under two heads, according as to whether the reproductive organs are or are not affected. If the reproductive organs are not affected, then variations caused by the impact of external forces will not be transmitted; if, on the other hand, they are affected, the next generation will show the effect. We have further seen that in the case of sexual reproduction a modification of the

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[1] Weismann, *On Heredity*, vol. ii. English edition, p. 161. Warren, E. 'Observation on Heredity in Parthenogenesis,' *Proc. Roy. Soc.* 65, 1899, p. 154. These are the only observations I know of on this subject. They tend to show the presence of a slight variability, but they are not entirely satisfactory. In connection with this matter I may refer to Weismann's view that *Cypris reptans*, the species upon which his observations were made, reproduces entirely by parthenogenesis, and has lost the power of sexual reproduction. This view is based on the fact that he has bred forty consecutive parthenogenetic generations and has never seen a male. As Weismann bases some important conclusions on this view, with regard to the importance of conjugation in rejuvenescence of organisms, I may point out that the fact that he has bred forty successive generations and has never seen a male cannot be regarded as conclusive evidence that males never appear. We know of many cases in which reproduction can continue for more than forty generations without the intervention of conjugation, *e.g.* ciliated infusoria, many plants, and of other species of crustacea in which the male is very rare and only appears after long intervals.

reproductive organs will, because of the intervention of conjugation, appear as an increase in genetic variability only. How will the matter stand in the case of asexual reproduction? First, with regard to modifications which do not affect the reproductive system—they, as in sexual reproduction, will not be transmitted. Secondly, as regards modifications which do affect the reproductive organs—they will be transmitted, *i.e.* they will affect the next generation; and the question arises, how will they be transmitted? For here we have the opportunity wanting in the case of sexual reproduction of studying the transmission of modifications of the reproductive system without the complications introduced by the act of conjugation.

In considering this matter, it must be remembered that the reproductive organs are with regard to external influences exactly as any other organ. They can be modified either directly or indirectly, though they are in animals often less liable to direct modification by reason of their internal position.[1] These modifications may, as in the case of other organs, be obvious to the eye of the observer, or they may be so slight as only to be detected by an alteration of function. Now, in the case of the reproductive organs this alteration of function will show itself in the individuals of the next generation (if not before) which proceed directly and without any complication from the affected tissue. How will these individuals be affected? Will they all be affected in the same kind of way, or will they be affected in different ways? Finally, will the modification last their lives only, or will it continue into subsequent asexually produced generations?

Let us endeavour to answer these questions:—

(1) How will the offspring be affected? That will depend entirely upon how the reproductive organ was affected. Will the modification in the offspring have any adaptive relation whatever to the external cause? Now here we have a capital opportunity, an opportunity not afforded at all by sexual reproduction, of examining by experiment and observation the Lamarckian position. My own opinion is that there will be no relation of an adaptive kind between the external cause and the modification of the offspring. For instance, let us imagine, as an experiment, that a number of parthenogenetically reproducing organisms are submitted to a temperature lower than that at which they are accustomed to live. Let us suppose that the cold affects their reproductive organs and produces a modification of the offspring. Will the modification be in the direction of enabling the offspring to flourish in a lower temperature than the parent? My own opinion, as I have said, is that there will probably be no such tendency in the offspring, if all possibility of selection be excluded. But that is only an opinion. The question is unsettled, and must remain unsettled until it is tested upon asexually reproducing organisms.

(2) Will they all be affected in the same kind of way? Yes, presumably they will. I arrive at this conclusion, not by experiment, but by reasoning from analogy. In the case of other organs of the body, the same external cause produces in all individuals acted upon, roughly speaking, the same kind of effect, *e.g.* action of sun upon skin, effect of transplanting maize, Porto Santo rabbits, &c. The question, however, cannot be settled in this way. It requires an experimental answer.

(3) Will the modification last beyond the life of the individuals produced by the affected reproductive organ? I can give no answer to this question. We have no data upon which to form a judgment. We cannot say whether it is possible permanently to modify the constitution of an organism in this way, or whether, however strong the cause may be, consistently of course with the non-destruction of life, the effects will gradually die away—it may be in one, it may be in two or more generations. There are cases known which might assist in settling these questions, but I must leave to another opportunity the task of examining them. I refer to such cases as *Artemia salina*, various cases of bud variation which cannot be included under the head of growth variation.

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[1] How far the abnormal position of the testes of mammalia may receive its explanation in this connection is a question worthy of consideration.

Senile Decay and Rejuvenescence of Organisms.

Another question, also of the utmost importance, confronts us at this point. As is well known, organisms are liable to wear and tear, sooner or later some part or parts essential to the maintenance of the vital functions wear out and are not renewed by the reparative processes which are supposed to be continually taking place in the organism. This constitutes what we call senile decay, and leads to the death of the organism. As a good example of the kind of cause of senile decay, we may mention the wearing out of the teeth, which in mammals at any rate are not replaced; the wearing out of the elastic tissue of the arterial wall, which is probably not replaced. There is no reason to suppose that the reparative process of any organism is sufficiently complete to prevent senile decay. There is probably always some part or parts which cannot be renewed, even in the simplest organisms. Maupas has shown that this holds for the ciliated Infusoria, and he has also shown how the renewal of life, which of course must be effected if the species is to continue, is brought about. He has shown that it is brought about by conjugation, during which process the organism may be said to be put into the melting-pot and reconstituted. For instance, many of the parts of the conjugating individuals are renewed, including the whole nuclear apparatus, which there is every reason to believe is of the greatest importance to living matter.

On reconsidering the life of the Metazoa in light of the facts established by Maupas for the Infusoria, we see that all Metazoa are in a continual state of fission, as are the ciliated Infusoria. They are continually dividing into two unequal parts, one of which we call the parent and the other the gamete. The parent Metazoon must eventually die; it cannot be put into the melting-pot; its parts cannot be completely renovated. The gamete can be put into the melting-pot of conjugation, and give rise to an entirely reconstituted organism, with all the parts and organs brand-new and able to last for a certain time, which is the length of life of the individual of the species.

Is there any other way than that of conjugation by which an organism can acquire a complete renewal of its organs? Is the renewal furnished by the development of all the parts afresh which takes place in a parthenogenetic ovum such a complete renewal? This question cannot now be certainly answered, but the balance of evidence is in favour of a negative answer. And this view of the matter is borne out by a consideration of the facts of the case. In all cases of conjugation which have been thoroughly investigated, the nuclear apparatus is completely renewed. It would appear indeed as though the real explanation of the uninuclear character of the Metazoon gamete is to be sought in the necessity of getting the nuclear apparatus into the simplest possible form for renewal. Now in the development of a parthenogenetic ovum the ordinary process of renewal of the nucleus is often in partial abeyance. As a rule it only divides once instead of twice, and there is, of course, no reinforcement by nuclear fusion. It is, of course, possible that the reinforcement by nuclear fusion which occurs in conjugation may have a different explanation from the nuclear reconstitution which takes place in the formation of polar bodies and similar structures. On the other hand, it may all be part of the same process. We cannot tell. So that we are unable to answer the question whether for complete rejuvenescence a new formation of all parts of the organism is sufficient, or whether a reconstitution of the nuclear apparatus of the kind which takes place in the maturation of the Metazoon ovum and the division of the micro-nucleus of Paramecium is also required; or finally, whether in addition to the latter phenomenon a reinforcement and reconstitution by fusing with another nucleus is also necessary for that complete rejuvenescence which enables an organism to begin the life cycle again and to pass through it completely.

With regard to buds in plants there is reason to believe that they share in the growing old of the parent. That is to say, if we suppose the average life of the individual to be 100 years, a bud removed at 50 will be 50 years of age, and only be able to live on the graft for 50 more years.

Heredity.

Having now spoken at some length of the phenomenon of variation, I must proceed to consider from the same general point of view the phenomenon of heredity.

As we have seen, in asexual reproduction heredity appears, as a general rule, if not always, to be complete. The offspring do not merely present resemblances to the parent—they are identical with it. And this fact does not appear to be astonishing when we consider the real nature of the process. Asexual reproduction consists in the separation off of a portion of the parent, which, like the parent, is endowed with the power of growth. In virtue of this property it will assume, if it does not already possess it, and if the conditions are approximately similar, the exact form of the parent. It is a portion of the parent; it is endowed with the same property of growth; the wonder would be if it assumed any other form than that of the parent. Indeed, it is doubtful if the word 'heredity' would ever have been invented if the only form of increase of organisms was the asexual one, because, there being no variation to contrast with it, it would not have struck us as a quality needing a name, any more than we have a name for that property of the number two which causes it to make four when duplicated.

The need for the word 'heredity' only becomes apparent when we consider that other form of reproduction in which the real act of reproduction is associated with the act of conjugation. Looking at reproduction from a broad point of view, we may sum up the difference between the two kinds, the sexual and the asexual, by saying that whereas the essence of sexual reproduction is the formation of a new individuality, asexual reproduction merely consists in increasing the number of one kind of individual. From this point of view sexual reproduction is better termed the creation of a new individuality, for that, and not the increase in the number of individuals, is its real result. Inasmuch as conjugation of two organisms is the essential feature of sexual reproduction, it would appear that the number of individuals would be actually diminished as a result of it; and this does really happen, though in a masked manner, for we are not in the habit of looking upon the spermatozoon and ovum as individuals, though it is absurd not to do so, as they contain latent all the properties of the species, and are sometimes able to manifest these properties (parthenogenetic ova) without conjugating. In some of the lower organisms the fact that conjugation does not result in an increase of the number of individuals, but only in the production of a new individuality, is quite apparent, for in them two of the ordinary individuals of the species fuse to form one (many Protozoa).

So that sexual reproduction gives us a new individuality which can spread to almost any extent by asexual reproduction. This asexual reproduction gives us a group of organisms which is quite different from a group of organisms produced by sexual reproduction. Whereas the latter groups constitute what we call species, the former group has, so far as I know, no special name, unless it be variety; but variety is not a satisfactory name, for it has been used in another sense by systematisers.

Heredity, then, is really applicable only to the appearance in a zygote of some of the properties of the gametes. A zygote has this property of one of the precedent gametes, and that property of the other, in virtue of the operation of what we call heredity; it has a third property possessed by neither of the precedent gametes in virtue of the action of variation, the nature of which we have already examined. It is impossible to say which property of a gamete will be inherited, and it is impossible to predict what odd property will result from the combination of the properties of the two gametes. Of one thing only are we certain, that they are never the same in zygotes formed by gametes produced in immediate succession from the same parent.

We may thus regard the activities of the zygote as the resultant of the dashing together of the activities of the gametes.

Conjugation, then, is a process of the utmost importance in Biology; it provides the mechanism by which organisms are able to vary, independently of the conditions in which they live. It lies, therefore, at the very root of the evolution problem; the power of combining to form a zygote is one of the fundamental properties of living matter.

Species.

Now let us consider one of the effects of this property upon organisms. The effect to which I refer is the division of animals into groups called species. Species are groups of organisms, the gametes of which are able to conjugate and produce normal zygotes. Now in Nature there appear to be many causes which prevent gametes from conjugating. First and most important of all is some physical incompatibility of the living matter which prevents that harmonious blending of the two gametes which is essential for the formation of a normal zygote. Very little is known as to the real nature of this incompatibility; in fact it is hardly an exaggeration to say that nothing is known. It may be that there is actual repulsion between the gametes, or it may be in some cases, at least, that the gametes are able to fuse, but not to undergo that intimate blending which is necessary for the production of a perfect zygote. In some cases we know that something like this happens; for instance, a blend can be obtained between the horse and the ass, but it is not a perfect blend, the product or zygote being imperfect in one most important particular—namely, reproductive power.

A second cause which prevents conjugation is a purely mechanical one—viz. some obstacle which prevents the two gametes from coming together. As an instance of this I may refer to those cases amongst plants in which conjugation is impossible, because the pollen tube is not long enough to reach the ovule. In yet other cases conjugation is impossible because the organisms are isolated from one another either geographically or in consequence of their habits. There are probably many causes which prevent conjugation, but, whatever they may be, the effect of them is to break up organisms into specific groups, the gametes of which do normally conjugate with one another.

In many cases, no doubt, the gametes of organisms which are kept apart in Nature by mechanical barriers will conjugate fully if brought together. But in the great majority of cases it is probable no amount of proximity will bring about complete conjugation. There is physical incompatibility. Here is a fruitful opening for investigation. Observations are urgently needed as to the real nature of this incompatibility.

Importance of the Study of Variation.

Another and most important effect of conjugation is, as we have seen, the much-spoken-of constitutional or genetic variations. They are, as we have already insisted, of the utmost importance to the evolutionist. Evolution would have been impossible without them, for it is made up of their summation. It becomes therefore desirable to find out to what extent a species is capable of varying. This can only be done, as Mr. Bateson has pointed out, by recording all variations found. Mr. Bateson, in his work already referred to, has carried this out, and has shown the way to a collection of these most important data. In order to carry it further, I would suggest that the collection be made not only for structure, but also for function. This has been done largely for the nervous functions by psychologists and naturalists who pay special attention to the instincts of animals; but we want a similar collection for other functions. For instance, the variations in the phenomena of heat and menstruation, and of rut amongst mammals, and so on. To do this is really only to apply the methods of comparative anatomy and comparative physiology to the members of a species, as they have already been applied to the different species and larger groups of the animal kingdom. Such investigations cannot fail to be of the greatest interest. Indeed, when we have learnt the normal habits and structure of a species, what more interesting study can there be than the study of the possibilities of variation contained within it? Then when we know the limits of variability of any given specific group, we proceed to try if we can by selective breeding or alteration of the conditions of life alter the variability, and perhaps call into existence a kind of variation quite different in character from that previously obtained as characteristic of the species.

The Evolution of Heredity and the Origin of Variation.

These remarks bring me to the consideration of a point to which I am anxious to call your attention, and which is an important aspect of our subject. Has the variability of organisms ever been different from what it is now? Has or has not evolution had its influence upon the property of organisms as it is supposed to have had upon their other properties? There is only one possible answer to this question. Undoubtedly the variability of organisms must have altered with the progress of evolution. It would be absurd to suppose that organisms have remained constant in this respect while they have undergone alteration in all their other properties. If the variability of organisms has altered, it becomes necessary to inquire in what direction has it altered? Has the alteration been one of diminution, or has it been one of increase? Of course, it is possible that there has been no general alteration in extent with the course of evolution, and that the alteration, on the whole, has been one of quality only. But passing over this third possibility, let us consider for the moment which of the two first named alternatives is likely to have occurred.

According to the Darwinian theory of evolution, one of the most important factors in determining the modification of organisms has been natural selection. Selection acts by preserving certain favourable variations, and allowing others less favourable to be killed off in the struggle for existence. It thus will come about that certain variations will be gradually eliminated. Meanwhile the variations of the selected organisms will themselves be submitted to selection, and certain of these will be in their turn eliminated. In this way a group of organisms becomes more and more closely adapted to its surroundings; and unless new variations make their appearance as the old unfavourable ones are eliminated, the variability of the species will diminish as the result of selection. Is it likely that new variations will appear in the manner suggested? To answer this question we must turn to the results obtained by human agency in the selective breeding of animals. The experience of breeders is that continued selection tends to produce a greater and greater purity of stock, characterised by small variability, so that if the selective breeding is carried too far, variation almost entirely ceases, and there is little opportunity left for the exercise of the breeder's art. When this condition has been arrived at, he is obliged, if he wants to produce any further modifications of his animals, to introduce new blood—*i.e.* to bring in an individual which has either been bred to a different standard, or one in which the variability has not been so completely extinguished.

It would thus appear, and I think we are justified in holding this view, at any rate provisionally, that the result of continued selection will be to diminish the variability of a species; and if carried far enough, to produce a race with so little variability, and so closely adapted to its surroundings, that the slightest alteration in the conditions of life will cause extinction.[1]

If selection tends to diminish the variability of a species, then it clearly follows that as selection has been by hypothesis the most important means of modifying organisms, variation must have been much greater in past times than it is now.

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[1] The expression 'extinction of species' seems to be used in two senses, which are generally confused. Firstly, a species may become modified so that the form with which we are familiar gradually gives place to one or more forms which have been gradually produced by its modification. That is to say, a character or series of characters becomes gradually modified or lost in successive generations. This is not really extinction, but development. Secondly, a species may gradually lose its variability, and become fixed in character. If the conditions then change, it is unable to adapt itself to them, and becomes truly extinct. In this case it leaves no descendants. We have to do with death, and not with development.

In fact it must have been progressively greater the farther we go back from the present time.

The argument which I have just laid before you points, if carried to its logical conclusion—and I see no reason why it should not be so carried—to the view that at the first origin of life upon the earth the variability of living matter consequent upon the act of conjugation must have been of enormous range: in other words, it points to the view that heredity was a much less important phenomenon than it is at present. Following out the same train of thought, we are inevitably driven to the conclusion that one of the most important results of the evolutionary change has been the gradual increase and perfection of heredity as a function of organisms and a gradual elimination of variability.

This view, if it can be established, is of the utmost importance to our theoretical conception of evolution, because it enables us to bring our requirements as to time within the limits granted by the physicists. If variation was markedly greater in the early periods of the existence of living matter, it is clear that it would have been possible for evolutionary change to have been effected much more rapidly than at present—especially when we remember that the world was then comparatively unoccupied by organisms, and that with the change of conditions consequent on the cooling and differentiation of the earth's surface, new places suitable for organic life were continually being formed. It will be observed that the conclusion we have now reached, viz. that variation was much greater near the dawn of life than it is now, and heredity a correspondingly less important phenomenon, is a deduction from the selection theory. It becomes, therefore, of some interest to inquire whether a suggestion obtained by a perfectly legitimate mode of reasoning receives any independent confirmation from other sources. The first source of facts to which we turn for such confirmation must obviously be palæontology. But palæontology unfortunately affords us no help. The facts of this science are too meagre to be of any use. Indeed, they are wanting altogether for the period which most immediately concerns us—namely, the period when the existing forms of life were established. This took place in the prefossiliferous period, for in the earliest fossiliferous rocks examples of almost all existing groups of animals are met with.

But although palæontology affords us no assistance, there is one class of facts which, when closely scrutinised, does lend some countenance to the view that when evolutionary change was at its greatest activity, *i.e.* when the existing forms of life were being established, variation was considerably greater than it is at the present day.

But as this address has already exceeded all reasonable limits, and as the question which we are now approaching is one of very great complexity and difficulty, I am reluctantly compelled to defer the full consideration and treatment of it to another occasion. I can only hope that the far-reaching importance of my subject and the interest of it may to some extent atone for the great length which this address has attained.

APPENDIX.

The following observations on the condition of the male reproductive organs in highly variable plants are quoted from Darwin's 'Variation of Animals and Plants under Domestication,' vol. ii. pp. 256 *et seq.*

In certain plant hybrids which are highly variable, it is known that the anthers contain many irregular pollen-grains. Exactly the same fact has been noticed by Max Wichura in many of our highly cultivated plants which are extremely variable, and which there is no reason to believe have been hybridised, such as the hyacinth, tulip, snapdragon, potato, cauliflower, &c.

The same observer also 'finds in certain wild forms the same coincidence between the state of the pollen and a high degree of variability, as in many species of *Rubus*; but in *R. cæsius* and *idæus*, which are not highly variable species, the pollen is sound.' A little further on Darwin says 'these facts indicate that there is some relation between the state of the reproductive organs and a tendency to variability; but we must not conclude that the relation is strict.' Finally he sums up the matter in these words: 'On the whole, it is probable that any cause affecting the organs of reproduction would likewise affect their product—that is, the offspring thus generated.'

FRIDAY, SEPTEMBER 15.

The following Papers were read:—

1. Astrosclera Willeyana, *the type of a new family of Recent Sponges. By* J. J. Lister, *M.A., F.Z.S., Demonstrator of Comparative Anatomy in the University of Cambridge.*

In the collections brought home by Dr. Willey from the Western Pacific were four specimens of a peculiar hard white organism which he found growing on dead coral at a depth of 30 fathoms, in Sandal Bay, Lifu, Loyalty Islands. These he has placed in my hands for examination. The specimens are cylindrical in shape, and measure about 10 mm. in height and 5 mm. in breadth. The base is slightly spreading, and the upper surface gently convex.

Skeleton.—The skeleton is formed of solid polyhedral elements, which are composed of crystalline fibres radiating from a central point. They are united into a mass so rigid that to obtain sections of it slices were cut with a fret-saw, and, after embedding in copal by von Koch's method, were ground down thin on a hone. The mineral constituent of the skeleton is carbonate of lime in the form—as the specific gravity shows—of *aragonite.* The skeleton is permeated by canals which open only on the upper surface. There is no large central space to which the canals are tributary. Many are approximately parallel with the axis, and they communicate very freely by branch canals, which run from one to another, dividing and anastomising (see fig. on p. 776).

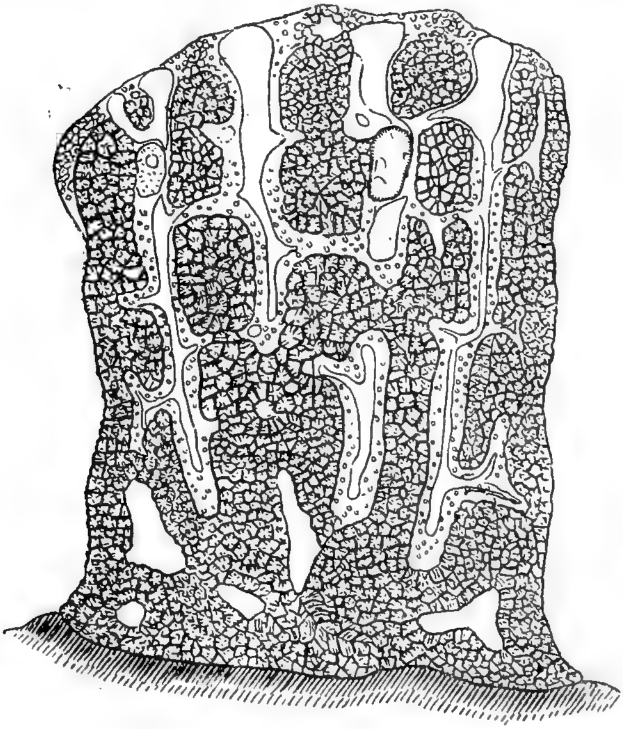
The sides are smooth and imperforate, while the curved upper surface is closely pitted by the openings of the canal system. In one specimen the upper surface is traversed by grooves, which radiate, with an approach to symmetry, from one point. These are apparently radially directed canals of the skeleton in course of formation. There is no indication that the central point is occupied by a canal larger than the others, whose openings are scattered over the surface.

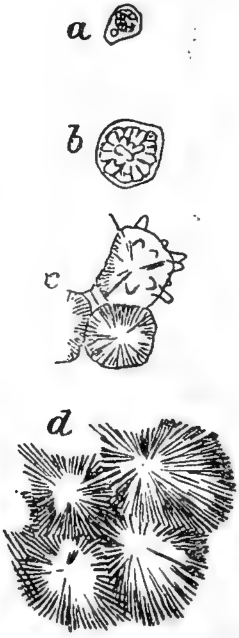
The ridges of the skeleton between the openings are produced into irregular crests and points formed of skeletal elements, which are more and more loosely connected with one another as the surface is approached.

The gelatinous layer which invests the upper surface is crowded with young growing skeletal elements, the small ones free and spherical, the larger packed together like hailstones, and assuming the polyhedral form.

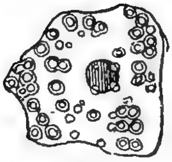
Origin of the Skeletal Elements.—The spherules take their origin in single cells of the jelly, near the upper surface. In the early stages of growth the granular nucleated cell body is seen as a thin investing layer surrounding the spherule, which is from the first composed of radiately arranged crystalline fibres. As the spherule increases in size it takes up its position as an element of the fixed skeleton, and in the course of their growth the angular spaces between adjacent skeletal elements are completely filled in to the exclusion of the soft parts. The elements thus lose their spherical shape and become polyhedral. The external surface of a spherule in contact with a layer of soft tissue is often beset with radiating points, and resembles a portion of a spheraster of a siliceous sponge. After decalcification a more or less abundant organic basis of the skeleton is left; the central parts of the spherules take a deeper stain, and are thus marked off from the peripheral portions.

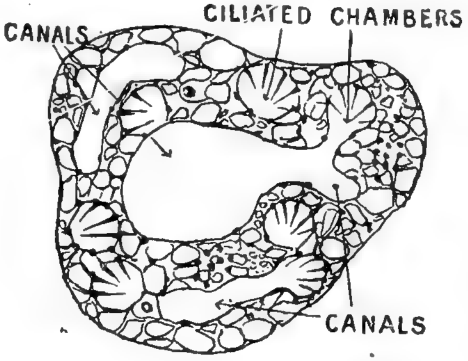
The Soft Tissues.—The gelatinous layer, above alluded to as investing the ridges of the skeleton, lines the openings of the canal system and extends as a sheet, thin in the centre, over the mouth of each canal. A round pore is frequently present at this point, but in many cases the membrane is not perforated; the spaces at the mouths of the canals are, however, in communication with one another by lateral channels through the jelly, beneath the surface membrane. Besides the cells in which the spherules are found, there are branched amœboid cells sparsely scattered through the jelly.





a-*d*, Stages in the growth of skeletal elements.





Section of soft tissue (highly magnified).

The soft tissues of the sponge are contained in the skeletal canals (as they may now be termed to distinguish them from the canals which run in the soft parts), and penetrated by the water-bearing canals which open by the pores at the surface. From the main canals small ones are given off which ramify in the layer of soft tissue in contact with the skeleton.

As the canals are followed downwards into the interior, the cellular elements in their walls, at first scattered, become more and more abundant, and the jelly less conspicuous. At a short distance from the surface the soft tissue assumes the characters which are maintained throughout the interior of the sponge. A section through it shows that it is largely made up of cells united into a reticulum with vacuolar spaces of various sizes forming the meshes. The jelly which is so conspicuous in the surface layers appears to be scanty or altogether absent here. Besides the smaller branched protoplasmic masses with nuclei $1{\cdot}5 - 2\mu$ in diameter, which make up the greater part of the reticulum, there are larger and more circumscribed cells with larger nuclei ($2 - 3\mu$ diam.) Scattered through the reticulum, and with their walls apparently formed by portions of it, are the ciliated chambers and the ramifying branches of the canal system.

Ciliated Chambers.—These are round or oval chambers of minute but fairly uniform size, the larger measuring 18 by 11μ, the smaller 10 by 8μ. (The sections of smaller diameter are doubtless in many cases transverse to the long axis of larger chambers.) Their walls are formed by cells which send out processes laterally, and these, joining with one another, bound the chamber, others extending away from the chamber are continuous with other cells of the reticulum, while a third set of processes project into the cavity of the chamber, and each, tapering gradually from its base, forms a flagellum which may extend across to the other side of the chamber. There is no indication of a collar, or of the abrupt truncated termination of the cell body at the base of the flagellum, characters which are usually seen in choanocytes. A well-marked nucleus is situated at the base of the flagellum at its junction with the body of the cell. The flagella project from about half the concave inner surface of the chamber, some four or five commonly appearing in section, and their tips thus converge, and are often seen to have become entangled. The remainder of the inner wall of the chamber is smooth. The cavity opens into a branch of the canal system by a narrow passage about 4μ in diameter.

Although the features of the ciliated chambers above described differ in many points from those usually met with in sponges, they are so distinctly seen as to give the impression that they are approximately those of the living tissue.

The larger branches of the canal system, with flattened nuclei scattered over their walls, are easily recognised, but in many cases it is difficult to decide whether a particular space met with in a section is to be referred to the canal system or to a vacuolar mesh of the reticulum, if indeed the two are distinct.

In some of the skeletal canals the tissue above described is abundant, in others only a thin lining of loose vacuolated tissue is found, but all intermediate conditions in the character of the soft tissue lying between the skeleton and the main trunks of the canal system are met with.

The existence of ciliated chambers implies the existence of afferent and efferent channels. I have not been able to recognise, from the structure, a differentiation of the canals into these two categories, but it seems clear that the efferent system is not collected into one or a few large channels, such as are commonly found in sponges. My impression is that there are a large number not only of afferent but efferent trunks to the canal system, supplying and draining approximately equal areas.

Reproduction.—Each of the three specimens which I examined by sections contained large eggs or embryos. They are found near the orifices of the larger canals, separated from the skeletal wall by a thin layer of soft tissue. I have not been able to recognise eggs in a young stage of growth. An advanced *ovum* in one specimen measures 0·1 mm. in length, and has a thick-walled nucleus 25μ in diameter, and a well-marked germinal spot. An *embryo* in the same specimen has a superficial layer of nuclei, and the protoplasm about them is disposed in columns perpendicular to the surface. Internally the columns are merged in the granular protoplasm which occupies the interior of the embryo, and this is obscurely divided into irregular masses, but not, so far as I can detect, containing nuclei. None of the embryos have a segmentation cavity. It appears, then, that the development leads to the formation of a larva of a *parenchymula* type, rather than an *amphiblastula*. I have not been able to recognise any stage in the formation of *spermatozoa*.

In the course of growth the soft tissues appear to be withdrawn from the skeletal canals in the basal region of the sponge, these being left empty, or with only a thin layer of tissue on their walls.

Zoological Position.—That the animal under consideration belongs to the *Porifera* seems clear from the presence in the soft tissues of numerous chambers provided with flagella and communicating with a system of canals which ultimately open to the exterior by pores. The soft tissues are, moreover, supported by a skeleton composed of elements which are secreted by cells of the jelly.

On the other hand, that it is not a *Cœlenterate* is shown by the absence of polyps, mesenteries, and thread-cells.

But admitting that *Astrosclera* is a Sponge, there are many features which separate it from the living members of this group. Among these may be mentioned:—

(*a*) The shape of the skeletal elements. They are polyhedra, which begin as spheres, and may pass through a spheraster stage.

(*b*) Their union to form a rigid skeleton to the exclusion of the soft parts. In *Petrostroma* of Döderlein the supporting skeleton is also formed of fused calcareous spicules, but these are modified quadriradiates.

(*c*) The mode of growth by the addition of new skeletal elements at the upper surface, and without interstitial growth.

(*d*) The limitation of the pores to the upper surface. *Teutorium* (Vosmaer), a siliceous sponge classed with the *Polymastidæ*, presents a similar limitation.

(*e*) The absence of large gastral spaces.

(*f*) The small size of the ciliated chambers. They do not exceed 18μ by 11μ, while the smallest size given by Hæckel for the *Leucones* (whose ciliated chambers are smaller than those of other Calcarea) is 60μ by 40μ. Among the non-Calcarea 42μ is the smallest diameter given for the ciliated chambers.

(*g*) The character of the cells bearing the flagella. They appear not to be collar-cells of the usual type, but more or less amœboid, and without a collar, the body of the cell gradually tapering into the flagellum.

From the Calcarea it differs also in the following features:—

(*a*) The flagellate cells are limited to about half the interior of the ciliated chambers.

(*b*) There appears to be a long and complicated canal system both on the afferent and efferent sides of the ciliated chambers.

(*c*) The mineral constituent of the skeleton is aragonite and not calcite.

While *Astrosclera* is very distinct from any of the families of living sponges, its resemblance to certain members of the group of fossil sponges *Pharetrones* is very striking. These are found in strata ranging from the Devonian to the Cretaceous periods.

The feature characteristic of many members of this group (though authorities are by no means agreed either on its essential characters or limits) is that the skeletal elements are united together into dense trabeculæ or 'fibres,' as they are technically called, between which a branched canal-work is often present, leading into a central gastral cavity. The latter, however, may be so shallow as almost to cease to exist. A cortical layer, which has been thought to be imperforate, often clothes the outer surface of the cylindrical members of this group, and in that case the pores leading to the interior would be limited to the upper part of the sponge. In some cases radiating grooves are present on the upper surface converging towards the mouth of the gastral cavity, the initial stage of the branched canals of the interior.

If we suppose the trabeculæ of the skeleton of one of the simple forms to increase in thickness, and the gastral cavity to become wholly obliterated (as is very nearly the case in *Stellispongia*), we have a form agreeing with *Astrosclera* in the larger features of the anatomy of the skeleton.

On turning our attention, however, to the elements of which the fibres of the skeleton are formed, we find that in the *Pharetrones* in which the structure is most perfectly preserved, they are well-marked tri- and quadriradiate spicules similar to those of other calcareous sponges.[1] They are closely packed together, the rays being bent to adapt them to one another to form the fibre of the sponge. The spicules have been clearly demonstrated in several genera, including, besides simple forms, the remarkable segmented sponges such as *Verticillites,* which consist of tubular segments whose walls are formed of close-packed spicules, and which are superposed one upon another, the roof of one forming the floor of its successor.

In the Triassic deposits of St. Cassian in the Tyrol, representatives of the *Pharetrones* occur, in which the fibres of the skeleton are made up, not of spicules, but of spheroidal masses, with a radiate structure strikingly resembling the elements of the skeleton of *Astrosclera.*[2]

The view of this structure generally held by palæontologists is that it is secondary, being due to a recrystallisation of the lime. If this is the case, it is certainly a remarkable coincidence that the structure should resemble so closely that of a living form, which in the larger features of the anatomy of its skeleton resembles members of the *Pharetrones.* A fact which supports the view of the secondary nature of the spherulitic structure is that the fossils in which it occurs are the representatives in the St. Cassian beds of both simple (*e.g. Corynella gracile,* Münstr.), and segmented (*e.g. Enoplocœlia* and *Thaumastocœlia*) forms of the *Pharetrones,* which as they occur elsewhere exhibit as we have seen well-marked tri- and quadriradiate spicules.

Supposing the spherulitic structure to be secondary in these fossils, the nature of the skeletal elements is a definite character dividing *Astrosclera* from the *Pharetrones.*

Under these circumstances it seems better to class *Astrosclera* as the type of a new family *Astroscleridæ,* possibly allied to the *Pharetrones,* but certainly without close affinity with any other known group of sponges.[3]

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2. *On the Morphology of the Cartilages of the Monotreme Larynx. By* JOHNSON SYMINGTON, *M.D., Professor of Anatomy, Queen's College, Belfast.*

This paper contained a description of the cartilaginous framework of the larynx of the ornithorhynchus and the echidna, based upon ordinary dissections and complete serial microscopic sections of the organ.

The condition of the thyroid cartilage in the monotremes is of special interest, as it forms the basis of Dubois' theory of the origin of this cartilage from two pairs of visceral arches, the fourth and fifth post-oral. The author referred to the different descriptions of this cartilage given by Dubois, Wiedersheim, Walker, and Gegenbaur, and showed that it consists of a single piece of cartilage, which includes a median ventral part and two pairs of cornua. The median portion is not, as usually represented, a separate element or copula, but is directly continuous with the cornua. The thyroid cartilage of the monotremes agrees, therefore, with that of the higher mammals in consisting of a single cartilaginous mass, but it differs in that its anterior and posterior cornua pass from the small median portion, or body, round the sides of the larynx in a dorsal and caudal direction nearly parallel with one another, and the anterior cornua are further peculiar in being continuous by a large part of their anterior borders with the posterior cornua of the hyoid.

According to Gegenbaur the cartilage of the epiglottis is a derivative of the sixth post-oral visceral arch. He based this theory mainly upon his observations to

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[1] These are beautifully shown in the Warminster specimens described by Hinde, *Ann. and Mag. of Nat. Hist.* ser. 5, vol. x. (1882), p. 185.

[2] Cp. Zittel, *Grundzüge der Paleontologie,* p. 59, fig. 88; also *Studien über fossilen Spongien,* iii., *Abh. k. bayer. Ak. Wiss.* Cl. ii. Bd. 13 *Abth.* 2 (1879), pl. xii. fig. 5.

[3] A fuller and illustrated description will appear in Dr Willey's *Zoological Results.*

the effect that in the monotremes the epiglottis is composed of hyaline cartilage, and thus, in its primitive form, has the same histological structure as the other visceral arches. The author's results are entirely opposed to those of Gegenbaur. He found its structure to be similar to that of ordinary mammals, viz. yellow elastic cartilage. The existence of an abundant network of elastic fibres was demonstrated by various stains, especially picric acid and orcein.

Both the ontogeny and the phylogeny of the mammalian epiglottis support the view that it is a single median structure, and not, as Gegenbaur believes, the result of the fusion of two lateral elements.

Gegenbaur's theory of the phylogeny of the epiglottis must be abandoned, while the view of Dubois that it is a new formation of cartilage in the submucous tissue, not represented in submammalian vertebrates, appears to me to be consistent with the known facts of its structure, relations, and comparative anatomy.

The arytenoid cartilages of the monotremes closely resemble those of the marsupialia except that they are relatively somewhat smaller. The interarytenoid cartilage is present and has the same relations as in marsupials, but in both echidna and ornithorhynchus there is an additional median cartilaginous element in the ventral wall of the larynx posterior to the interarytenoids

3. *The Palpebral and Oculomotor Apparatus of Fishes.*
By N. Bishop Harman, *M.B.*, *F.R.C.S.*

This paper is based upon observations drawn from the examination of seventy species of fishes, a number which includes examples of most British and some foreign species.

(1) *Palpebral Apparatus.*—Gradations in form were found from simple to complex forms, but it was to be noted that this gradation did not coincide with any plan of development of orders of fish, since the most complex were found in species nearest the main line of phylogeny.

The occurrence of simple forms of provision did not show any scheme of classification either from relation or habitat. In more complex forms an 'extra palpebral fold' found in salmon and herring appears to serve as a 'fender' to the eye in fishes frequenting river and seashore.

The provision of greatest interest was found in the nictitating membrane of selachians. The relative values of these folds in Carcharias, Galeus, Mustelus, and Scyllium appear to depend on the coincident condition of the ordinary palpebral margin. The certainty of the presence of this membrane in the last-named fish was noted by observation on the living fish.

The development of the membrane as an epiblast-clad fold of dermis springing from the ocular aspect of a previously formed lower lid was shown by serial sections of the region in Mustelus embryos.

The source of the complex musculature of the eyelids of these fish was traced by the same means to the branchial musculature of the spiracle; this remarkable transference of muscle tissue from a branchial musculature to so dissimilar an apparatus as palpebral folds was further shown by the inverse ratio existing between the condition of spiracle and nictitating membrane. In those fish in which the latter is at its highest development the spiracle is absent, and *vice versâ.*

(2) *Relation of Bulb to Orbital Walls.*—The presence of an orbital sac was noted. Between its least developed form as a bursal sac separating the bulb from the underlying pharyngeal muscles in the fishing frog, to the large sac affording complete investment to the orbit and to the structures within it, and the special muscular evagination of the sac to form the recessus orbitalis of Holt in the pleuronectids, a complete gradation of form can be traced.

Investing the bulb was found a complete membrane attached peripherally to the palpebral folds, and affording tubular sheaths to the muscles; the membrane in its relations agreed well with the capsule of Tenon in the higher mammals.

The eyes of many cartilaginous fishes are supported by a rod of cartilage; rays exhibit the structure in its most complete form of cup, stem and ball, and socket-joint; the stem is stayed by ligaments. In sharks it dwindles into a slender rod, and is absent in some. Its origin was found to be by an independent chondrification within the mesoblast packing of the orbit.

The eyes of many bony fishes are supported by a ligament in close relation to the optic nerve. The occurrence of the ligament was very frequent in fresh-water fishes.

(3) *Musculature.*—The eye-muscles of fishes are singularly uniform in their relations. Among the variations found may be noted that in *Zygæna Maleus* The short M. recti are attached to the distant basis cranii by means of a long common tendon.

Provision for projection and retraction of the bulb was found in a few cases, the special movement of the eyes of *Periopthalmus koelreuteri* is probably not of this nature; but of elevation and depression.

The formation of palpebral retractors by a superficial delamination of the M. recti was noted in some cases.

A special form of M. obliquus superior was found to exist in both eyes of all pleuronectids, which provides for the *rotation* of the eye. This muscle consists here of two parts, one like the normal M. obliquus superior of other fish, a second in a long, slender, strap-like portion, which embraces the upper and outer quadrant of the bulb. The axis of vision of these fish can be noted to be frequently in a state of convergence; it is particularly interesting to note this specialisation in this connection, since like conditions of the muscle are found in animals possessing the capacity of convergence of visual axes, *e.g.* horse and man. This indicated the possibility of independent evolution of organs in widely severed types along similar lines when the conditions of use are similar.[1]

4. *The Pelvic Symphysial Bone of the Indian Elephant.*

By Professor R. J. ANDERSON.

The symphysial cartilage of many mammals is often converted into bone. Numerous examples have been noted and commented on by myself and others. It is only necessary to refer to the fact that ligaments are often converted into bone. The tentorium cerebelli of certain carnivora, the ligaments of the pelvis (sacro-sciatic) in the sloth and armadillo, the tendons in the leg of the turkey, the supra-scapular ligament in man, and the abdominal fibrous bands in the crocodile, are the often-cited examples of bones that are developed in tendinous or membranous structures.

The symphysial cartilage or bone has been, in the pelvis, regarded as the equivalent (homologous to the whole or part) of the sternum, and has been called a pelvisternum. Whether this be so or not, the actual condition of the bone is of considerable morphological interest.

Mr. Schlüter of Halle supplied to our Museum three years ago the rough skeleton of an elephant. When cleaned and mounted, it appeared to have been about eight feet high at the shoulder. The ischio-pubic epiphyses are still separate, and the iliac crest, still incomplete, is not united to the ilium. The head of the femur and the great trochanter are not united to the shaft of the thigh-bone.

A wedge-shaped bone exists between the pubes of opposite sides, the anterior surface is triangular, is two and a half inches in height, and one and a quarter inches wide This surface is convex from below upwards. The lower surface, which is keeled, is two and a half inches in length. The bone tapers posteriorly.

The skeleton of the elephant in the National Museum of Ireland has a small pelvic symphysial bone, and the camel in the Museum of the Royal College of Surgeons of Ireland has also a well-formed example of the same bone. Many skeletons have, however, been so well (?) cleaned that the symphyses have disappeared.

It is not easy to account for the symphysial cartilage or bone morphologically,

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[1] The paper has been published *in extenso*, with plates, in the *Journal of Anatomy and Physiology*, Nov. 1899, vol. xxxiv. p. 1.

but the observations of Albrecht, although somewhat disconnected, are worthy of consideration. It will be remembered, however, that the sternum is in its inception very intimately connected with the rib arches, to which the ribs are hinged, and which, with the spinal column, form the fixed bars on which the ribs swing, and is, as nearly as possible, the result of the fusion of the lower ends of the ribs to form a beam, from which the ribs are afterwards segmented and made to swing on the sternal and dorsal hinges, whilst two rows of (lateral) centres of ossification lead, in the course of development, to the solidification of the sternum. The symphysial cartilage, in man at least, presents occasionally for observation a pelvic fissure.

5. *A few Notes on Rhythmic Motion. By* Professor R. J. ANDERSON.

6. *The Crystallisation of Beeswax and its Influence on the Formation of the Cells of Bees. By* CHARLES DAWSON, *F.G.S., &c., and* S. A. WOODHEAD, *B.Sc., F.C.S.*

The hexagonal arrangement of the cells of bees has been generally ascribed to a structural instinct of bees; the object of this paper is now to show that the form of the bee-cell is chiefly influenced by a kind of crystalline formation due to the cooling of the wax.

7. *Report on Photographic Records of Pedigree Stock.* See Reports, p. 424.

SATURDAY, SEPTEMBER 16.

The following Reports were read:—

1. *First Report on the Plankton and Physical Conditions of the English Channel.*—See Reports, p. 444.

2. *Report on the Occupation of a Table at the Zoological Station at Naples* See Reports, p. 431.

3. *Report on the Occupation of a Table at the Marine Biological Laboratory, Plymouth.*—See Reports, p. 437.

MONDAY, SEPTEMBER 18.

The following Papers and Reports were read:—

1 *The Development of Lepidosiren paradoxa. By* J. GRAHAM KERR.

2. *Animals in which Nutrition has no Influence in Determining Sex. By* JAMES F. GEMMILL.

The edible mussel (*Mytilus edulis*) may be found at all different levels between moderately high and low tide marks. The individuals are fixed, and feed only when covered by water. Those which are placed high up in the tidal zone are not so well nourished as those which have a lower position. The former have less time during which feeding is possible, and are much smaller in size than the latter. Mussels have the sexes separate. Their larval free-swimming stage ceases before sex is differentiated, as far as can be made out by histological examination. There is not a relatively greater number of females in the middle and lower zones, nor a relatively greater number of males in the higher zones. The inference is that in the mussel nutrition has no influence in determining sex.

The common limpet (*Patella vulgata*) is also found everywhere in the tidal zone. Its sexes are separate, and the free-swimming stage ceases before sex is differentiated. The limpet is not fixed in the same sense as the mussel, but from its habits it may be considered as practically fixed.

The same facts regarding the numerical proportion of males and females at different levels were found to hold good for the limpet as for the mussel, and the same inferences were drawn. In the mussel and the limpet there are no well-marked secondary sexual characters, and the ovary and testes are equal in bulk. On the other hand, in the special animals in which nutrition has been distinctly shown to influence the determination of sex there is a disproportion sometimes extreme between the amounts of the male and female sexual products. This is due chiefly to the fact that the eggs in these cases are provided with much deutoplasm, while the sperm is small in amount. The presence of deutoplasm in large quantity cannot, however, be considered to be primitively characteristic of ova.

Bearing of the foregoing on the general questions of the evolution and determination of sex.

3. *Exhibition of Newly Discovered Remains of* Neomylodon *from Patagonia.*
By F. P. MORENO *and* A. SMITH WOODWARD.

On behalf of Dr. F. P. Moreno, Director of the La Plata Museum, Mr. A. Smith Woodward exhibited some newly discovered remains of the supposed extinct ground-sloth *Neomylodon*, discovered by Dr. R. Hauthal in a cavern in Patagonia. The animal had previously been known only by a piece of armoured skin from the same cavern. The new specimens comprised a skull, evidently broken by man, and some well-preserved pieces of excrement. These were found beneath a layer of earth in the cave, with a large quantity of hay and other evidence of the presence of man. The excrement showed that the animal fed on grasses and herbs, not on the foliage of trees. The skull, which still showed pieces of flesh and cartilage adhering to it, seemed to be identical with one from the Pampa formation further north, named *Glossotherium* or *Grypotherium*, as already observed by Dr. Santiago Roth. The theory of Dr. Hauthal, that these ground-sloths were kept in captivity in the cave by the ancient Patagonians, was adversely criticised by several speakers, and the fresh appearance of the specimens was specially commented upon.

4. *Exhibition of and Remarks on a Skull of the extinct Chelonian* Miolania *from Patagonia.* *By* F. P. MORENO *and* A. SMITH WOODWARD.

Mr. Smith Woodward also exhibited, on behalf of Dr. Moreno, a skull of the extinct Chelonian reptile, *Miolania*, obtained by Dr. Roth for the La Plata Museum during his recent expedition to Chubut. The skull proved to be essentially identical with others already discovered in superficial deposits in Queensland and in Lord Howe's Island, 400 miles off the coast of New South Wales. The discovery was thus of great interest, as apparently favouring the hypothesis of a former great antarctic continent, of which Australia and Patagonia are now mere remnants.

5. *The Fur Seals of the Behring Sea.*
By G. E. H. BARRETT-HAMILTON.

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6. *Report on Bird Migration in Great Britain and Ireland.*
See Reports, p. 447.

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7. *Report on 'Index Animalium.'* See Reports, p. 429.

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8. *Report on the Zoology of the Sandwich Islands.* See Reports, p. 436.

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9. *Report on Zoological and Botanical Publications.* See Reports, p. 444.

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10. *Report on the Zoology and Botany of the West India Islands.*
See Reports, p. 441.

TUESDAY, SEPTEMBER 19.

1. *Experiments on the Artificial Rearing of Sea-Fish.*
By W. GARSTANG, *M.A.*

Recent experiments at the Plymouth laboratory with the larvæ of the Butterfly Blenny (*Blennius ocellaris*) have shown that under suitable conditions the metamorphosis of Teleostean larvæ can be completed with a death-rate not exceeding 30 per cent. or 40 per cent. of the original numbers. The failure of MM. Fabre-Domergue and Biètrix in their experiments upon *Cottus*, and of Cunningham in the case of other fishes, is probably to be attributed to their employment either of absolutely stagnant water or of water in a state of very slow circulation. In my experiments the mortality in the early stages of development, when stagnant water was employed, was invariably very high. The larvæ remained inactive and refused to feed, exactly as in the experiments of the French observers. But if during the first week of development the water was kept in a constant state of gentle agitation by means of the 'plunger' devised by Messrs. Allen and Brown, the larvæ remained healthy and active, and were incessantly on the look-out for food particles. On the other hand, agitation of the water appears to be unnecessary in the later stages of development, for if the larvæ are kept healthy in agitated water during the first week of their development they may complete their metamorphosis in absolutely stagnant water, provided it is properly oxygenated and supplied with food, and is kept free from the accumulation of organic débris.

The success of my later experiments was so complete that I propose to continue them on a larger scale during the coming spawning season with the larvæ of food-fishes, in the hope of throwing light upon the difficult problems of sea-fish culture.

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2. *Plaice Culture in the Limfjord, Denmark.*
By Dr. C. G. JOH. PETERSEN.

The Limfjord runs right across the northern part of the peninsula of Jutland, there being an entrance from the North Sea at Thyborön, and another from the

Cattegat at Hals. The distance between these two entrances is about ninety English miles.

The fjord consists of several extensive broads connected with each other by sounds and narrow channels. The total area of the water-surface is estimated at 416 square English miles. The average depth is between three and four fathoms, and the greatest depth is only twelve fathoms. Close to the shore, and where strong currents prevail, the bottom consists of shells, gravel, and sand, but elsewhere it is a soft blue mud. *Zostera maritima* grows in great luxuriance in most of the shallow reaches. In summer the temperature of the water of the Limfjord is several degrees higher than that of the North Sea and Cattegat, but in winter it is much lower, and the surface is then frequently covered with a thick layer of ice. The salinity of the water decreases from the North Sea towards the inner Broads, where it was often nearly fresh. There is scarcely any tide; the rise and fall of level, and the currents are chiefly determined by the action of the wind. The shores of the Limfjord are varied and picturesque, many of the hills being crowned by the characteristic Viking Mounds.

The fjord has witnessed many changes. During the Stone Age the water stood at a higher level and was much salter, especially in the eastern part. This is proved by the position, far from the present shore, of the ancient kitchen-middens with abundance of oyster shells. This salt-water period was followed by several others, in some of which the water became nearly fresh; the oysters disappeared, and the fjord contained many fresh-water fish. The last great change took place in 1825, when the North Sea broke into the fjord near Thyborön. The water, in consequence, became salter, and the oysters subsequently returned to the fjord.

The Thyborön Channel is now about half a mile wide: the navigable part, with a depth of eight to twelve feet, is kept open by the continual work of a Hopper dredger. The Nissum Broad, which is in direct communication with the North Sea by means of this channel, has an area of about seventy square miles. This Broad is every year crowded with small plaice. I estimate that there is here at least one plaice on every square fathom of the bottom, a calculation made by means of counting all the plaice fished with a plaice-seine on different places of the Broad, every haul describing an area of about one-quarter Tönde Land (1 Tönde Land = $1\frac{4}{11}$ acre).[1] On July 1 last a haul was made here with a Danish plaice-seine, for the information of some of the delegates to the recent Stockholm Conference. The whole operation occupied less than an hour, and 3,400 plaice were landed on the deck of the fishery steamer *Sallingsünd.* The majority of these fish measured between seven and eight inches, a few were much smaller, and only one measured thirteen inches.

No fertilised plaice eggs have ever been observed in this or any other part of the Limfjord, but plaice from two to seven inches in length come in from the North Sea in abundance in spring. Many of these migrate farther into the fjord, but others migrate out into the North Sea again, in winter, for specimens labelled in the Nissum Broad have been captured in the North Sea.[2] The plaice does not breed in the fjord; but the fry of the year immigrates in the course of the year from the North Sea. The plaice are so crowded in the Nissum Broad, that they do not grow fast from want of sufficient food. Labelled specimens were found to have grown only half an inch in six months, while other specimens from the Nissum Broad, placed in another Broad at the same time, increased five inches in length during the same period.[3]

It may be mentioned here, that over the whole Limfjord quantitative examina-

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[1] Comp. Report from the Danish Biological Station, vi. 1895, p. 23.

[2] Comp. *loc. cit.* p. 6, and 8–10, and Table I. belonging to this Report, where a graphical scheme is given showing (1) that the size of the plaice increases with the distance from the North Sea; (2) that the fry of the year only is to be found in the western part of the Limfjord.

[3] Comp. *loc. cit.* p. 20, and Appendix II. to this Report: 'On the Labelling of Living Plaice in the Limfjord in 1895.'

tions have been made by an apparatus which covers one square foot bottom surface and takes up all invertebrates (bivalves, worms, &c.) living on this. In this way it was shown that there are many places where 1,400 bivalves (Abra, Corbula, and Solen) live on one square foot bottom surface, and that, for instance, in the Thisted Broad, where the plaice grows quicker and becomes larger than in the other Broads, food suitable for plaice is not more abundant than in the other Broads. The different growth must therefore be owing to the different number of fish per Tönde Land:

In Nissum Broad there are at least 932 plaice per Tönde Land.
In Kaas Broad „ „ 375 „ „
In Veno Bugt „ „ 297 „ „
In Thisted Broad „ at most 7 „ „

On July 2, a haul of the seine, under precisely similar conditions as in Nissum Broad, was taken in Kaas Broad, which is farther removed from the North Sea entrance than the Nissum Broad. This haul yielded only 1,400 plaice, but they were of larger size, the majority measuring eight and a half to nine and a half inches. My view that the small size and slow growth of the plaice in the Nissum Broad is due to overcrowding is confirmed by the interesting experiments in the Thisted Broad. One haul was made on July 3, 1899, in this Broad, and thirty-six plaice were caught; all these fish were of a larger size than those in the other Broads, and their damaged fin-rays showed that they all really were transplanted. The transplantation of these fish was made in March and April 1899. This Broad is about forty miles from the North Sea entrance at Thyborön, and a few years ago contained practically no plaice. Thousands of plaice from seven to ten inches in length are now every year transported by the fishermen, partly aided by a Government grant, from the North Sea to this Thisted Broad in April, and it has been found that, by November of the same year, they have grown to thirteen and fifteen inches in length. Generally speaking, these transplanted fish weigh one-fifth of a pound when put into the Thisted Broad in April, and weighed one pound when taken out in November.

The cost of transplanting a young plaice from the North Sea is one-sixth of a penny, and the value of the plaice, when recaptured in November, is fourpence. Last year, between 100,000 and 200,000 were transplanted in this way, and practically all the fish were recaptured for the market.

I believe that there is food enough in the Thisted Broad to support 30,000 plaice on every square mile, so that 500,000 might be transported to this Broad annually. There are other Broads in the Limfjord where there are now no plaice, and it is believed that 3,000,000 plaice might be transplanted to the Limfjord annually. Should this scheme of fish culture be carried out, there would be an enormous increase in the value of the Danish plaice fisheries. There is now before the Danish Parliament a bill asking for a grant of 1,000*l.* a year for transplanting these young plaice, with the view of finding out how many of these fish can live on each square mile of the fjord and, at the same time, yield an economic result in the direction here indicated.

Although there is at present no definite statistical information on the subject, I am of opinion that there is no diminution in the number of small immature plaice on the coasts of Denmark. Nature appears to yield a constant and abundant supply. The supply of food does not seem to be sufficient for the young fish in many places. On the other hand, my researches in the Cattegat show that there large-sized spawning plaice have diminished in number.

Dr. J. Hjort has this year transplanted from the Danish coast 22,000 small plaice to the Christiania fjord in Norway; it will be most interesting to learn the result of his experiments.

Should these prove successful, there can be little doubt that a similar kind of fish culture could be carried on in many of the sea lochs of other countries.

3. *On the Occurrence of the Grey Gurnard* (Trigla gurnardus, *L.*), *and its Spawning in the Inshore and Offshore Waters. By* W. C. McIntosh.

In the following remarks the grey gurnard is used to illustrate certain features of the resources of the sea, and it is of some importance in this respect, though it has to be remembered that the gurnard is a fish that often swims in mid-water, and occasionally may be caught near the surface.

In the Trawling Investigations of 1884 (Royal Commission, under Lord Dalhousie), the grey gurnard ranked, as regards numbers, third in the list of saleable fishes, only the haddock and the whiting exceeding it in total numbers. In that report the fishes, as they ought to be in all such inquiries, were arranged according to months as well as stations, and it appears therefrom that few gurnards occur in the trawl in January or February, but they are found in large numbers in March, increase still more in April, and in May attain their maximum in St. Andrews Bay. They remain in fair, though smaller numbers, in the bay in June, July, and August, and in the latter month even increase in numbers at nine miles from land. Their occurrence, however, is not confined to inshore waters, for at Smith Bank, off Caithness, they were in considerable numbers in April, and many not fully ripe, and so in 24 to 30 fathoms water, 4 to 8 miles S.E. of the Isle of Man.

Again, in May, in water 32 to 40 fathoms in depth, and 25 to 38 miles from land, they were also in considerable numbers, and spawning. In June and July they were still found in offshore waters, and some spawning. In the middle of August large gurnards were extremely numerous 15 miles from land, two hauls of the trawl giving respectively 363 and 456 specimens. These facts showed that gurnards were scarce in the trawl, both in inshore and offshore waters in the early months, became more conspicuous in both in April, had high numbers in May and June in inshore waters, and considerable numbers in offshore waters. The distribution of the species was further alluded to in the 'Food-fishes.'[1]

In the 'Resources of the Sea,' the gurnard, from the returns of the *Garland*,[2] formed one of the most conspicuous features in connection with the round fishes, and showed, more or less, the spindle formed by marine animals—vertebrate and invertebrate—during the year, the wide central part of the spindle occurring in the warmer months, and the figure tapering off to a point in January and again in December. Different areas, however, vary: thus in St. Andrews Bay the capture of gurnards is nearly double that in the Forth, and the larger forms (over 11 inches) show a great increase in August, while those from 7 to 10 inches, and those under 7 inches, have their maximum, during the decade, in June. It must be borne in mind that in this area, however, there were serious blanks in the decade in the important months of May and August.

In the Forth, again, the maximum captures of the gurnards over 11 inches are found in the ten years (and taking each year by itself) to fall in no less than six months, viz. April, May, June, July, August, and September, the number of times in each month varying. May has the pre-eminence of three maxima, yet August remains steadily high throughout, as in the totals for fishes generally in the returns of the *Garland*. It is doubtful, however, if such increase in August is due to a 'second migration,' like the herring, for spawning purposes, as Dr. Fulton, the able superintendent of the Fishery Board's investigations, supposes. Of the next size (7 to 10 inches), the maxima are found in two months only, viz. May and June, and August never attains prominence. Those under 7 inches have their maxima in five months, viz. from May to October—July being absent.

Now the fact that the smaller forms (most of which do not spawn) show a decided tendency to increase in certain months, should make caution necessary in attributing the increase in inshore waters in August to this function (spawning). Experience proves that the spawning of the gurnard goes on from the end of April till September, and that no special accession of ova occurs in August;

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[1] *Life Histories of the Food-fishes*, McIntosh and Masterman, p. 136.

[2] The ship of the Fishery Board for Scotland.

indeed, the eggs are fewer than in June. Moreover, spawning gurnards are common in the offshore waters during the same period, and while it is rare to find post-larval and very young gurnards in St. Andrews Bay or the Forth, they occur in numbers in the offshore waters. Again, as above mentioned, there are other fishes which show an increase in August, and though that of the larger sizes is not so pronounced, still such increase has to be taken into consideration.

It is curious that the grey gurnard, though stated to be inshore spawned in the blue-book (just as the dab is also in error claimed as an inshore spawner), has not been used by the Fishery Board of Scotland to substantiate their large closures of areas against trawling. The following table may explain the cause of the silence on this head:

Grey Gurnard. Average per Haul, 1886–1895.

Year	St. Andrews Bay	Forth	Year	St. Andrews Bay	Forth
1886	24	10	1891	13	15
1887	52	20	1892	27	19
1888	20	13	1893	13	15
1889	18	13	1894	8	9
1890	21	9	1895	44	14
Average	25	13	Average	20	15

Considering the differences in the circumstances under which the work was carried on in the two quinquennial periods (viz. as regards warmer and colder months, inequality of hauls on stations, duration of haul, and other features), it is remarkable that the divergences were not more pronounced. No fish, indeed, could more conclusively show that the position taken up in the 'Resources of the Sea' is that which best agrees with the facts of the case. Such a fish to-day is very much in the position it has always held in the ocean. It is true the larger forms of some species become fewer under persistent fishing, and this occurs irrespective of trawling—as, for example, in former years off the coast of America and Australia. Increased wariness—for fishes, both marine and fresh-water, have much more intelligence than is usually supposed—must also be taken into account. There is no need to fear the serious decadence of our marine fisheries. When we doubt, let us remember the herring with its eggs deposited on the bottom, and think how much more likely it is to suffer by the operations of man than almost all the other marine food-fishes, with their transparent and minute floating or pelagic eggs—disseminated widely by tides and currents.

4. *On the Thames Estuary: its Physico-Biological Aspects as bearing upon its Fisheries. By* Dr. J. MURIE.

5. *Interim Report on a Circulatory Apparatus for keeping Aquatic Organisms under definite Physical Conditions.* See Reports, p. 431.

6. *Exhibition of Dr. Petersen's Closing Net for Quantitative Estimation of Plankton. By* W. GARSTANG, M.A.

SECTION E.—GEOGRAPHY.

PRESIDENT OF THE SECTION—Sir JOHN MURRAY, K.C.B., F.R.S., D.Sc., LL.D.

THURSDAY, SEPTEMBER 14.

The President delivered the following Address:—

IN his opening Address to the members of the British Association at the Ipswich meeting, the President cast a retrospective glance at the progress that had taken place in the several branches of scientific inquiry from the time of the formation of the Association in 1831 down to 1895, the year in which were published the last two of the fifty volumes of Reports containing the scientific results of the voyage of H.M.S. *Challenger*. In that very able and detailed review there is no reference whatever to the work of the numerous expeditions which had been fitted out by this and other countries for the exploration of the depths of the sea, nor is there any mention of the great advance in our knowledge of the ocean during the period of sixty-five years then under consideration. This omission may be accounted for by the fact that, at the time of the formation of the British Association, knowledge concerning the ocean was, literally speaking, superficial. The study of marine phenomena had hitherto been almost entirely limited to the surface and shallow waters of the ocean, to the survey of coasts and of oceanic routes directly useful for commercial purposes. Down to that time there had been no systematic attempts to ascertain the physical and biological conditions of those regions of the earth's surface covered by the deeper waters of the ocean; indeed, most of the apparatus necessary for such investigations had not yet been invented.

The difficulties connected with the exploration of the greater depths of the sea arise principally from the fact that, in the majority of cases, the observations are necessarily indirect. At the surface of the ocean direct observation is possible, but our knowledge of the conditions prevailing in deep water, and of all that is there taking place, is almost wholly dependent on the correct working of instruments, the action of which at the critical moment is hidden from sight.

It was the desire to establish telegraphic communication between Europe and America that gave the first direct impulse to the scientific exploration of the great ocean-basins, and at the present day the survey of new cable routes still yields each year a large amount of accurate knowledge regarding the floor of the ocean. Immediately before the *Challenger* Expedition there was a marked improvement in all the apparatus used in marine investigations, and thus during the *Challenger* Expedition the great ocean-basins were for the first time systematically and successfully explored. This expedition, which lasted for nearly four years, was successful beyond the expectations of its promoters, and opened out a new era in the study of oceanography. A great many sciences were enriched by a grand accumulation of new facts. Large collections were sent and brought home, and were subsequently described by specialists belonging to almost every civilised nation. Since the *Challenger* Expedition there has been almost a revolution in the methods employed in deep-sea observations. The most profound abysses of the ocean are now being everywhere examined by sailors and scientific men with increasing precision, rapidity, and success.

The recognition of oceanography as a distinct branch of science may be said to date from the commencement of the *Challenger* investigations. The fuller knowledge we now possess about all oceanic phenomena has had a great modifying influence on many general conceptions as to the nature and extent of those changes which the crust of the earth is now undergoing and has undergone in past geological times. Our knowledge of the ocean is still very incomplete. So much has, however, already been acquired that the historian will, in all probability, point to the oceanographical discoveries during the past forty years as the most important addition to the natural knowledge of our planet since the great geographical voyages associated with the names of Columbus, Da Gama, and Magellan, at the end of the fifteenth and the beginning of the sixteenth centuries.

It is not my intention on this occasion to attempt anything like a general review of the present state of oceanographic science. But, as nearly all the samples of marine deposits collected during the past thirty years have passed through my hands, I shall endeavour briefly to point out what, in general, their detailed examination teaches with respect to the present condition of the floor of the ocean, and I will thereafter indicate what appears to me to be the bearing of some of these results on speculations as to the evolution of the existing surface features of our planet.

Depth of the Ocean.

All measurements of depth, by which we ascertain the relief of that part of the earth's crust covered by water, are referred to the sea-surface; the measurements of height on the land are likewise referred to sea-level. It is admitted that the ocean has a very complicated undulating surface, in consequence of the attraction which the heterogeneous and elevated portions of the lithosphere exercise on the liquid hydrosphere. In the opinion of geodesists the geoid may in some places depart from the figure of the spheroid by 1,000 feet. Still it is not likely that this surface of the geoid departs so widely from the mean ellipsoidal form as to introduce a great error into our estimates of the elevations and depressions on the surface of the lithosphere.

The soundings over the water-surface of the globe have accumulated at a rapid rate during the past fifty years. In the shallow water, where it is necessary to know the depth for purposes of navigation, the soundings may now be spoken of as innumerable; the 100-fathom line surrounding the land can therefore often be drawn in with much exactness. Compared with this shallow-water region, the soundings in deep water beyond the 100-fathom line are much less numerous; each year, however, there are large additions to our knowledge. Within the last decade over ten thousand deep soundings have been taken by British ships alone. The deep soundings are scattered over the different ocean-basins in varying proportions, being now most numerous in the North Atlantic and South-west Pacific, and in these two regions the contour-lines of depth may be drawn in with greater confidence than in the other divisions of the great ocean-basins. It may be pointed out that 659 soundings taken quite recently during cable surveys in the North Atlantic, although much closer together than is usually the case, and yielding much detailed information to cable engineers, have, from a general point of view, necessitated but little alteration in the contour-lines drawn on the *Challenger* bathymetrical maps published in 1895. Again, the recent soundings of the German s.s. *Valdivia* in the Atlantic, Indian, and Southern Oceans have not caused very great alteration in the positions of the contour-lines on the *Challenger* maps, if we except one occasion in the South Atlantic when a depth of 2,000 fathoms was expected and the sounding machine recorded a depth of only 536 fathoms, and again in the great Southern Ocean when depths exceeding 3,000 fathoms were obtained in a region where the contour-lines indicated between 1,000 and 2,000 fathoms. This latter discovery suggests that the great depth recorded by Ross to the south-east of South Georgia may not be very far from the truth.

I have redrawn the several contour-lines of depth in the great ocean-basins, after careful consideration of the most recent data, and these may now be regarded as a somewhat close approximation to the actual state of matters, with the possible exception of the great Southern and Antarctic Oceans, where there are relatively few soundings, but where the projected Antarctic Expeditions should soon be at work. On the whole, it may be said that the general tendency of recent soundings is to extend the area with depths greater than 1,000 fathoms, and to show that numerous volcanic cones rise from the general level of the floor of the ocean-basins up to various levels beneath the sea-surface.

The areas marked out by the contour-lines of depth are now estimated as follows:—

Between the shore and 100 fms.,	7,000,000 sq. geo. m.	(or 7% of the sea-bed)
„ 100 „ 1,000 „	10,000,000 „ „	(or 10% „ „)
„ 1,000 „ 2,000 „	22,000,000 „ „	(or 21% „ „)
„ 2,000 „ 3,000 „	57,000,000 „ „	(or 55% „ „)
Over 3,000 fathoms,	7,000,000 „ „	(or 7% „ „)
	103,000,000 sq. geo. m.	100 per cent.

From these results it appears that considerably more than half of the sea floor lies at a depth exceeding 2,000 fathoms, or over two geographical miles. It is interesting to note that the area within the 100-fathom line occupies 7,000,000 square geographical miles, whereas the area occupied by the next succeeding 900 fathoms (viz. between 100 and 1,000 fathoms) occupies only 10,000,000 square geographical miles. This points to a relatively rapid descent of the sea-floor along the continental slopes between 100 and 1,000 fathoms, and therefore confirms the results gained by actual soundings in this region, many of which indicate steep inclines or even perpendicular cliffs. Not only are the continental slopes the seat of many deposit-slips and seismic disturbances, but Mr. Benest has given good reasons for believing that underground rivers sometimes enter the sea at depths beyond 100 fathoms, and there bring about sudden changes in deep water. Again, the relatively large area covered by the continental shelf between the shore-line and 100 fathoms points to the wearing away of the land by current and wave action.

On the *Challenger* charts all areas where the depth exceeds 3,000 fathoms have been called 'Deeps,' and distinctive names have been conferred upon them. Forty-three such depressions are now known, and the positions of these are shown on the map here exhibited; twenty-four are situated in the Pacific Ocean, three in the Indian Ocean, fifteen in the Atlantic Ocean, and one in the Southern and Antarctic Oceans. The area occupied by these thirty-nine deeps is estimated at 7,152,000 square geographical miles, or about 7 per cent. of the total water-surface of the globe. Within these deeps over 250 soundings have been recorded, of which twenty-four exceed 4,000 fathoms, including three exceeding 5,000 fathoms.

Depths exceeding 4,000 fathoms (or four geographical miles) have been recorded within eight of the deeps, viz. in the North Atlantic within the Nares Deep; in the Antarctic within the Ross Deep; in the Banda Sea within the Weber Deep; in the North Pacific within the Challenger, Tuscarora, and Supan Deeps; and in the South Pacific within the Aldrich and Richards Deeps. Depths exceeding 5,000 fathoms have been hitherto recorded only within the Aldrich Deep of the South Pacific, to the east of the Kermadecs and Friendly Islands, where the greatest depth is 5,155 fathoms, or 530 feet more than five geographical miles, being about 2,000 feet more below the level of the sea than the summit of Mount Everest in the Himalayas is above it. The levels on the surface of the lithosphere thus oscillate between the limits of about ten geographical miles (more than eighteen kilometres).

Temperature of the Ocean-floor.

Our knowledge of the temperature on the floor of the ocean is derived from observations in the layers of water immediately above the bottom by means of deep-sea thermometers, from the electric resistance of telegraph cables resting on the bed of the great ocean-basins, and from the temperature of large masses of mud and ooze brought up by the dredge from great depths. These observations are now sufficiently numerous to permit of some general statements as to the distribution of temperature over the bottom of the great oceans.

All the temperatures recorded up to the present time in the sub-surface waters of the open ocean indicate that at a depth of about 100 fathoms seasonal variation of temperature disappears. Beyond that depth there is a constant, or nearly constant, temperature at any one place throughout the year. In some special positions, and under some peculiar conditions, a lateral shifting of large bodies of water takes place on the floor of the ocean at depths greater than 100 fathoms. This phenomenon has been well illustrated by Professor Libbey off the east coast of North America, where the Gulf Stream and Labrador Current run side by side in opposite directions. This lateral shifting cannot, however, be called seasonal, for it appears to be effected by violent storms, or strong off-shore winds bringing up colder water from considerable depths to supply the place of the surface drift, so that the colder water covers stretches of the ocean's bed which under normal conditions are overlaid by warmer strata of water. Sudden changes of temperature like these cause the destruction of innumerable marine animals, and produce very marked peculiarities in the deposits over the areas thus affected.

It is estimated that 92 per cent. of the entire sea-floor has a temperature lower than 40° F. This is in striking contrast to the temperature prevailing at the surface of the ocean, only 16 per cent. of which has a mean temperature under 40° F. The temperature over nearly the whole of the floor of the Indian Ocean in deep water is under 35° F. A similar temperature occurs over a large part of the South Atlantic and certain parts of the Pacific, but at the bottom of the North Atlantic basin and over a very large portion of the Pacific the temperature is higher than 35° F. In depths beyond 2,000 fathoms, the average temperature over the floor of the North Atlantic is about 2° F. above the average temperature at the bottom of the Indian Ocean and South Atlantic, while the average temperature of the bed of the Pacific is intermediate between these.

It is admitted that the low temperature of the deep sea has been acquired at the surface in Polar and sub-Polar regions, chiefly within the higher latitudes of the southern hemisphere, where the cooled surface water sinks to the bottom and spreads slowly over the floor of the ocean into equatorial regions. These cold waters carry with them into the deep sea the gases of the atmosphere, which are everywhere taken up at the surface according to the known laws of gas absorption. In this way myriads of living animals are enabled to carry on their existence at all depths in the open ocean. The nitrogen remains more or less constant at all times and places, but the proportion of oxygen is frequently much reduced in deep water, owing to the processes of oxidation and respiration which are there going on.

The deep sea is a region of darkness as well as of low temperature, for the direct rays of the sun are wholly absorbed in passing through the superficial layers of water. Plant-life is in consequence quite absent over 93 per cent. of the bottom of the ocean, or 66 per cent. of the whole surface of the lithosphere. The abundant deep-sea fauna, which covers the floor of the ocean, is therefore ultimately dependent for food upon organic matter assimilated by plants near its surface, in the shallower waters near the coast-lines, and on the surface of the dry land itself.

As has been already stated, about 7,000,000 square geographical miles of the sea-floor lies within the 100-fathom line, and this area is in consequence subject to seasonal variations of temperature, to strong currents, to the effects of sunlight, and presents a great variety of physical conditions. The planktonic plant-life is here reinforced by the littoral seaweeds, and animal-life is very abundant. About 40 per cent. of the water over the bottom of this shallow-water area has a mean temperature under 40° F., while 20 per cent. has a mean temperature between 40° and 60° F., and 40 per cent. a temperature of over 60° F.

It follows from this that only 3 per cent. of the floor of the ocean presents conditions of temperature favourable for the vigorous growth of corals and those other benthonic organisms which make up coral reefs and require a temperature of over 60° F. all the year round. On the other hand, more than half of the surface of the ocean has a temperature which never falls below 60° F. at any time of the year. In these surface-waters with a high temperature, the shells of pelagic Molluscs, Foraminifera, Algæ, and other planktonic organisms are secreted in great abundance, and fall to the bottom after death.

It thus happens that, at the present time, over nearly the whole floor of the ocean we have mingled in the deposits the remains of organisms which had lived under widely different physical conditions, since the remains of organisms which lived in tropical sunlight, and in water at a temperature above 80° F., all their lives, now lie buried in the same deposit on the sea-floor together with the remains of other organisms which lived all their lives in darkness and at a temperature near to the freezing-point of fresh water.

Marine Deposits on the Ocean-floor.

The marine deposits now forming over the floor of the ocean present many interesting peculiarities according to their geographical and bathymetrical position. On the continental shelf, within the 100-fathom line, sands and gravels predominate, while on the continental slopes beyond the 100-fathom line, Blue Muds, Green Muds, and Red Muds, together with Volcanic Muds and Coral Muds, prevail, the two latter kinds of deposits being, however, more characteristic of the shallow water around oceanic islands. The composition of all these Terrigenous Deposits depends on the structure of the adjoining land. Around continental shores, except where coral reefs, limestones, and volcanic rocks are present, the materials consist principally of fragments and minerals derived from the disintegration of the ancient rocks of the continents, the most characteristic and abundant mineral species being quartz. River detritus extends in many instances far from the land, while off high and bold coasts, where no large rivers enter the sea, pelagic conditions may be found in somewhat close proximity to the shore-line. It is in these latter positions that Green Muds containing much glauconite, and other deposits containing many phosphatic nodules, have for the most part been found; as, for instance, off the eastern coast of the United States, off the Cape of Good Hope, and off the eastern coasts of Australia and Japan. The presence of glauconitic grains and phosphatic nodules in the deposit at these places appears to be very intimately associated with a great annual range of temperature in the surface and shallow waters, and the consequent destruction of myriads of marine animals. As an example of this phenomenon may be mentioned the destruction of the tile-fish in the spring of 1882 off the eastern coast of North America, when a layer six feet in thickness of dead fish and other marine animals was believed to cover the ocean-floor for many square miles.

In all the Terrigenous Deposits the evidences of the mechanical action of tides, of currents, and of a great variety of physical conditions, may almost everywhere be detected, and it is possible to recognise in these deposits an accumulation of materials analogous to many of the marine stratified rocks of the continents, such as sandstones, quartzites, shales, marls, greensands, chalks, limestones, conglomerates, and volcanic grits.

With increasing depth and distance from the continents the deposits gradually lose their terrigenous character, the particles derived directly from the emerged land decrease in size and in number, the evidences of mechanical action disappear, and the deposits pass slowly into what have been called Pelagic Deposits at an average distance of about 200 miles from continental coast-lines. The materials composing Pelagic Deposits are not directly derived from the disintegration of the continents and other land-surfaces. They are largely made up of the shells and skeletons of marine organisms secreted in the surface waters of the ocean, consisting either of carbonate of lime, such as pelagic Molluscs, pelagic Foraminifera, and pelagic Algæ, or of silica, such as Diatoms and Radiolarians. The inorganic constituents of the Pelagic Deposits are for the most part derived from the attrition of floating pumice, from the disintegration of water-logged pumice, from showers of volcanic ashes, and from the *débris* ejected from submarine volcanoes, together with the products of their decomposition. Quartz particles, which play so important a *rôle* in the Terrigenous Deposits, are almost wholly absent, except where the surface waters of the ocean are affected by floating ice, or where the prevailing winds have driven the desert sands far into the oceanic areas. Glauconite is likewise absent from these abysmal regions. The various kinds of Pelagic Deposits are named according to their characteristic constituents, Pteropod Oozes, Globigerina Oozes, Diatom Oozes, Radiolarian Oozes, and Red Clay.

The distribution of the deep-sea deposits over the floor of the ocean is shown on the map here exhibited, but it must be remembered that there is no sharp line of demarcation between them; the Terrigenous pass gradually into the Pelagic Deposits, and the varieties of each of these great divisions also pass insensibly the one into the other, so that it is often difficult to fix the name of a given sample.

On another map here exhibited the percentage distribution of carbonate of lime in the deposits over the floor of the ocean has been represented, the results being founded on an extremely large number of analyses. The results are also shown in the following table:—

	Sq. Geo. Miles.	Percentage.
Over 75% $CaCO_3$ . .	6,000,000	5·8
50 to 75% ,, . .	24,000,000	23·2
25 to 50% ,, . .	14,000,000	13·5
Under 25% ,, . .	59,000,000	57·5
	103,000,000	100

The carbonate of lime shells derived from the surface play a great and puzzling *rôle* in all deep-sea deposits, varying in abundance according to the depth of the ocean and the temperature of the surface waters. In tropical regions removed from land, where the depths are less than 600 fathoms, the carbonate of lime due to the remains of these organisms from the surface may rise to 80 or 90 per cent.; with increase of depth, and under the same surface conditions, the percentage of carbonate of lime slowly diminishes, till, at depths of about 2,000 fathoms, the average percentage falls to about 60, at 2,400 fathoms to about 30, and at about 2,600 fathoms to about 10, beyond which depth there may be only traces of carbonate of lime due to the presence of surface shells. The thin and more delicate surface shells first disappear from the deposits, the thicker and denser ones alone persist to greater depths. A careful examination of a large number of observations shows that the percentage of carbonate of lime in the deposits falls off much more rapidly at depths between 2,200 and 2,500 fathoms than at other depths.

The Red Clay, which occurs in all the deeper stretches of the ocean far from land, and covers nearly half of the whole sea-floor, contains—in addition to volcanic *débris*, clayey matter, the oxides of iron and manganese—numerous remains of whales, sharks, and other fishes, together with zeolitic crystals, manganese nodules, and minute magnetic spherules, which are believed to have a cosmic origin. One haul of a small trawl in the Central Pacific brought to the surface on one occasion, from a depth of about two and a half miles, many bushels of manganese nodules, along with fifteen hundred sharks' teeth, over fifty fragments of earbones and other bones of whales. Some of these organic remains, such as the *Carcharodon* and *Lamna* teeth and the bones of the Ziphioid whales, belong apparently to extinct species. One or two of these sharks' teeth, earbones, or cosmic spherules, may be occasionally found in a Globigerina Ooze, but their occurrence in this or any deposits other than Red Clay is extremely rare.

Our knowledge of the marine deposits is limited to the superficial layers; as a rule the sounding-tube does not penetrate more than six or eight inches, but in some positions the sounding-tube and dredge have been known to sink fully two feet into the deposit. Sometimes a Red Clay is overlaid by a Globigerina Ooze, more frequently a Red Clay overlies a Globigerina Ooze, the transition between the two layers being either abrupt or gradual. In some positions it is possible to account for these layers by referring them to changes in the condition of the surface waters, but in other situations it seems necessary to call in elevations and subsidences of the sea-floor.

If the whole of the carbonate of lime shells be removed by dilute acid from a typical sample of Globigerina Ooze, the inorganic residue left behind is quite similar in composition to a typical Red Clay. This suggests that possibly, owing to some hypogene action, such as the escape of carbonic acid through the sea-floor, a deposit that once was a Globigerina Ooze might be slowly converted into a Red Clay. However, this is not the interpretation which commends itself after an examination of all the data at present available; a consideration of the rate of accumulation probably affords a more correct interpretation. It appears certain that the Terrigenous Deposits accumulate much more rapidly than the Pelagic Deposits. Among the Pelagic Deposits the Pteropod and Globigerina Oozes of the tropical regions, being made up of the calcareous shells of a much larger number of tropical species, apparently accumulate at a greater rate than the Globigerina Oozes in extra-tropical areas. Diatom Ooze being composed of both calcareous and siliceous organisms has again a more rapid rate of deposition than Radiolarian Ooze. In Red Clay the minimum rate of accumulation takes place. The number of sharks' teeth, of earbones and other bones of Cetaceans, and of cosmic spherules, in a deposit may indeed be taken as a measure of the rate of deposition. These spherules, teeth, and bones are probably more abundant in the Red Clays, because few other substances there fall to the bottom to cover them up, and they thus form an appreciable part of the whole deposit. The volcanic materials in a Red Clay having, because of the slow accumulation, been for a long time exposed to the action of sea-water, have been profoundly altered. The massive manganese-iron nodules and zeolitic crystals present in the deposit are secondary products arising from the decomposition of these volcanic materials, just as the formation of glauconite, phosphatic, and calcareous and barytic nodules accompanies the decomposition of terrigenous rocks and minerals in deposits nearer continental shores. There is thus a striking difference between the average chemical and mineralogical composition of Terrigenous and Pelagic Deposits.

It would be extremely interesting to have a detailed examination of one of those deep holes where a typical Red Clay is present, and even to bore some depth into such a deposit if possible, for in these positions it is probable that not more than a few feet of deposit have accumulated since the close of the Tertiary period. One such area lies to the south-west of Australia, and its examination might possibly form part of the programme of the approaching Antarctic explorations.

Life on the Ocean-floor.

It has already been stated that plant-life is limited to the shallow waters, but fishes and members of all the invertebrate groups are distributed over the floor of the ocean at all depths. The majority of these deep-sea animals live by eating the mud, clay, or ooze, or by catching the minute particles of organic matter which fall from the surface. It is probably not far from the truth to say that three-fourths of the deposits now covering the floor of the ocean have passed through the alimentary canals of marine animals. These mud-eating species, many of which are of gigantic size when compared with their allies living in the shallow coastal waters, become in turn the prey of numerous rapacious animals armed with peculiar prehensile and tactile organs. Some fishes are blind, while others have very large eyes. Phosphorescent light plays a most important *rôle* in the deep sea, and is correlated with the prevailing red and brown colours of deep-sea organisms. Phosphorescent organs appear sometimes to act as a bull's-eye lantern to enable particles of food to be picked up, and at other times as a lure or a warning. All these peculiar adaptations indicate that the struggle for life may be not much less severe in the deep sea than in the shallower waters of the ocean.

Many deep-sea animals present archaic characters; still the deep sea cannot be said to contain more remnants of faunas which flourished in remote geological periods than the shallow and fresh waters of the continents. Indeed, king-crabs

Lingulas, Trigonias, Port Jackson sharks, *Ceratodus*, *Lepidosiren*, and *Protopterus*, probably represent older faunas than anything to be found in the deep sea.

Sir Wyville Thomson was of opinion that, from the Silurian period to the present day, there had been as now a continuous deep ocean with a bottom temperature oscillating about the freezing-point of fresh water, and that there had always been an abyssal fauna. I incline to the view that in Palæozoic times the ocean-basins were not so deep as they are now; that the ocean then had throughout a nearly uniform high temperature, and that life was either absent or represented only by bacteria and other low forms in great depths, as is now the case in the Black Sea, where life is practically absent beyond 100 fathoms, and where the deeper waters are saturated with sulphuretted hydrogen. This is not, however, the place to enter on speculations concerning the origin of the deep-sea fauna, nor to dwell on what has been called 'bipolarity' in the distribution of marine organisms.

Evolution of the Continental and Oceanic Areas.

I have now pointed out what appear to me to be some of the more general results arrived at in recent years regarding the present condition of the floor of the ocean. I may now be permitted to indicate the possible bearing of these results on opinions as to the origin of some fundamental geographical phenomena; for instance, on the evolution of the protruding continents and sunken ocean-basins. In dealing with such a problem much that is hypothetical must necessarily be introduced, but these speculations are based on ascertained scientific facts.

The well-known American geologist, Dutton, says: 'It has been much the habit of geologists to attempt to explain the progressive elevation of plateaus and mountain platforms, and also the folding of strata, by one and the same process. I hold the two processes to be distinct, and having no necessary relation to each other. There are plicated regions which are little or not at all elevated, and there are elevated regions which are not plicated.' Speaking of great regional uplifts, he says further: 'What the real nature of the uplifting force may be is, to my mind, an entire mystery, but I think we may discern at least one of its attributes, and that is a gradual expansion or a diminution of density of the subterranean magmas. . . . We know of no cause which could either add to the mass or diminish the density, yet one of the two must surely have happened. . . . Hence I infer that the cause which elevates the land involves an expansion of the underlying magmas, and the cause which depresses it is a shrinkage of the magmas; the nature of the process is at present a complete mystery.' I shall endeavour to show how the detailed study of marine deposits may help to solve the mystery here referred to by Dutton.

The surface of the globe has not always been as we now see it. When, in the past, the surface had a temperature of about 400° F., what is now the water of the ocean must have existed as water vapour in the atmosphere, which would thereby—as well as because of the presence of other substances—be increased in density and volume. Life, as we know it, could not then exist. Again, science foresees a time when low temperatures, like those produced by Professor Dewar at the Royal Institution, will prevail over the face of the earth. The hydrosphere and atmosphere will then have disappeared within the rocky crust, or the waters of the ocean will have become solid rock, and over their surface will roll an ocean of liquid air about forty feet in depth. Life, as we know it, unless it undergoes suitable secular modifications, will be extinct. Somewhere between these two indefinite points of time in the evolution of our planet it is our privilege to live, to investigate, and to speculate concerning the antecedent and future conditions of things.

When we regard our globe with the mind's eye, it appears at the present time to be formed of concentric spheres, very like, and still very unlike, the successive coats of an onion. Within is situated the vast nucleus or *centrosphere*; surrounding this is what may be called the *tektosphere*,[1] a shell of materials in a state bordering

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[1] τηκτός, molten.

on fusion, upon which rests and creeps the *lithosphere*. Then follow *hydrosphere* and *atmosphere*, with the included *biosphere*.[1] To the interaction of these six geospheres, through energy derived from internal and external sources, may be referred all the existing superficial phenomena of the planet.

The vast interior of the planetary mass, although not under direct observation, is known, from the results of the astronomer and physicist, to have a mean density of 5·6, or twice that of ordinary surface rock. The substances brought within the reach of observation in veinstones, in lavas, and hypogene rocks—by the action of water as a solvent and sublimant—warrant the belief that the centrosphere is largely made up of metals and metalloids with imprisoned gases. It is admitted that the vast nucleus has a very high temperature, but so enormous is the pressure of the superincumbent crust that the melting-point of the substances in the interior is believed to be raised to a higher value than the temperature there existing—the centrosphere in consequence remains solid, for it may be assumed that the melting-point of rock-forming materials is raised by increase of pressure. Astronomers from a study of precession and nutation have long been convinced that the centrosphere must be practically solid.

Recent seismological observations indicate the transmission of two types of waves through the earth—the condensational-rarefactional and the purely distortional—and the study of these tremors supports the view that the centrosphere is not only solid, but possesses great uniformity of structure. The seismological investigations of Professors Milne and Knott point also to a fairly abrupt boundary or transition surface, where the solid nucleus passes into the somewhat plastic magma on which the firm upper crust rests.

In this plastic layer or shell—named the *tektosphere*—the materials are most probably in a state of unstable equilibrium and bordering on fusion. Here the loose-textured solids of the external crust are converted into the denser solids of the nucleus or into molten masses, at a critical point of temperature and pressure; deep-seated rocks may in consequence escape through fissures in the lithosphere. Within the lithosphere itself the temperature falls off so rapidly towards the surface as to be everywhere below the melting-point of any substance there under its particular pressure.

Now, as the solid centrosphere slowly contracted from loss of heat, the primitive lithosphere, in accommodating itself—through changes in the tektosphere—to the shrinking nucleus, would be buckled, warped, and thrown into ridges. That these movements are still going on is shown by the fact that the lithosphere is everywhere and at all times in a slight but measurable state of pulsation. The rigidity of the primitive rocky crust would permit of considerable deformations of the kind here indicated. Indeed, the compression of mountain chains has most probably been brought about in this manner, but the same cannot be said of the elevation of plateaus, of mountain platforms, and of continents.

From many lines of investigation it is concluded, as we have seen, that the centrosphere is homogeneous in structure. Direct observation, on the other hand, shows that the lithosphere is heterogeneous in composition. How has this heterogeneity been brought about? The original crust was almost certainly composed of complex and stable silicates, all the silicon dioxide being in combination with bases. Lord Kelvin has pointed out that, when the solid crust began to form, it would rapidly cool over its whole surface; the precipitation of water would accelerate this process, and there would soon be an approximation to present conditions. As time went on the plastic or critical layer—the tektosphere—immediately beneath the crust would gradually sink deeper and deeper, while ruptures and re-adjustments would become less and less frequent than in earlier stages. With the first fall of rain the silicates of the crust would be attacked by water and carbon dioxide, which can at low temperatures displace silicon dioxide from its combinations. The silicates, in consequence, have been continuously robbed of a part, or the whole, of their bases. The silica thus set free goes ultimately to form quartz veins and quartz sand on or about the emerged land, while

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[1] βίος, life.

the bases leached out of the disintegrating rocks are carried out into the ocean and ocean-basins. A continuous disintegration and differentiation of materials of the lithosphere, accompanied by a sort of migration and selection among mineral substances, is thus always in progress. Through the agency of life, carbonate of lime accumulates in one place; through the agency of winds, quartz sand is heaped up in another; through the agency of water, beds of clay, of oxides of iron and of manganese are spread out in other directions.

The contraction of the centrosphere supplies the force which folds and crumples the lithosphere. The combined effect of hydrosphere, atmosphere, and biosphere on the lithosphere gives direction and a determinate mode of action to that force. From the earliest geological times the most resistent dust of the continents has been strewn along the marginal belt of the sea-floor skirting the land. At the present time the deposits over this area contain on the average about 70 per cent. of free and combined silica, mostly in the form of quartz sand. In the abysmal deposits far from land there is an average of only about 30 per cent. of silica, and hardly any of this in the form of quartz sand. Lime, iron, and the other bases largely predominate in these abysmal regions. The continuous loading on the margins of the emerged land by deposits tends by increased pressure to keep the materials of the tektosphere in a solid condition immediately beneath the loaded area. The unloading of emerged land tends by relief of pressure to produce a viscous condition of the tektosphere immediately beneath the denuded surfaces. Under the influence of the continuous shakings, tremors, and tremblings always taking place in the lithosphere the materials of the tektosphere yield to the stresses acting on them, and the deep-seated portions of the terrigenous deposits are slowly carried towards, over, or underneath the emerged land. The rocks subsequently re-formed beneath continental areas out of these terrigenous materials, under great pressure and in hydrothermal conditions, would be more acid than the rocks from which they were originally derived, and it is well known that the acid silicates have a lower specific gravity than the intermediate or basic ones. By a continual repetition of this process the continental protuberances have been gradually built up of lighter materials than the other parts of the lithosphere. The relatively light quartz, which is also the most refractory, the most stable, and the least fusible among rock-forming minerals, plays in all this the principal *rôle.* The average height of the surface of the continents is about three miles above the average level of the abysmal regions. If now we assume the average density of the crust beneath the continents to be 2·5, and of the part beneath the abysmal regions to be 3, then the spheroidal surface of equal pressure—the tektosphere—would have a minimum depth of eighteen miles beneath the continents and fifteen miles beneath the oceans, or if we assume the density of the crust beneath the continents to be 2·5, and beneath the abysmal regions to be 2·8, then the tektosphere would be twenty-eight miles beneath the continents and twenty-five miles beneath the oceans. The present condition of the earth's crust might be brought about by the disintegration of a quantity of quartz-free volcanic rock, covering the continental areas to a depth of eighteen miles, and the re-formation of rocks out of the disintegrated materials.

Where the lighter and more bulky substances have accumulated there has been a relative increase of volume, and in consequence bulging has taken place at the surface over the continental areas. Where the denser materials have been laid down there has been flattening, and in consequence a depression of the abysmal regions of the ocean-basins. It is known that, as a general rule, where large masses of sediment have been deposited, their deposition has been accompanied by a depression of the area. On the other hand, where broad mountain platforms have been subjected to extensive erosion, the loss of altitude by denudation has been made good by a rise of the platform. This points to a movement of matter on to the continental areas.

If this be anything like a true conception of the interactions that are taking place between the various geospheres of which our globe is made up, then we can understand why, in the gradual evolution of the surface features, the average level of the continental plains now stands permanently about three miles above the average level of those plains which form the floor of the deep ocean-basins. We may also understand how the defect of mass under the continents and an excess of mass under the oceans have been brought about, as well as deficiency of mass under mountains and excess of mass under plains. Even the local anomalies indicated by the plumb-line, gravity, and magnetic observations may in this way receive a rational explanation. It has been urged that an enormous time—greater even than what is demanded by Darwin—would be necessary for an evolution of the existing surface features on these lines. I do not think so. Indeed, in all that relates to geological time I agree, generally speaking, with the physicists rather than with the biologists and geologists.

Progress of Oceanic Research.

I have now touched on some of the problems and speculations suggested by recent deep-sea explorations; and there are many others, equally attractive, to which no reference has been made. It is abundantly evident that, for the satisfactory explanation of many marine phenomena, further observations and explorations are necessary. Happily there is no sign that the interest in oceanographical work has in any way slackened. On the contrary, the number of scientific men and ships engaged in the study of the ocean is rapidly increasing. Among all civilised peoples and in all quarters of the globe the economic importance of many of the problems that await solution is clearly recognised.

We have every reason to be proud of the work continually carried on by the officers and ships attached to the Hydrographic Department of the British Navy. They have surveyed coasts in all parts of the world for the purposes of navigation, and within the past few years have greatly enlarged our knowledge of the sea-bed and deeper waters over wide stretches of the Pacific and other oceans. The samples of the bottom which are procured, being always carefully preserved by the officers, have enabled very definite notions to be formed as to the geographical and bathymetrical distribution of marine deposits.

The ships belonging to the various British Telegraph Cable Companies have done most excellent work in this as well as in other directions. Even during the present year Mr. R. E. Peake has in the s.s. *Britannia* procured 477 deep soundings in the North Atlantic, besides a large collection of deep-sea deposits, and many deep-sea temperature and current observations.

The French have been extending the valuable work of the *Talisman* and *Travailleur*, while the Prince of Monaco is at the present moment carrying on his oceanic investigations in the Arctic Seas with a large new yacht elaborately and specially fitted out for such work. The Russians have recently been engaged in the scientific exploration of the Black Sea and the Caspian Sea, and a special ship is now employed in the investigation of the Arctic fisheries of the Murman coast under the direction of Professor Knipowitsch. Admiral Makaroff has this summer been hammering his way through Arctic ice, and at the same time carrying on a great variety of systematic observations and experiments on board the *Yermak*—the most powerful and most effective instrument of marine research ever constructed. Mr. Alexander Agassiz has this year recommenced his deep-sea explorations in the Pacific on board the U.S. steamer *Albatross.* He proposes to cross the Pacific in several directions, and to conduct investigations among the Paumotu and other coral island groups. Professor Weber is similarly employed on board a Dutch man-of-war in the East Indian Seas. The Deutsche Seewarte at Hamburg, under the direction of Dr. Neumayer, continues its praiseworthy assistance and encouragement to all investigators of the ocean, and this year the important German Deep-sea Expedition, in the s.s. *Valdivia*, arrived home after most successful oceanographical explorations in the Atlantic, Indian, and Great Southern Oceans.

The *Belgica* has returned to Europe safely with a wealth of geological and biological collections and physical observations, after spending, for the first time on record, a whole winter among the icefields and icebergs of the Antarctic. Mr. Borchgrevink in December last again penetrated to Cape Adare, successfully landed his party at that point, and is now wintering on the Antarctic continent. The expeditions of Lieutenant Peary, of Professor Nathorst, of Captain Sverdrup, and of the Duke of Abbruzzi, which are now in progress, may be expected to yield much new information about the condition of the Arctic Ocean. Mr. Wellman has just returned from the north of Franz Josef Land, with observations of considerable interest.

Some of the scientific results obtained by the expeditions in the Danish steamer *Ingolf* have lately been published, and these, along with the results of the joint work pursued for many years by the Swedes, Danes, and Norwegians, may ultimately have great economic value from their direct bearing on Fishery problems, and on weather forecasting over long periods of time.

Largely through the influence of Professor Otto Pettersson an International Conference assembled at Stockholm a few months ago, for the purpose of deliberating as to a programme of conjoint scientific work in the North Sea and northern parts of the Atlantic, with special reference to the economic aspect of sea-fisheries. A programme was successfully drawn up, and an organisation suggested for carrying it into effect; these proposals are now under the consideration of the several States. The Norwegian Government has voted a large sum of money for building a special vessel to conduct marine investigations of the nature recommended by this conference. It is to be hoped the other North Sea Powers may soon follow this excellent example.

The various marine stations and laboratories for scientific research in all parts of the world furnish each year much new knowledge concerning the ocean. Among our own people the excellent work carried on by the Marine Biological Association, the Irish Fisheries Department, the Scottish Fishery Board, the Lancashire Fisheries Committee, the Cape and Canadian Fisheries Departments, is well worthy of recognition and continued support. Mr. George Murray, Mr. H. N. Dickson, Professor Cleve, Professor Otto Pettersson, Mr. Robert Irvine, and others have, with the assistance of the officers of the Mercantile Marine, accumulated in recent years a vast amount of information regarding the distribution of temperature and salinity, as well as of the planktonic organisms at the surface of the ocean. The papers by Mr. H. C. Russell on the icebergs and currents of the Great Southern Ocean, and of Mr. F. W. Walker on the density of the water in the Southern Hemisphere, show that the Australian colonies are taking a practical interest in oceanographical problems.

Proposed Antarctic Explorations.

The great event of the year, from a geographical point of view, is the progress that has been made towards the realisation of a scheme for the thorough scientific exploration in the near future of the whole South Polar region. The British and German Governments have voted or guaranteed large sums of money to assist in promoting this object, and princely donations have likewise been received from private individuals, in this connection the action of Mr. L. W. Longstaff in making a gift of 25,000*l.*, and of Mr. A. C. Harmsworth in promising 5,000*l.*, being beyond all praise.

There is an earnest desire among the scientific men of Britain and Germany that there should be some sort of co-operation with regard to the scientific work of the two expeditions, and that these should both sail in 1901, so that the invaluable gain attaching to simultaneous observations may be secured. Beyond this nothing has, as yet, been definitely settled. The members of the Association will presently have an opportunity of expressing their opinions as to what should be attempted by the British Expedition, how the work in connection with it should be arranged, and how the various researches in view can best be carried to a successful issue.

I have long taken a deep interest in Antarctic exploration, because such exploration must necessarily deal largely with oceanographical problems, and also because I have had the privilege of studying the conditions of the ocean within both the Arctic and Antarctic circles. In the year 1886 I published an article on the subject of Antarctic Exploration in the 'Scottish Geographical Magazine.' This article led to an interesting interview, especially when viewed in the light of after events, for, a few weeks after it appeared in type, a young Norwegian walked into the *Challenger* office in Edinburgh to ask when the proposed expedition would probably start, and if there were any chance of his services being accepted. His name was Nansen.

When at the request of the President I addressed the Royal Geographical Society on the same subject in the year 1893, I made the following statement as to what it seemed to me should be the general character of the proposed exploration: 'A dash at the South Pole is not, however, what I advocate, nor do I believe *that* is what British Science at the present time desires. It demands rather a steady, continuous, laborious, and systematic exploration of the whole southern region with all the appliances of the modern investigator.' At the same time I urged further, that these explorations should be undertaken by the Royal Navy in two ships, and that the work should extend over two winters and three summers.

This scheme must now be abandoned, so far at least as the Royal Navy is concerned, for the Government has intimated that it can spare neither ships nor officers, men nor money, for an undertaking of such magnitude. The example of Foreign Powers—rather than the representations from our own scientific men—appears to have been chiefly instrumental in at last inducing the Government to promise a sum of 45,000*l.*, provided that an equal amount be forthcoming from other sources. This resolve throws the responsibility for the financial administration, for the equipment, and for the management of this exploration, on the representative scientific societies, which have no organisation ready for carrying out important executive work on such an extensive scale. I am doubtful whether this state of matters should be regarded as a sign of increasing lukewarmness on the part of the Government towards marine research, or should rather be looked on as a most unexpected and welcome recognition of the growing importance of science and scientific men to the affairs of the nation. Let us adopt the latter view, and accept the heavy responsibility attached thereto.

Any one who will take the trouble to read, in the 'Proceedings' of the Royal Society of London, the account of the discussion which recently took place on 'The Scientific Advantages of an Antarctic Expedition,' will gather some idea of the number and wide range of the subjects which it is urged should be investigated within the Antarctic area; the proposed researches have to do with almost every branch of science. Unless an earnest attempt be made to approach very near to the ideal there sketched out, widespread and lasting disappointment will certainly be felt among the scientific men of this country. The proposed expedition should not be one of adventure. Not a rapid invasion and a sudden retreat, with tales of hardships and risks, but a scientific occupation of the unknown area by observation and experiment, should be aimed at in these days.

I have all along estimated the cost of a well-equipped Antarctic Expedition at about 150,000*l.* I see no reason for changing my views on this point at the present time, nor on the general scope of the work to be undertaken by the proposed expedition, as set forth in the papers I have published on the subject. There is now a sum of at most 90,000*l.* in hand, or in view. If one ship should be specially built for penetrating the icy region, and be sent south with one naturalist on board, then such an expedition may, it will be granted, bring back interesting and important results. But it must be distinctly understood that this is not the kind of exploration scientific men have been urging on the British public for the past fifteen or twenty years. We must, if possible, have two ships, with landing parties for stations on shore, and with a recognised scientific leader and staff on board of each ship. Although we cannot have the Royal Navy, these ships can be most efficiently officered and manned from the Mercantile Marine. With only one ship many of the proposed observations would have to be cut out of the programme. In anticipation of this being the case, there are at the present moment irreconcilable differences of opinion among those most interested in these explorations, as to which sciences must be sacrificed.

The difficulties which at present surround this undertaking are fundamentally those of money. These difficulties would at once disappear, and others would certainly be overcome, should the members of the British Association at this meeting agree to place in the hands of their President a sum of 50,000*l.*, so that the total amount available for Antarctic exploration would become something like 150,000*l.* Although there is but one central Government, surely there are within the bounds of this great Empire two more men like Mr. Longstaff. The Government has suddenly placed the burden of upholding the high traditions of Great Britain in marine research and exploration on the shoulders of her scientific men. In their name I appeal to all our well-to-do fellow-countrymen in every walk of life for assistance, so that these new duties may be discharged in a manner worthy of the Empire and of the well-earned reputation of British Science.

The following Papers and Report were read:—

1. *On Polar Exploration by means of Icebreakers.*
By Admiral MAKAROFF, *Imperial Russian Navy.*

The steel steamer *Zermak*, of 8,000 tons displacement, was specially built for use as an icebreaker for keeping open the route to Baltic ports in winter and through the Kara Sea in summer. The trial trip of the vessel to the Arctic ice north of Spitzbergen was described, and its advantages of strength, speed, and comfort over all previous exploring vessels were explained.

2. *Physical Observations in the Barents Sea.* *By* W. S. BRUCE.

3. *Report of the Committee on African Climatology.* See Reports, p. 448.

4. *Seismology in relation to the Interior of the Earth.*
By JOHN MILNE, *F.R.S.*

After the blow or blows have been struck which cause an earthquake a flood of motion sets out in all directions over the surface of the earth, and in all directions through its interior. That which passes over the surface does so in waves which, whilst travelling at a fairly constant velocity, increase in amplitude and period. The waves which pass through the interior travel swifter and swifter the nearer their path is to a diameter. At a distant station the first motion recorded is that which has travelled through the earth, and the last that which has travelled round its surface. Intermediate motion would be that which had passed through the earth and then completed its journey to the observing station through the surface. Observation shows that the average velocity with which waves pass through the earth varies with the square root of the average depth of the paths they follow. Coupling this observation with the knowledge we possess respecting the density of our world as a whole and the density of the materials on its surface, Dr. C. G. Knott shows that the elasticity which governs the transmission of the precursors of the real earthquake increases at a rate of about 1 per cent. for every mile of descent.

The second section of the paper treated of the motion following the originating blows of an earthquake. It was a common observation to find that large earthquakes are a few minutes later followed by other violent disturbances, and because these second shocks had characteristics similar to the first ones they might be regarded as 'echoes.' Such symmetrical repetitions, which were illustrated by seismograms, indicate that we were not dealing with irregular adjustment of fractured materials, but with phenomena analogous to musical reverberations.

FRIDAY, SEPTEMBER 15.

The following Papers and Report were read:—

1. *On the Voyage of the 'Southern Cross' from Hobart to Cape Adare.*
By HUGH ROBERT MILL, *D.Sc., F.R.S.E.*

By permission of Sir George Newnes the particulars of the voyage of his Polar yacht *Southern Cross* from Tasmania to Cape Adare conveying the Antarctic expedition under the command of Mr. Borchgrevink were laid before the Section.

The *Southern Cross* left the Thames on August 24, 1898, and Hobart on December 19, reached the first ice on December 30 in 61° 56′ S. and 159° E., and entered the heavy pack on January 1, 1899. She worked her way slowly to 66° 46′ S. on January 31, then turned northward, got clear of the pack, and entered it again farther east on February 13, and passed through easily, anchoring off the beach near Cape Adare on February 17. In spite of heavy storms the whole party was safely landed with their stores, and the ship left for the north on February 28.

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2. *The Problem of Antarctic Exploration. By* HENRYK ARCTOWSKI.

The question of Antarctic exploration is now before the scientific world, and it must be answered in such a manner that the results of the voyages of exploration may be in accordance with modern requirements. A great step in our knowledge of the physical conditions of the globe is about to be made.

I would insist, in the first place, that it is necessary to aim not only at the discovery of new lands and the observation of their configuration. The geology of these lands must be studied, and also the glaciers and the condition of the sea-ice which surround them. The various physical and natural sciences have then to be considered, taking account of magnetic and meteorological conditions, fauna, flora, &c. All these, however, concern only one side of the question, for in the southern hemisphere not only are the Antarctic lands—continent or islands—totally unknown, but also a very large part of the three great neighbouring oceans. At the present day it is impossible to consider the land alone; the whole Antarctic area exhibits phenomena which remain very imperfectly known. I refer specially to the great questions of atmospheric circulation, climate, circumpolar oceanography, and magnetic conditions.

Hence Antarctic explorations must be conducted in three ways:—

1. A system of fixed stations arranged between the edge of the continents and the zone of ice. These stations should be supplied with all necessary magnetic and meteorological instruments, and continue at work simultaneously for one year at least.
2. During the same year two polar expeditions should set out on opposite sides towards the South Pole. This would require two vessels strong enough to withstand the pack and equipped for wintering.
3. Finally a circumpolar expedition, planned to follow the edge of the pack right round, and specially equipped for oceanographical and zoological work. This expedition would also survey the accessible parts of the Antarctic coast.

Such a system of exploration must necessarily be the work of several nations. Weyprecht's idea should be revived and followed. Antarctic exploration must be conducted systematically, and it ought to be international. A series of circumpolar stations, where comparable and simultaneous observations are carried on, would make the results of the British and German Antarctic expeditions remarkably complete, and vastly enhance their value.

I should suggest the following arrangement of stations.

A polygon of stations should unite South America and the Antarctic lands. The path of the cyclonic storms passes to the south of Cape Horn, and—at least during part of the year—to the north of Palmer Land. The polygon should include stations on the east and west coasts of Graham Land, and one of the South

Shetland Islands, on South Orkney and on one of the Sandwich Islands, together with stations at Cape Pillar, Cape Virgins, Cape Horn, Staten Island and the Falklands. With such a system of observations it would be possible to determine exactly the track of every cyclone crossing the polygon of stations. This is a matter of very great practical importance. These cyclones seem to travel in the general direction of the upper winds from west to east, and to follow the outline of Alexander, Graham, and Palmer Lands, but how and why this is so we cannot tell as yet. Between South America and the Antarctic land there is a belt of low pressure which seems to encircle the Antarctic region where there is apparently a permanent anticyclone; but observations are wanting to determine the associated conditions of atmospheric circulation.

It seems scarcely necessary to insist on the advantages which two other polygons of stations would offer, one to the south of the Indian Ocean, the other between New Zealand and Victoria Land. The second polygon would be formed by the islands of Prince Edward, Crozet, Kerguelen, and a station on Enderby Land. The third polygon would include the Balleny, Macquarie, and Auckland Islands. This would be a particularly interesting polygon on account of its comparative proximity to the magnetic pole.

The two vessels designed to winter in the pack should approach along the meridians of 145° W. and 35° E. Imprisoned in the pack, as the *Belgica* was, these vessels would be able to carry on oceanographical and zoological work, and also to collect magnetic and meteorological observations, thus adding two stations near the pole to the various polygons. From the meteorological point of view it would be extremely interesting for these vessels to reach high latitudes, for the region near the pole will probably differ greatly from the northern edge of the Antarctic lands in everything regarding atmospheric pressure, wind, and storms.

As to the circumpolar expeditions I think that the vessel intended for this purpose should be quite independent of those which penetrate the pack. The region is too great to admit of the whole voyage being completed in one season—three would probably be necessary. It is not easy to indicate the route which should be followed, for everything depends on circumstances. Still it may be observed that—in summer at least—easterly winds predominate near the edge of the south polar pack, and therefore it would be advantageous to proceed from east to west.

Leaving the River Plate in September the vessel might commence work at the South Shetlands at the beginning of October. The months from November to March might be occupied in the voyage from 60° W. to 150° W. along the pack, and thence a passage might be made to Melbourne. The following summer the extreme south of the Indian Ocean might occupy the vessel, and a third season might be devoted to the Antarctic Atlantic.

This programme is doubtless but a dream. I often wished, on board the *Belgica,* that I dared to propose it as a programme, because it seemed to me perfectly realisable. One may perhaps speak of it at the dawn of a new century.

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3. *Notes on the Physical and Chemical Work of an Antarctic Expedition.*
By J. Y. BUCHANAN, F.R.S.

In an Antarctic Expedition, the physical and chemical work to be done falls into two classes, according as it has to be done at sea or on land.

The principal object at the outset of the expedition should be to push energetically southwards, and effect a landing in the most suitable place in the highest possible southern latitude, and there establish the principal station. The locality should be chosen where the ship, or one of the ships, would find safe winter quarters.

As the principal object is to establish the expedition as advantageously as possible on land, no time should be spent unnecessarily at sea. For this reason magnetic observations at sea should not be contemplated. They take up an enormous amount of time, and besides, if they are to be of any use, the distribution of iron in the ship has to be arranged under such restrictions as to interfere materially with the usefulness of the ship in other directions. On land the magnetic observations would occupy a first place, also pendulum observations for the determination of the intensity of gravity and tidal observations.

It has been the general experience of Antarctic navigators that the heavy pack ice is met with at a considerable distance from land, and between it and the land there is comparatively open water The ice which would cover this water in winter would probably loosen earlier than the heavy pack, and the ship, if wintering inside, might be able to move much earlier than it would be possible for her to pass the pack; and this would be an additional advantage of finding winter quarters for the ship.

Perhaps the most important work to be done is to obtain a complete meteorological record during the whole of the sojourn of the expedition in Antarctic regions, whether at sea or on land. At present, any view as to the meteorological conditions on the Antarctic land may be held, because we have no facts by which to regulate our speculations. The expedition should be fully supplied with instruments for this purpose, and especially with self-recording instruments.

As the station must necessarily be on land, and not on ice, geological observations will be made as a matter of course.

What distinguishes the Antarctic regions above everything is the development of ice as a geological feature, whether it is met with at sea as icebergs, or on land as glaciers, or a continuous covering. It is almost certain that any station on land will be within easy reach of a glacier, and means should be taken to establish marks as early as possible which will enable its motion to be observed before darkness sets in and after the sun reappears. The Greenland glaciers appear to move about three times as fast as the Swiss ones. Do the Antarctic ones move faster still? In Spitzbergen the glacier streams sometimes take very large proportions. How does it stand with the Antarctic ones in this respect? The 'grain' of the Spitzbergen glaciers does not seem to be larger than that of the principal Swiss glaciers. The Antarctic land ice must be dissected with a view to the determination of the size and the articulation of the grain. It is, therefore, of the first importance that the chemist and physicist should have spent some time both in summer and in winter examining for himself the conditions of one of the Swiss glaciers. This is quite as necessary for him as having spent a certain time in a chemical or a physical laboratory.

The ordinary work of a chemist and physicist at sea is now so well understood that it is hardly necessary to say much on it. The temperature and density of the surface water are observed at stated intervals. Whenever it is possible the temperature of the water at the bottom and at intermediate depths is observed and samples obtained. The gases dissolved in the water at the surface, at the bottom, and at intermediate depths, should be boiled out and preserved for analysis as often as possible. The proportion of oxygen to nitrogen in the gas gives an idea of the extent to which the dissolved atmosphere has been *used*, or of the amount of animal life which it has supported.

The apparatus for use on deck and in the laboratory is so various, and has been so often described, that little more remains to be said about it than that most observers prefer their own apparatus.

With regard to the district which would fall to the English expedition to explore, I should welcome an arrangement which would enable it to follow to its Antarctic source the remarkable stream of very cold water which the *Challenger* found flowing at the bottom of the depression which runs along the eastern coast of South America from the River Plate to the equator. This work would also carry the expedition in the direction of Weddell's highest latitude, and of Ross's deepest sounding. The base of the English expedition would then be the Falkland Islands.

Much more might be said about the work which a chemist and physicist may find to do under various circumstances; but it is to be assumed that whoever is appointed will know his business. His principal duty, in a new region like the

Antarctic, will be to keep his science and his art handy to be turned to good account whenever the occasion may arise.

4. *On Antarctic Exploration with reference to its Botanical Bearings.* *By* G. Murray, *F.R.S.*

5. *Report of the Committee on the Exploration of Sokotra.* See Reports, p. 460.

6. *Travels in East Bokhara.* *By* Mrs. W. Rickmer Rickmers.

Accompanied by Mr. Rickmers and Dr. v. Krafft, I left the ancient capital of Bokhara in June, 1898. The object of the journey was the exploration of some of the little-known parts of the eastern provinces of the Khanate. After a two-weeks' ride on horseback through steppe and loess, the mountains of the province of Baljuan were reached.

We lived for five months among the conglomerate mountains of the Yakh-Su Valley. This region is extremely wild and fantastic, reminding one at the same time of the Dolomites and the 'Bad Lands,' with their dark and deep cañons. The natives, who speak a Persian dialect, extract gold from the alluvial deposits in these valleys. Their method is very primitive, and yields them a precarious livelihood, but experiments conducted on a large scale have shown that modern processes must assure big profits to enterprising pioneers. The stones composing the conglomerate are mostly crystalline, and the whole formation, which is in places 4,000 ft. thick, is ascribed by Dr. v. Krafft to the tertiary period. The highest summit, a towering cupola, is 13,000 ft. high, and was several times climbed. A glacier of the second order comes down on one side, and is curious for having a moraine composed of rounded fragments, which, of course, could not be otherwise, seeing that the mountain is entirely composed of conglomerate. Mr. Rickmers and Dr. v. Krafft, after several attempts, succeeded in making the first ascent of the Kuch-Manar, a jagged peak 12,000 ft. in height. The views obtained from these points were most beautiful and instructive; towards the east one beheld an ocean of snow and ice, bounded by the Pamir and the Alai, whereas towards the west the ground sloped down to the immense Transcaspian plain.

Much time was devoted to the examination of phenomena new to the literature of physical geography. These were the 'Barriers of the Dandushka,' which are remarkable for having been formed by hydrodynamic agencies, and for having subsequently been pierced by a cañon, likewise formed by water. Vegetable and animal life was not abundant. Thin woods are only to be found in some of the more secluded valleys, where the natives rarely penetrate.

Excursions into the surrounding provinces were also made. Dr. v. Krafft visited Darwaz, and brought back valuable geological information. Mr. Rickmers and I went to Kulab, and thence to the Afghan frontier, where we spent several days among the jungles of the Oxus.

The return journey was *viâ* Baljuan, Karatagh, Baissnu, and Kitab to Samarkand. From Samarkand an interesting lake, the Timur-Dera-Kul, situated at a great height among the mountains, was visited.

7. *A Journey in Western Oaxaca, Mexico.* *By* O. H. Howarth.

The exploration of a portion of the State of Oaxaca, lying south and west between the capital city and the sea, became necessary in the latter part of last year, with a view to ascertain a possible route between the valley of Rio Minas, on the upper course of the Peñoles river, and a point on the Southern Railway, without traversing the high mountain ridges extending between that valley and the city, on a direct line. The whole region is mountainous, being an expansion of the parallel main ranges of the Western Sierra Madre continued through the States of Guerrero and Oaxaca as far south as the Isthmus of Tehuantepec. The ridges, though approximately parallel, are of somewhat irregular conformation. They rise generally to an altitude of between 8,000 and 9,000 feet, being intersected by valleys of generally greater breadth than the cañons of the same range further north; these valleys, however, descending to levels of from 3,000 to 4,000 feet, and of course to still lower elevations as the ranges approach the Pacific Coast. The ranges are largely covered with varied foliage, and the prospect from any of the high ridges is of great magnificence.

On leaving the city of Oaxaca in a westerly direction an open rolling country, partly bare of vegetation, is traversed for a distance of nine or ten miles to the foothills of the nearest range, crossing the river Atoyac close to the city. A prominent object in the centre of this tract is the white dome of the unfinished monastery of Cuilapa, a remarkable structure of high architectural interest raised by Cortez during his occupation of the country, and said to have also comprised a residence for the Princess Malintzi or Malinche. The evidence of this is, however, doubtful, and may possibly have been based on the existence in one of the transepts of a massive inscribed gravestone on which the name of Cortez appears. Entering the range by the winding cañon of Zavaleta a gradual ascent is made to a summit clothed with pine forests, where natural ice is prepared and stored on a singular native system. The trail issues above the little mountain village of San Pablo Cuatro Venados, or St. Paul of the Four Deer, one of the most remarkable sites of early settlement in Mexico. Following the ridge another descent commences through a heavily timbered cañon to the mining village of San Miguel Peras, some fifteen miles further. A mile beyond this is the meeting of two forks of the Rio Verde, and the usual uncertain nomenclature as to rivers and other local features is encountered. A second ascent to 9,000 feet has then to be accomplished by exceedingly rough trails, succeeded by a descent into a valley of less depth, but falling gradually to the north and south of the point of crossing. On reascending from this, a summit is reached crowned by a native village known as Huitepec, occupied by a population of Indians whose language proved to be entirely distinct from any of the known dialects of the State, and apparently isolated. It possesses several peculiarities, and seems to be a solitary survival of one of the most ancient tongues of Central America.

Immediately beyond this the geological formation changes suddenly, the next descent being entirely covered with vast irregular boulders of grey limestone, amongst which the threading of a trail with horses and pack-mules is a matter of extreme difficulty. Again a high ridge has to be traversed at an altitude equal to the previous ones, amongst alternations of pine and scrub-oak growth and open spaces of a long fine grass, with a variety of flowering plants. At some six or seven miles beyond Huitepec the trail enters the head of an extremely steep cañon, the side of which it skirts with an available width of sometimes not more than a foot or eighteen inches, this track being known as the Infiernillo or 'Little Infernal,' a name which the traveller by it considers by no means inappropriate, especially in the season of rains, when the clayey surface becomes slippery with moisture.

Finally, the trail leads out upon a fourth ridge, overlooking the attractive valley of Rio Minas, with its winding river, a last descent being now made to a level of 4,200 feet. The few inhabitants of this country, a delightful one both in climate and fertility, are of a simple and hospitable disposition, and engaged, so far as they follow any pursuit at all, entirely in agricultural occupations, though surrounded by rich mineral formations. The general absence of animal life is noticeable, though the valleys abound with butterflies and other insects. Poisonous insects of all kinds, and also snakes, appear to be very rare; in fact, almost unknown.

The difficulty of access from the well-populated valley of Oaxaca has no doubt contributed to the isolation of a district so inviting. Further down the course of the Peñoles river, where it issues westward, the valley divides to the north-west and south-east, and without any great change of elevation in the former direction trends towards the district capital of Nochistlan at a distance of about thirty-five miles, and thence in an easterly course towards the line of the Southern Railway at Parian, some thirty miles north of the city of Oaxaca. This latter approach has a good road, which, prior to the existence of the railway, would merely have led into the mountains again. It may be expected, however, that slow as the Mexicans are to recognise or avail themselves of any advantages of communication, the better access from the north to these productive valleys may gradually lead to their occupation and development, when further explored under European auspices.

The climatic conditions are similar to those of all the southern interior of Mexico, though, owing to the intersection of the country by long and lofty ridges, the rainfall during the wet season is somewhat greater. The journey here described was undertaken during the month of December last, when the atmospheric conditions are perhaps unrivalled in the world as to temperature and salubrity.

SATURDAY, SEPTEMBER 16.

The following Papers were read:—

1. *Oceanographical and Meteorological Results of the German Deep-sea Expedition in the 'Valdivia.' By* Dr. GERHARD SCHOTT.

The voyage of the *Valdivia* was undertaken at the cost of the Imperial German Government, and may be generally described as a circumnavigation of Africa, although the route involved some wide sweeps away from that continent. From Capetown the route led southward into the Antarctic Ocean until the ice-pack forbade further progress; then along the edge of the ice from 0° to 60° East longitude, then north to Kerguelen. The two main geographical results of the cruise were the rediscovery of Bouvet Island, and the sounding of the whole of the tropical Indian Ocean for the first time.

The oceanographical work included a large number of deep-sea soundings. The *Valdivia* was provided with two sounding machines. The Sigsbee machine worked remarkably well even in very stormy weather. The introduction of an electromotor for reeling in the line was a novelty that turned out most satisfactory; it is especially to be commended for Polar work in which steam pipes are apt to freeze. The best results of the sounding work were on the southern part of the cruise, from Capetown to Bouvet Island, thence along the edge of the ice to the vicinity of Enderby Land, and thence to Kerguelen, because the ship was then in waters which had rarely been visited, and because of the discovery of remarkably great depths of 2,800 to 3,000 fathoms, in place of the supposed Antarctic plateau. Many details of the form of the ocean-bed were also studied, as, for example, the enclosed seas between the west of Sumatra and the Nias Islands, the steep submarine slope from Sumatra to the Indian Ocean, the connection of the Chagos Islands with the Maldives, and the slope of the Agulhas bank to the deep sea.

The measurement of deep-sea temperature came next in importance. We can only refer here to the results obtained in the tropical Indian Ocean and on the margin of the ice. In the first-named instance an extraordinarily rapid transition between the temperature of the superficial layer heated by the sun and the deeper mass of cold water was observed, forming a sort of *Sprungschicht* between the depths of 50 and 100 fathoms. On the border of the ice the distribution of temperature was a cold layer on the surface, produced by the melting of ice with a temperature of from 29° to 30° F.; below 50 fathoms warmer and salter water (the temperature rising from 32° to 35° F.), and below that to nearly 1,000 fathoms a steadily falling temperature. The larger icebergs all dip into the warmer layer. This arrangement of temperature is not identical with that found in the Antarctic by the *Challenger*, although similar to it.

The expedition has also carried out exact observations on the ice conditions, distinguishing the floating ice into three categories: (1) *Drift-ice,* low broken blocks, often evidently broken-off parts of glaciers; (2) *Pack-ice,* composed of greenish stratified masses of frozen sea-water; and (3) *Icebergs.* The icebergs observed in the western part of the *Valdivia's* route, *i.e.* in the neighbourhood of Bouvet Island, were much water-worn and varied in outline, having evidently been afloat for a long time, while in the eastern part, near Enderby Land, they were fresh, tabular, and regular in form, and had a height of from 100 to 180 feet above the surface.

Amongst the meteorological work that accomplished in the far south can alone be mentioned. The expedition saw nothing of the 'brave west winds' south of 55° S., but only light winds (though often storms) from E., N.E., and N., with frequent calms and a quiet sea with fog on many occasions. In spite of the frequency of east winds the barometer showed no sign of rising towards the south, as the existence of an Antarctic anticyclone would seem to imply, but fell steadily.

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2. *On the Mean Temperature of the Surface Waters of the Sea round the British Coasts, and its Relation to that of the Air. By* H. N. DICKSON, *F.R.S.E.*

The mean monthly and annual temperatures of the surface waters of the sea during the period 1880–97 are shown for sixty-five stations distributed round the coasts of England, Scotland, and Ireland. The average for the year at the entrance to the English Channel is nearly 54° F., it falls as the Channel narrows to 52° between the Start and Cape la Hague, and remains steady to beyond the Straits of Dover, at least as far as the East Goodwin light vessel. On the south-west coast of Ireland the annual mean is about 52°, falling to 51° in St. George's Channel, and 50° in the Irish Sea. A slow fall from 52° to 50° takes place on the west coast of Ireland until the N.W. corner is reached. The mean of 49° persists along the north coast of Ireland to the North Channel, and along the whole of the west coast of Scotland to Stornoway. On the east coast temperature falls very quickly, as soon as we get out of range of the Straits of Dover, to 50° off Suffolk and Norfolk, and then there is a gradual fall as we go northwards, to 48° off the coast of Northumberland, 47½° off Aberdeenshire, and 47° at the Orkneys and Shetlands. The effect of the tidal streams in mixing the waters is exceedingly well marked. The annual minimum of temperature rarely occurs in March, most frequently in January, especially at stations open to the Atlantic. The annual maximum occurs almost everywhere in August.

Mean temperatures of the surface water are compared with the forty-year averages for the air, recently published by Buchan. A comparison shows that the mean annual difference has hitherto been somewhat over-estimated, especially on the western coast; in no case is the mean excess of sea over air greater than 2° F. The maximum difference occurs everywhere in November and December, and is greatest on the south coast of England between Portland Bill and the Straits of Dover.

MONDAY, SEPTEMBER 18.

The following Papers were read:—

1. *The Bathymetrical Survey of the Scottish Fresh-water Lochs. By* Sir JOHN MURRAY, *K.C.B., and* F. P. PULLAR.

2. *The Distribution of Nitrogen and Ammonia in Ocean Water.*
By Sir JOHN MURRAY, *K.C.B.*, *and* ROBERT IRVINE.

3. *Temperature and Salinity of the Surface Water of the North Atlantic during* 1896 *and* 1897. *By* H. N. DICKSON.

The completed series of forty-eight monthly charts of surface temperature and salinity, the mode of construction of which was described in a paper read before the Section last year, is exhibited, and along with it, maps showing the departures from the mean distribution of air pressure and temperature during the same period. A number of new features in the movements of surface waters are disclosed, notably in connection with the distribution of polar waters from the western Atlantic.

4. *On the Terminology of the Forms of Suboceanic Relief.*
By HUGH ROBERT MILL, *D.Sc., F.R.S.E.*

The Royal Geographical Society is at present engaged in the investigation of the whole great subject of the terminology of geography, and at the approaching International Geographical Congress at Berlin the question of the terminology and nomenclature of the forms of the floor of the ocean is to be discussed by representatives of different countries. The fact that the forms of the ocean floor cannot be seen, but only felt out by soundings, makes their study one of peculiar difficulty. Some distinguished authorities believe that our present knowledge of the deep sea is too slight to justify any systematic nomenclature. Meanwhile each investigator introduces a set of names of his own, for the most part based on analogies with land forms visible to the eye.

It is obvious that there are two great classes of forms, elevations above and depressions below the general level of the ocean floor; but the question is how many subdivisions of each can be recognised as distinctive and deserving of generic names. I am inclined to put forward tentatively the following general scheme of terminology, premising that no attempt be made to localise any precise type of form unless a considerable number of soundings exists to define it:—

Depression.—The general term for any sub-oceanic hollow.

Basin.—A relatively wide depression, with comparatively gently sloping sides.

Caldron.—A relatively wide depression, with comparatively steeply sloping sides.

Furrow.—A relatively narrow depression with comparatively gently sloping sides.

Trough.—A relatively narrow depression with comparatively steeply sloping sides.

Wall.—Any submarine slope comparable in steepness to a precipice on land.

Floor.—Any very gentle submarine slope or nearly level surface.

Elevation.—Any inequality above the general level of the ocean floor.

Rise.—A relatively narrow elevation.

Bank.—A relatively wide elevation.

Shoal.—An elevation coming within five fathoms of the surface, so as to be a danger to shipping.

Shelf.—A nearly horizontal bank attached to the land and bordered seaward by a much more abrupt downward slope.

Any suggestions as to the forms which are really typical and the terms which are most appropriate for their designation will be carefully considered.

5. *Twelve Years' Work of the Ordnance Survey.*

By Colonel Sir JOHN FARQUHARSON, *K.C.B.*

In October 1887 I was ordered to take up at Southampton, where the headquarters of the Survey are established, the duties of Executive Officer, or second in command, of the Ordnance Survey. Sir Charles Wilson was then Director-General; and in March 1894 I succeeded him in the latter position, which I retained until March of this year, when, on the expiry of my five years' term of office, I handed over the duties to Colonel Duncan A. Johnston, R.E., the present Director-General. I propose in this paper to give a short summary of the work done by the Ordnance Survey Department in the period of nearly twelve years, from October 1887 to March 1899, during which I was either Executive Officer or Director-General, and during which, in one or other of those capacities, the whole of the work of the Survey passed through my hands.

During those twelve years there have been probably more changes made in the character of the work done by the Survey than in any other equal period of its history; and, as regards the areas covered by its operations, they have been largely in excess of the areas covered during any previous equal period. This is, of course, due to the fact that Revisions have now largely taken the place of original Surveys.

I propose first to deal with the progress made, from 1887 to 1899, in the following branches of the work:

The progress (to completion in 1890) of the original Cadastral Survey of England and Wales, including the 6-inch surveys of uncultivated districts.

The progress made on Re-surveys for the larger scales of various counties of England and Scotland which had been originally surveyed for the 6-inch scale only; and the progress made on the Revision of the original Cadastral Surveys of England and Scotland, whether on the 25-inch or 6-inch scale.

The progress made on the Re-survey of Ireland for the $\frac{1}{2500}$ or 25-inch scale.

The progress made on the completion of the original new series engraved 1-inch maps of Great Britain and Ireland, both in outline and with hills.

The progress made on the Revision of the new series 1-inch engraved outline maps of Great Britain and Ireland, and the commencement of the issue for Scotland and the North of England (and for Ireland ultimately) of the same revised 1-inch map with hills in brown by double printing.

The progress made with coloured 1-inch maps of the South of England.

The progress made with maps on scales smaller than 1 inch to a mile.

The simplest, and probably the clearest method of showing the work done under the above heads will be by diagrams, which have been prepared.

A short account is given of the nature, causes, and results of any changes made since 1887 in the system of carrying out the Survey, some of which may be due to the reports of Committees, or suggestions from the general public, while others have been necessitated by the changes which have taken place in the character of the work done by the Department.

Observations are made as to the style and quality of the maps on all scales, both old and new. But as specimens of these maps are provided for inspection by members of the Association, these observations are very brief. Specimens of foreign maps, so far as available, are also provided for inspection by members, and comparison with the English maps.

The Ordnance Survey Department, in 1887, published town maps at the cost of the State, on the scales of 10 feet ($\frac{1}{528}$) and 5 feet ($\frac{1}{1056}$) to a mile. It does so no longer.

The sales of the Ordnance Survey maps were in 1887 in the hands of the Stationery Office: they are now in the hands of the Ordnance Survey Department itself.

Some remarks are also made as to the organisation and superintendence of the Department and of its work; as to the use or otherwise made of the Ordnance Survey maps by other departments of the State and by the public generally; and as to the important work which still remains to be done by the Ordnance Survey.

6. *On Sand-Dunes bordering the Delta of the Nile.*
By VAUGHAN CORNISH, *M.Sc., F.R.G.S., F.C.S.*

The author visited Egypt in April–May, 1899, in continuation of his work upon Sand-dunes (see 'Geographical Journal,' March 1897, the first of a series of papers upon 'Kumatology'). Observations of sand-dunes and allied phenomena were made upon twenty-three days along the line of the Suez Canal between Port Said and Serapeum, on the Syrian route from Kantara, in the neighbourhood of Ismailia, and on the line from Ismailia to Abu Hammad, between Cairo and Terieh, on the western margin of the Delta, and in the neighbourhood of Helwan and Sakara. About fifty photographs and eight drawings, suitable for reproduction, were obtained of sand-dunes, wind-erosion structures, and of tree-planting directed against the encroachment of sand. The photographs of dunes include both Barchanes (or Medanos) and the curious hollows which, in Arabia, are called Fuljes, as well as gently undulating surfaces, covering the country like a mantle of snow, with no sharp ridge or slipping lee cliff. Measurements of ripples and dunes were made, and samples of sand were taken, from which (two only at present) micro-photographs have been prepared.

Ripples.—The author had previously measured twelve wind-formed ripples in the blown sea sand on the Dorset coast. The average ratio of length to height was $\frac{L}{H} = 18{\cdot}4$. The least height was ·06 inch, and the greatest ·34 inch. These measurements were, for the most part, of one or two individual ripples. Mr. E. A. Floyer measured six of the largest kind of ripples on the El Arish route, and obtained $\frac{L}{H} = 17{\cdot}7$ with H from 6 to 10·6 inches. The author measured thirty-seven *consecutive* ripples to leeward of a sand-dune near Ismailia. The ripples had an average height of 1·43 inches, and the average $\frac{L}{H}$ was 16·57. The appearance of these was intermediate between that of ripples where accumulation is rapid (which never grow large), and the large and nearly symmetrical ripples (? analogous to sastrugi), as much as 11 feet in wave-length, the formation of which is apparently accompanied by a considerable lowering of the general level.

Dunes.—A tract of a few hundred acres of small, but true, dunes (not ripples) on a sandy foreland, exposed during the fall of the Nile, afforded an opportunity for similar measurements.

Higher and lower dunes succeeded one another, and viewed transversely, the ridges were strongly undulating. Nevertheless, a line having been marked out in the up-and-down-wind direction, the *average* $\frac{L}{H}$ for twenty-four consecutive dunes was found to be 18·04, average height 20 inches. Another set of measurements taken near the same line on the succeeding day, gave $\frac{L}{H} = 17{\cdot}89$ for twenty-three consecutive dunes. Apparently the ridges are formed of the nearly uniform $(\frac{L}{H} = 18)$ shape, and lateral inequalities are subsequently developed in the manner explained in the 'Geographical Journal,' June 1898, pp. 637–9, but these do not affect the *average* $\frac{L}{H}$. The author hopes to make similar measurements of trains of larger dunes.

The straight, slipping lee cliff of dunes is caused by the undercutting of the eddy. In the dunes near Ismailia a progressive development of the profile form was observed. At first both windward and lee slopes are very gentle, and the highest point is near the middle. The summit apparently moves to leeward, and the lee slope becomes steeper; a slipping cliff is formed on the upper part of the lee slope. This pushes back towards the summit, and the windward slope grows steeper. Finally, windward and average leeward slope become of nearly equal steepness, and the top of the cliff coincides with the summit of the dune.

Dune Tracts.—The condition for formation of a dune tract in a sandy district is that the rate of travel of the sand should be locally diminished without a corresponding diminution in the supply of sand. The persistence of such condition may cause a stationary dune massif without fixation.

In the sandy district visited by the author the formation of a dune tract or dune massif appears to be chiefly determined by the presence of ground moisture, which gives coherence to the sand. Thus the boundaries of these massifs frequently appear inexplicable when an explanation is sought in the wind. Within the bounds of the massif, however, the modelling of the surface is explicable by the action of the winds.

TUESDAY, SEPTEMBER 19.

1. *The Anthropogeography of certain Places in British New Guinea and Sarawak. By* A. C. HADDON, *D.Sc., F.R.S.*

2. *A Visit to the Karch-Chal Mountains, Transcaucasia.*

By W. RICKMER RICKMERS.

In the summer of 1895, accompanied by Dr. A. Hacker, of Vienna, I visited the Karch-Chal Mountains, in Transcaucasia. This group is S.E. of Batum, and, in a straight line, about 30 miles distant from that port. The route taken was along the Chorokh River, through a well-wooded valley rich in copper ore. A carriage road can be used as far as the village Borchkha, where one leaves the river and ascends by one of the side valleys. These are fairly well cultivated, containing numerous villages inhabited by Ajars or Lazes, a people speaking a dialect produced by the mixture of Georgian and Osmanli. They were originally Georgian Christians, and ruined churches can be found in several places, even at a height of 4,000 ft. Now the country is thoroughly Mohammedanised. Maize and tobacco are the chief produce.

After leaving the region of the picturesquely situated villages, with their brown wooden houses, the ascent leads through a forest of magnificent beeches and other leaf-trees. In the midst of this luxuriant vegetation, at a height of 5,000 ft., a hot spring has given birth to a primitive watering-place called Otingo, consisting of three sheds, and chiefly frequented by Armenians from Artwin. Above this comes a zone of dense fir-woods, with an impenetrable undergrowth of laurel and rhododendron, the abode of numerous bears. At a level of *ca.* 7,000 ft. one steps forth on to the undulating Alpine pastures where the cattle are sent to graze during two summer months. The Yailas, corresponding to the *Sennhütten* of the Alps, are almost exactly like their European counterparts. In one of the huts we lived for many weeks, save when, for a change, we passed the nights in a cave 3,000 ft. higher or on the summit of a mountain.

The principal peaks of the group are on an average 12,000 ft. high, and surround a plateau about 11,000 ft. high. Eight peaks were climbed, some proving fairly difficult. Photographs were taken, and a collection of Alpine plants made, which has thrown light on the mountain flora of these regions. Large mammals, such as ibex or chamois, were not observed, but eagles and vultures were plentiful.

Three days and nights were spent on the top of the highest summits in order to obtain a series of barometrical and thermometrical observations. Mr. Hacker sketched a panorama of the range from this point.

A small and very steep glacier was also discovered; it feeds a beautiful little green lake. Towards the end of August snowy weather alternated with days of sunshine, and once we were obliged to wait a whole fortnight in one of the huts for the fog to lift.

On the return journey a visit was paid to the town of Artwin, one of the most important Armenian settlements in these parts. It dominates a beautiful gorge of the Chorokh, and offers many interesting aspects of native life.

3. *A Journey in King Menelek's Dominions.* *By* Captain M. S. WELLBY.

The Paper deals with the following subjects:—

Reference to the capital of Abyssinia—Travelling with King Menelek's army—Breakfast with his Imperial Majesty—Present and future character of the Abyssinian people—Abyssinian power and conquests—Effect of different foods on the human body—Bottego, the Italian explorer—A chain of lakes and an independent tribe—Effect on the tribes of King Menelek's rule—The devils of Walamo—Religious beliefs of the Asilli tribes—The outflow of the river Womo (Omo)—A volcano—Lake Gallop: waves in tropical Africa—The unknown land between Gallop and the Nile Valley—An advanced post in the Sudan—My Abyssinian followers.

4. *The Discovery of Australia.* *By* EDWARD HEAWOOD, *M.A.*

The first authenticated voyage to Australia was made by a Dutch vessel in 1606, but it has been thought by many, from indications on maps of a much earlier date, that voyages had been made by the navigators of some other European nation, early in the previous century. These maps are of the Dieppe school of cartography, and are all—as regards this part of the world—based on one prototype, the earliest known to us dating from about 1536. They show a continental land to the south-east of Java, bearing the name Jave la Grande, 'the Greater Java,' in distinction from Java proper. The fairly full nomenclature round the coasts has been thought to imply an actual discovery, and as Australia is the only large land in this quarter of the globe, the land delineated has been supposed to represent Australia.

A comparison of the outlines of these maps with those of Australia shows little real resemblance, while other considerations would rather lead to the conclusion that Jave la Grande really represents a reduplication of Java proper in a greatly exaggerated form. The influence of the old writers, especially Marco Polo, was still very great at the beginning of the sixteenth century. That traveller spoke of Java as Java Major, with a circuit of 3,000 miles, and his nomenclature was followed by a large number of map makers. The native charts in use before the advent of the Portuguese gave Java an inclination to the south-east, such as is shown by the coast-line on the French maps, while the earliest Portuguese map of the Archipelago presents a somewhat similar reduplication of Java. The charts of Rodriguez, partly based on native material, are a proof that large-scale representations of Java were in existence at the time, while the extent of coast-line definitely shown on the earliest of the French maps is absolutely identical with that of the Javan coasts known to the Portuguese about 1519. The correspondence of the outline is fairly satisfactory, especially in the south-west, while the scanty indications of the nomenclature point to Java at least as much as to Australia.

Finally, the hypothetical nature of other details in these maps as regards the Far East should make us hesitate to base the assumption of a discovery of Australia in the fifteenth century on their unsupported testimony.

5. *A Journey to Wilczek Land and the Problem of Arctic Exploration.*
By WALTER WELLMAN.

6. *The Relations of Christmas Island to the Neighbouring Lands.*
By C. W. Andrews, *B.Sc., F.G.S.*

The author points out that in Christmas Island there is a long series of Tertiary deposits, ranging, probably, from the Upper Eocene at least to the end of the Miocene, and that these rocks are closely similar to deposits of the same age in Java and the neighbouring islands.

The relations of the present fauna and flora are considered, and it is shown that they most nearly resemble those of the Indo-Malayan sub-region, but that in certain cases the species are the same as some found in Ceylon, &c. Some of the means by which the various plants and animals may have reached the island are referred to.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION—HENRY HIGGS, LL.B., F.S.S.

THURSDAY, SEPTEMBER 14.

The President delivered the following Address:—

THE prime concern of the economist and of the statistician is the condition of the people. Other matters which engage their attention—particular problems, questions of history, discussions of method, developments of theory—all derive their ultimate importance from their bearing upon this central subject. The statistician measures the changing phenomena of the production, distribution, and consumption of wealth, which to a large extent reflect and determine the material condition of the people. The economist analyses the motives of these phenomena, and endeavours to trace the connection between cause and effect. He is unable to push his analysis far without a firm mastery of the theory of value, the perfecting of which has been the chief stride made by economic science in the nineteenth century. When we read the 'Wealth of Nations' we are forced to admit that in sheer sagacity Adam Smith is unsurpassed by any of his successors. It is only when we come to his imperfect and unconnected views upon value that we feel the power of increased knowledge. J. S. Mill supposed in 1848 that the last word had been said on the theory of value. In his third book he writes: 'In a state of society in which the industrial system is entirely founded on purchase and sale . . . the question of value is fundamental. Almost every speculation respecting the economical interests of a society thus constituted implies some theory of value: the smallest error on this subject infects with corresponding error all our other conclusions, and anything vague or misty in our conception of it creates confusion and uncertainty in everything else.' And he adds: 'Happily, there is nothing in the laws of value which remains for the present or any future writer to clear up; the theory of the subject is complete.'

We know now that he was wrong. Thanks in the main to economists still alive, and especially to the mathematical economists, we have at length a theory of value so formally exact that, whatever may be added to it in the future, time can take nothing from it, while it is sufficiently flexible to lend itself as well to a *régime* of monopoly as to one of competition. Yet our confidence in this instrument of analysis is far from inspiring us with the assurance which has done so much to discredit economics by provoking its professors to dogmatise upon problems with the whole facts of which they were imperfectly acquainted. Given certain conditions of supply and certain conditions of demand, the economist should have no doubt as to the resulting determination of value; but he is more than ever alert to make sure that he has all the material factors of the case before him; that he understands the facts and their mutual relation before he ventures to pronounce an opinion upon any mixed question. He must have the facts before he can analyse them. A small array of syllogisms, which, as Bacon says, 'master the assent and not the subject,' are not an adequate equipment for him. He sees more and more the need for careful and industrious investigation, and prominent among the subjects which await his trained observation are the condition of the people and the related subject of the consumption of wealth. Training is, indeed, indispensable. Every social question has its purely economic elements for the skilled economist to unravel, and when this part of his task has been achieved, he is at an advantage in approaching the other parts of it, while his habit of mind helps him to know what to look out for and what to expect.

It is a curious paradox that, busying ourselves as we do with the condition of the people, we are lamentably lacking in precision in our knowledge of the economic life and state of the British people in the present day. Political economy has, however, followed the lines of development of political power. At one time it was, as the Germans say, cameralistic—an affair of the council chamber, a question of the power and resources of the king. Taking a wider but still restricted view of society, it became capitalistic, identifying the economic interests of the community to a too great extent with those of the capitalist class. It has at length become frankly democratic, looking consciously and directly to the prosperity of the people at large.

Thus, then, we have at once a more accurate theory, a livelier sense of caution as to its limitations in practice, and the widest possible field of study. So far as most of us are concerned, we might as well spend our time in verifying the ready reckoner as in tracing and retracing the lines of pure theory. These tools are made for use. Economic science is likely to make the most satisfactory progress if we watch the social forces that surround us, detecting the operation of economic law in all its manifestations, and in observing, co-ordinating, and recording the facts of economic life. It is not enough, to borrow the language of the biologist (part of which he himself borrowed from the old economists), to talk of the struggle for existence, the survival of the fittest, and of evolution. We want, above all, his spirit and his method—the careful, minute, systematic observation of life as affected by environment, heredity, and habit. Different problems are brought to the front by different circumstances and appeal to different minds; but at all times and to all economists the condition of the people is of chief interest, and the consumption of wealth is so closely connected with it that it might seem superfluous to plead for its study. Yet some such plea is necessary. The arts of production improve apace. The victories of science are rapidly utilised by manufacturers anxious to make a fortune. Even here the descriptive study of the subject is hampered by the trade secrets involved in many processes, and by a feeling that production may safely be left to the unresting intelligence of captains of industry, so that the onlooker is chiefly concerned in this branch of the subject with solicitude for the health and safety of the workmen employed. The departments of distribution and exchange appeal especially to the pride of intellect. The delicate theorems of value in all their branches—wages, rent, interest, profits, the problems of taxation, the alluring study of currency, the mechanism of banking and exchange—have attracted the greatest share of the economist's attention. On the practical side of distribution the growth of trade unions, the spread of education, the improved standard of living, have increased the bargaining power of the working classes and combined with other causes to effect a gratifying improvement in the distribution of wealth, so that they receive a growing share of the growing national dividend. The practical and the speculative aspects alike of the consumption of wealth have received less consideration. Nobody sees his way to a fortune through the spread of more knowledge of domestic economy in workmen's homes; and the scientific observer has curbed his curiosity before what might seem an inquisitorial investigation into the question, What becomes of wages? Economists long ago discovered the necessity of distinguishing between money wages and real wages. It is now necessary for us to distinguish between real wages and utilities—not to stop at the fact that so many shillings a week *might* procure such and such necessaries, comforts, or luxuries, but to ascertain how they *are* expended. From the first we can deduce what the economic condition of the people might be; from the second we shall know what it is. And when we know what it is we shall see more clearly what with more wisdom it might become.

Wealth, after all, is a means to an end. It is not enough to maximise wealth, we must strive to maximise utilities. And we can no more judge of the condition of a people from its receipts alone, than we can judge of the financial condition of a nation from a mere statement of its revenues.

The condition of the people has, of course, improved, and is improving. Public hygiene has made great progress, and houses are better and more sanitary, though for this and other reasons rents have risen. Wages are higher. Commodities are cheaper. Co-operation and the better organisation of retail business, giving no credit, have saved some of the profits of middlemen for the benefit of the consumer, while authority fights without ceasing against frauds in weights and measures, and adulteration. Free libraries, museums, picture galleries, parks, public gardens and promenades have multiplied, and it is almost sufficient to observe that no one seems to be too poor to command the use of a bicycle. But with all this progress it is to be feared that housekeeping is no better understood than it was two centuries ago—perhaps even not so well. In the interval it has become enormously simplified. The complete housewife is no longer a brewer, a baker, a dyer, a tailor, and a host of other specialists rolled into one. But among the working classes the advent of the factory system has increased the employment of women and girls away from home to such an extent that many of them now marry with a minimum of domestic experience, and are with the best intentions the innocent agents of inefficiency and waste, even in this simplified household.

If we were suddenly swallowed up by the ocean, it appears probable that the foreign student would find it easier to describe from existing documents the life and home of the British craftsman in the middle ages than of his descendant of to-day. In part, no doubt, our fiscal system, with its few taxes upon articles of food and its light pressure on the working classes, is responsible for this neglect. During the Napoleonic war Pitt sent for Arthur Young to ask him what were the ordinary and necessary expenses of a workman's family, and the question would again become one of practical politics if any large addition were required in the proceeds of indirect taxation. Taxation has the one advantage of providing us with statistics. We know tolerably well the facts in the mass about the consumption of tea and coffee, dried fruits and tobacco, and of alcohol, while the income tax (aided in the near future by returns of the death duties) may give us some idea of the stratification of the wealthier classes. But the details of consumption are still obscure. It has already been suggested that some restraint may arise from the sentiment that individuals are likely to resent what they may regard as a prying into their affairs. But when we travel abroad we are curious to notice, and do notice without giving offence, the dress, the habits, and the food of peasants and workmen; and it is difficult to resist the conclusion that we are less observant at home because these common and trivial details appear to us unworthy of attention. In his 'Principles of Economics' Professor Marshall says: 'Perhaps 100,000,000*l.* annually are spent even by the working classes, and 400,000,000*l.* by the rest of the population of England, in ways that do little or nothing towards making life nobler or truly happier.' And, again, speaking before the Royal Statistical Society in 1893: 'Something like the whole imperial revenue, say 100 millions a year, might be saved if a sufficient number of able women went about the country and induced the other women to manage their households as they did themselves.' These figures show, at any rate, the possibilities of greatness in the economic progress which may result from attention to the humblest details of domestic life.

Economics, like other sciences, lies under a great debt of obligation to French pioneers. The Physiocrats, or *économistes,* of the eighteenth century were the first school of writers to make it worthy of the name of a science. In Cournot France gave us a giant of originality in pure theory. In Comte we have a philosopher fruitful in suggestion to the narrower economist. In Le Play we have a writer as yet little known in England, but to whom recognition and respect are gradually coming for his early perception of the importance of ascertaining the facts of consumption, and it is to Le Play's 'family budgets,' the receipts and expenses of workmen's families, that I desire especially to call attention. I have given elsewhere an account of his life and work.[1] Broadly speaking, he set himself by the comparative study of workmen's families in different countries of Europe to arrive at the causes of well-being and of misery among the labouring classes. The subject was too large to lead him in many directions to very precise conclusions. We are reminded in reading him of an incident at a dinner of the Political Economy Club in 1876, when Mr. Robert Lowe propounded the question, 'What are the more important results which have followed from the publication of the "Wealth of Nations" just one hundred years ago?' Some of the most enthusiastic admirers of Adam Smith were present, Mr. Gladstone and M. Léon Say among the number; and Mr. Lowe trenchantly declared that it all came to this: 'The causes of wealth are two, industry and thrift; the causes of poverty are two, idleness and waste.' It was left to Mr. W. E. Forster to make the rugged remark, 'You don't want to go to Adam Smith for that—you can get that out of the Proverbs of Solomon.' And Le Play's conclusions frequently go still further back, to the Decalogue. There are, however, many observations, suggestive and original, upon the material facts, the economic life, of the families he brought under review. And we are now concerned rather with his method than with his conclusions. Given half a dozen Le Plays applying their minds to the study of the consumption of wealth among the working classes of England, we might expect soon to see a greater advance in comfort, a greater rise in the standard of life, than improved arts of production alone are likely to yield in a generation. Certain English writers had, indeed, prepared family budgets before Le Play arose. But their method was usually incomplete, except for the specific purpose they had before them. David Davies and Sir F. Eden were chiefly concerned with the poor law, Arthur Young and Cobbett with agricultural politics, Dudley Baxter and Leone Levi with taxation. Le Play may fairly be called the father of the scientific family budget. His studies of four English families[2] are the most complete economic pictures of English popular life to be found in literature. With the aid of some local authority he chose what was thought a fairly typical family, and then, frankly explaining his scientific object and securing confidence, he set himself to study it. Nothing of economic interest is too unimportant for him to record. A minute inventory and valuation of clothes, furniture, and household goods; a detailed account, item by item, of income from all sources and of expenditure upon all objects for a year, with the quantities and prices of foods, &c.; a description of the family, member by member, their past history, their environment, how they came to be where they are and to earn their living as they do; their resources in the present, their provision for the future; their meals, hygiene, and recreations; their social, moral, political, and religious observances—nothing escapes him. And the whole is organised, classified, fitted into a framework identical for all cases, with the painstaking and methodical industry of the naturalist Contrasted with this the realism of novelists, the occasional excursions of journalists, the observations of professed economists, are pitiably incomplete. As early as 1857 Le Play found one ardent admirer in England, Mr. W. L. Sargant, whose 'Economy of the Labouring Classes,' avowedly inspired by Le Play, is a valuable and interesting piece of work. Since then, however, with the magnificent exception of Mr. Charles Booth, little has been done to throw light upon the mode of life of the wage-earners of England. The Board of Trade heralded the formation of its Labour Department by issuing a Blue Book—unhappily without sequel—entitled 'Returns of Expenditure by Working Men,' 1889, and the Economic Club has published a useful collection of studies in 'Family Budgets,' 1896. But we shall probably still depend very much upon foreign observers for fuller knowledge of the subject. M. René Lavollée, an adherent who may almost be called a colleague of Le Play, has devoted to England a whole volume of his important work 'Les Classes Ouvrières en Europe: études sur leur situation matérielle et morale.'[3]

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[1] *Harvard Quarterly Journal of Economics*, vol. iv. 1890; *Journal of Royal Statistical Society*, March 1893; Palgrave's *Dictionary of Political Economy*, *s.v.* Le Play, 1896

[2] *Les Ouvriers Européens*, Paris, folio, 1855.

[3] Paris, 1896, tom. iii. 656 pp., large 8vo.

M. Urbain Guérin, another member of the Société d'Économie Sociale founded by Le Play to carry on his work, has recently added a study of a tanner's family in Nottingham to Le Play's gallery of portraits: and some of the young members of the Musée Social and the École Libre des Sciences Politiques have come among us animated with the same scientific curiosity. A vivid (and, so far as Newcastle is concerned, a trustworthy) sketch by a German miner, 'How the English Workman lives,' just translated into English, is our latest debt to foreign observers. It may be hoped that the British Association, largely attended as it is by persons who would shrink from more ambitious scientific labours, will furnish some workers ready to do their country the very real service of recording such facts as they can collect about the economic habits of our own people, and so helping us to know ourselves.

Consider, for a moment, the consumption of food. To the ordinary English workman life would seem unendurable without white wheaten bread. Other forms of bread he knows there are, but he has unreasoning prejudices against wholemeal bread—the food of workhouses and prisons—and against rye bread or other kinds of bread, the food of foreigners. But in many parts of Europe the working classes have no bread. Cereals of some sort, prepared in some way, they of course employ. Wheat, oats, rye, barley, maize, buckwheat, even chestnuts, are used indifferently in different places, and rice and potatoes are among the substitutes. What is the relative value of these as food-stuffs, and what is the best mode of preparing them? The reasons which induced men in the middle ages to consume the cereals of their own neighbourhood have been so much weakened by the cheapening of transport and the international specialisation of industries, that the conservatism of food habits is brought into strong relief when we find neighbouring peoples abandoning, first in town and then in country, marked distinctions of national costumes, but clinging everywhere to national differences of food. We are perhaps on the eve of considerable changes here. Two years ago an American economist told me in Boston that fruit had been the great ally of the workmen in a recent severe strike. There had been an exceptionally large crop of bananas, which were sold at one cent apiece, and the strikers had sustained themselves and their families almost entirely upon bananas at a trifling cost—very greatly below their usual expense for food. Returning to London I found bananas on sale in the streets for a halfpenny. No doubt they were consumed here in addition to, and not in substitution for, ordinary food; but they illustrate the fact that the foods of other latitudes are no longer the sole luxury of the rich, but are brought within the reach of all classes, and that our popular food habits need no longer be made to conform to the narrow range of former days, but may be put upon a wider rational basis. The vegetarians, largely dependent upon other countries, have recognised this. The chemist and the physiologist might give us great assistance in these matters. Most of the calculations which I have seen as to the constituents of foods, their heat-giving and nutritive properties, appear to ignore the greater or less facility with which the different foods are assimilated. It is surprising that rice, in some respects the most economical of all grains, needing no milling, easily cooked and easily digested, is not more largely consumed by the poorer families in this country.

The effect upon our food habits of the introduction of railways and the supply of comparatively cheap fuel to every household is almost incalculable. But for this the consumption of tea, perhaps even of potatoes where there is no peat, would be very small. The preference of the French for liquid, and of the English for solid, food has been attributed to the greater relative facilities which the French once enjoyed for making a fire, though the persistence (if not the origin) of our popular habits in this respect probably lies rather in the fact that a Frenchwoman's cookery makes greater demands upon her time and attention. One result of this preference is that the essential juices of meat preserved by the French in soups and ragouts are with us to a large extent absolutely wasted. Owners of small house properties complain that, however well trapped their sinks may be, the pipes are constantly choked, and that the mysterious mischief is almost invariably cured by liberal doses of boiling water which melt the solidified fats cast away in a state of solution. The number of persons who died of starvation in the administrative county of London in 1898, or whose death was accelerated by privation, amounted to 48; and we shall be pretty safe in estimating the total number in the United Kingdom at something less than 500. The common and inevitable reflection is that they might have been easily relieved from the superfluities of the rich; but it is true also that their sufficient sustenance was destroyed many times over through the ignorance of the poor. It would be difficult to find an English cookery book which a workman's wife would not reject as too fanciful and ambitious to be practical. A little French treatise, *La parfaite Cuisinière, ou l'Art d'utiliser les Restes,* strikes in its title at any rate the keynote of the popular domestic economy of which we stand much in need in England. Housekeeping, even the humblest, is a skilled business. To know what to buy, how to use it, and how to utilise waste does not come by the light of nature. If more knowledge and more imagination were devoted to the teaching of cookery in our Board schools, the family meal might be made more varied, more appetising, more attractive, and more economical, leaving a larger margin for the comforts, culture, and recreations which help to develop the best social qualities. A happy family is a family of good citizens. It would be discourteous to another Section of this Association to quote without reserve the *mot* of Brillat-Savarin: 'He who discovers a new dish does more for the happiness of mankind than he who discovers a new planet.' We must stipulate that the new dish effects an improvement in the economy of the working classes.

Take, again, the consumption of coal. Mr. Sargant says: 'It is impossible to say how much of the superiority of English health and longevity is owing to the use of open fireplaces; probably a considerable part is owing to it. We all know how close and stifling is the atmosphere of a room heated by a stove, and how much more difficult it is to keep a room perfectly ventilated in summer than it is in winter, when the fire is constantly changing the air. It may be true that three-fourths of the heat of our fireplaces passes up the chimney and is lost to us; but we gain far more advantage by the fresh air constantly introduced into the room.' Now with improved grates and improved fireplaces we may retain all the advantages of the open fire without so great a waste either of the substance of the consumer or of the national stock of coal; and attention is already being devoted to this fact in middle-class households, but some time must yet elapse before the advantage is reaped by the working classes. At a former meeting of this Association Mr. Edward Atkinson exhibited a portable oven or cooking-stove, which was a marvel of simplicity and economy. He has described it at length in his 'Science of Nutrition,' 1892. He argues that the attempts to combine cooking with the warming of a room or house are absurdly wasteful; that almost the whole of the fuel used in cooking is wasted; and that nine-tenths of the time devoted to watching the process of cooking is wasted; and he estimates the waste of food from bad cooking in the United States at 1,000,000,000 dollars a year. I have not, however, heard of his oven being at all extensively used.

Upon the thorny subject of dress it is perilous to venture; but it is impossible to be in the neighbourhood of a London park on a Sunday afternoon without feeling that the efforts of domestic servants to follow the rapidly changing vagaries of fashion are carried to a pernicious degree of waste. The blouse of the French workman and the bare head of the Parisian factory-girl or flower-girl are infinitely more pleasing than the soiled and frowsy woollens or the dowdy hats of their English fellows, nor does the difference of climate afford an adequate explanation of the difference of habit. We must perhaps admit a greater dislike in England to any external indication of a difference in wealth by a costume different in kind. M. Lavollée, after referring to the low price of the ready-made suits which the English factories 'fling by the million on the markets of the world, including their own,' adds: 'This extraordinary cheapness is, however, not always without inconvenience to the consumer. If the clothes he buys cost little, they are not lasting, and their renewal becomes in the long run very burdensome. This renewal is, too, the more frequent in that the wife of the English workman is in general far from skilful in sewing and mending. Whether she lacks inclination, or the necessary training, or whether the fatigues of a too frequent maternity make her *rôle* as a housewife too difficult for her to support, the woman of the people is generally, on the other side of the Channel, a rather poor cook, an indifferent needlewoman, and a still more indifferent hand at repairs.' As a consequence, he says, the English workman has often no alternative but to wear his garments in holes or to replace them by others. Given an equal income, there is probably no doubt that a French working-class family will be better fed and better clad than a corresponding English family dealing in the same market, and will lay up a larger stock of the household goods, and especially linen, which are the pride of the French peasant.

The waste resulting from the immoderate use of alcohol and from the widespread habit of betting, serious as they are, need not detain me, as I wish to confine myself more particularly to waste which can hardly be called intentional. It is not suggested that every man should confine his expenditure to what is strictly necessary to maintain his social position. The great German writer on finance, Professor Wagner, is accustomed to say that 'parsimony is not a principle.' It is sometimes, indeed, a bad policy and a wasteful policy; and life would be a very dull business if its monotony were not relieved by amusement and variety even at the occasional expense of thrift. Le Play refers to tobacco as 'the most economical of all recreations.' How else, he asks, could the Hartz miner 'give himself an agreeable sensation' a thousand times in a year at so low a cost as 10 francs? But nobody would wish to see a free man using his tobacco like the Russian prisoners described to me by Prince Kropotkin, as chewing it, drying and smoking it, and finally snuffing the ashes! Nor should we desire to eradicate from society the impulses of hospitality, and even of a certain measure of display. An austere and selfish avarice, if generally diffused, may strike at the very existence of a nation.

Another respect in which French example may be profitable to us is the municipal management of funerals (*pompes funèbres*). Many a struggling family of the working classes has been seriously crippled by launching out into exaggerated expenses at the death of one of its members, and especially of a bread-winner. The French system, while preserving the highest respect for the dead, has some respect for the living, who are frequently unable and unwilling at a time of bereavement to resist any suggestion for expensive display which seems to them a last token of affection as well as a proof of self-respect.

As regards housing, the English cottage or artisan's house is regarded on the Continent rather as a model for imitation than as a subject for criticism; but the pressure of population upon space in our large cities, joined with a love of life in the town, may possibly prove too strong for the individualist's desire for a house to himself. If we should be driven to what Mrs. Leonard Courtney has proposed to call Associated Homes, the *famillistère* founded by M. Godin at Guise, and rooted in the idea of Fourier's *phalanstère,* will show us what has already been achieved in this direction. Dissociated from industrial enterprise it might easily become popular in England. Some of its collective economies are certainly deserving of imitation, and the experience not only of the Continent, but also of America, may soon bring us face to face with the question whether the preparation of dinners, in large towns, should not—at least for the working classes—be left to the outside specialist like the old home industries of baking and brewing. An excellent example of scientific observation is 'Les Maisons types' by M. de Foville, the well-known master of the French Mint. He describes in detail the various forms of huts, cottages, and houses scattered over France in such a fashion that it is said the traveller in a railway train may tell, by reading the book, through what part of the country he is passing; and he gives the reasons, founded upon history or local circumstances, for the peculiarities in architecture to be observed. The book is a useful warning against rash generalisations as to the best type of house for a working man.

A well-informed writer shows, in an article in the 'Times' of the 28th ult., that not less than fifty million gallons of water a day might be saved in London 'without withdrawing a drop from any legitimate purpose, public or private, including the watering of plants.' He says: 'The detection of waste is carried out by means of meters placed on the mains, which record automatically the quantity of water passing hour by hour throughout the day and night. The whole area served by a given water supply is mapped out into small districts, each of which is controlled by one of these detective meters. The chart traced by the apparatus shows precisely how much water is used in each of the twenty-four hours. It records in a graphic form and with singular fidelity the daily life of the people. It shows when they get up in the morning, when they go to bed at night, when they wash the tea-things, the children, and the clothes; it shows in a suburban district when the head of the household comes home from the city and starts watering his flowers; it shows when the watering-cart goes round; but, above all, it shows when the water is running away to waste and how much.'

I quote this not to multiply examples of the waste of wealth, but to illustrate the insight which a few figures, such as those recorded by this meter, give us into the lives of the people. How much more does the account-book, a detective meter of every economic action, give us an animated photograph of the family life! Nothing is so calculated to stimulate social sympathy or to suggest questions for consideration. Like a doctor's notes of his patients the facts are not for publication in any form which will reveal the identity of the subject; but when we have enough of them they will be of the highest scientific value. We have at present too few to offer any useful generalisations. All that can be done is to serve as a finger-post to point the road along which there is work to be done.

If nothing has been said about the waste and extravagance of the wealthier classes, it is because economy is with them of less moment. They suffer little or no privation from extravagance, and derive less advantage from checking it than those to whom every little is a help. And so far as much of this waste is concerned, they sin against the light. It is one thing to point out a more excellent way to the unwary, another to preach to those who, seeing the better, follow the worse.

But the expenditure of the working classes is also, from a scientific point of view, vastly more important. Their expenses are more uniform, less disturbed by fantasy, or hospitality, or expensive travel, and will give us more insight into the hitherto inscrutable laws of demand. The time is far removed when any reduction in the cost of living could be successfully made the pretext for a reduction in the rate of wages. The Committee on the Aged Deserving Poor recommends under certain conditions pensions varying with the 'cost of living in the locality.' The same factor, we are told, enters into the adjustment of postmen's wages as between town and town. How are we to know the comparative cost of living without these details of expenditure? How else can we measure with any exactness the progress of civilisation itself? How else can we discover the cohesive force of the family in holding together the structure of society, the mutual succour of young and old, the strong and the infirm or sick, the well-to-do and the victim of accident or ill-luck? To what department soever of economic life we turn our eyes we find live men and women, born into families, living in families, their social happiness and efficiency largely dependent on their family lives, and when we consider how greatly our knowledge and insight into society will be increased by a more intimate acquaintance with the economics of the family, we may well cherish the highest hopes for the future progress of our science. The theory of this subject, at any rate, is not 'complete.' It has not even been begun.

Upon certain aspects of the spending or using of wealth as opposed to the getting of wealth, like the expenditure of central and local governments, it would hardly be proper for me to enlarge. The first is subject to the watchful control of the taxpayer, of Parliament, and of a highly trained civil service; the second to the jealous criticism of the ratepayer and his representative. But there is some social expenditure, like the scandalous multiplication of advertisements (which by a refinement of cruelty give us no rest night or day), which is wicked to a degree. In all these matters of the consumption of wealth, individually and collectively, we are as yet, it must be again repeated, too ignorant of the facts. An unimaginative people as we are, we are fortunately fond enough of travel to have suggestions constantly forced upon us by the different experiences and habits of foreign countries. And we are happy in a neighbour like France, with her literary and social charms and graces, her scientific lucidity and inventiveness, and the contrasts of her social genius to inspire comparisons, and in many respects to set us examples. I have singled out one of her many writers for attention, precisely because of this quality of suggestiveness. Other investigators have, of course, attacked the subject. In Belgium and Switzerland, Germany, Italy and Austria, and the United States, governments and individuals have recently undertaken the preparation of family budgets; but in many respects Le Play's monographs are the first and greatest of all. They yield excellent material, upon which Science, in its various branches, has yet to do work which will benefit mankind in general; and promises especially to benefit the people of this country. The cosmopolitan attitude of the older economists was largely due to their centring their attention upon the problems of exchange. To them the globe was peopled by men like ourselves, producing the fruits of the earth, anxious to exchange them to the greatest mutual advantage, but hindered from doing so by the perversity of national governments. The facts of consumption, at any rate, are local. They are often determined by geology, geography, climate, and occupation; and, however fully we may admit the economic solidarity of the world, and the advantage which one part of it derives from the prosperity of another, yet we may be easily forgiven for thinking that our first duty lies to our own brethren; that our natural work is that which lies at our own doors; that, as the old proverb says, 'the skin is nearer than the shirt.' And we may fairly be excused if we attempt to make our contribution to the welfare of the human family through the improvement of the consumption of wealth and the condition of the people in our own land.

The following Papers were read:—

1. *The Mercantile System of* Laisser Faire. *By* ETHEL R. FARADAY, *M.A.*

The English *laisser faire* school, originally founded on a cosmopolitan theory of economics, occupies at present a position as purely nationalist as that of the mercantile school which it succeeded. This is the effect of a dogmatic insistence on the economic ideal as stated by Cobden, and a resulting indifference towards five recent developments of economic thought: the separation of the science from the art of economics, the definition of the science and of its subject wealth, the humanist philosophy, the imperial idea, and the theory of relativity. The early free-traders, sharing the confusion prevalent fifty years ago between the economic science and art, exaggerated the functions of liberty in both, and were led in consequence to an uncritical identification of individual and cosmopolitan with national interests. They inherited Adam Smith's inclination to confine the idea of wealth to material goods; and by over-estimating, not the importance of material interests, but their influence, exposed themselves to the charge of materialism and selfishness, both individual and national. Cobden himself was not a materialist, and never lost sight of the human element in economics; but his followers have neglected this aspect of his teaching, and have laid a disproportionate stress on those points which circumstances had already obliged him to assert with exceptional force. They have moreover imitated his undiscriminating dislike for imperialism, and, while constantly sacrificing cosmopolitan theory to nationalist practice, have ignored the possibilities of the empire as an economic unit satisfying both nationalist and cosmopolitan ideals. The *laisser faire* school have never advanced beyond the mercantile theory of colonies, and their policy if unchecked would have led, as that of their predecessors did, to disintegration. Their neglect of the imperial idea, as illustrated by their recent insensibility to the injuries inflicted, by a policy of non-interference, on India and the West Indies, may be further explained by their refusal to admit the principle of relativity into the application of economic laws. But the safety and utility of economic, as of other truths, depend on the acknowledgment of their relativity.

2. *On Geometrical Illustrations of the Theory of Rent.*[1]
By Professor J. D. EVERETT, *F.R.S.*

If x denote outlay, inclusive of interest, and y the return which it brings, then $y-x$ will be the surplus which governs rent. Let z stand for $y-x$, and let the curve whose co-ordinates are x, z be plotted, also the curve whose co-ordinates are x, y, the axis of x being in both cases horizontal.

The cultivator aims at making the surplus profit z a maximum. The condition for this is $\frac{dz}{dx}=0$, or $\frac{dy}{dx}=1$; in other words, that a very small increment (positive or negative) of x brings an equal increment of y and leaves z unchanged. For that value of x which makes z a maximum, the tangent to the x, z curve is horizontal, and the tangent to the x, y curve slopes at 45°. For smaller values the tangent to the x, y curve is steeper, and for larger values less steep than 45°. The received theory asserts that the actual rent as settled by competition will be the maximum value of z. More precisely, in view of the practical impossibility of foreseeing what outlay will in a given year be most remunerative, the rent may be taken to be that value of z which makes as near an approach to the maximum as a fairly skilful cultivator will usually attain.

The ordinary mode of graphically illustrating rent is by a curve in which the abscissa x represents outlay, and the ordinate η is such that the integral of ηdx, from $x=0$ to any specified value of the outlay x, represents the return for that outlay. The rent is represented by that portion of the area which lies above a horizontal line drawn through the top of the last ordinate, the last ordinate being that which corresponds to the limit of profitable cultivation. This mode of representation is less simple than either of the two above employed. It also involves the inconvenience of assigning a shape to the early part of the curve—a part which has no definite shape—and the further drawback of representing two comparable things, outlay and return, by two magnitudes which are not comparable, length and area.

3. *On the Use of Galtonian and other Curves to represent Statistics.*
By Professor F. Y. EDGEWORTH.

Comparing different modes of representing statistics of *frequency*, such as the returns which specify the number of persons in a country having each amount of income, the author gives the preference to those formulæ which not only fit the data, but also are recommended by an *a priori* reason. Such a reason is commonly afforded by the phenomena of organic and social life: where a great number of independently varying influences go to the formation of a result, the quantity of that result is apt to vary according to the normal law of 'error' or frequency. The symmetrical curve which is often employed to express that law is but a first approximation, the normal curve of frequency is in general somewhat unsymmetrical. A very unsymmetrical group, indeed such as that which the frequency of incomes of different sizes constitutes, cannot be represented by a normal curve, but it may often be connected therewith by the hypothesis that each observation, though not identical with or proportional to, is yet dependent on a *function* of some attribute which fluctuates according to the normal law.

FRIDAY, SEPTEMBER 15.

The following Papers were read:—

1. *Some Aspects of American Municipal Finance.*
By J. H. HOLLANDER, *Ph.D.*, *Johns Hopkins University.*

The fiscal activities of cities of the United States of 50,000 or more inhabitants have been characterised in the main by, (1) Progressive expenditure, (2) inelastic revenue, (3) increasing funded indebtedness, (4) crude budgetary procedure.

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[1] Published in the *Journal of the Royal Statistical Society*, December 1899.

The problem of expenditure is that of the modern industrial city. Urban growth involves an improvement in the quality, and in, up to a certain point, a more than proportionate increase in the cost of municipal service. It is not only a question of paving and lighting more streets, but of substituting asphalt for rough stones, and electric light for oil lamps.

The essential source of municipal income in the United States has been the general property tax. Inefficiency of administrative machinery and the escape of intangible wealth have combined to render this tax an increasingly rigid form of revenue. Save in the case of cities still undergoing rapid expansion, the taxable basis increases slowly, and increased expenditure necessitates an addition to a burdensome and, not infrequently, an oppressive local rate.

These two conditions—urgency of municipal expenditure and inelasticity of municipal income—have heightened the natural tendency of the American city to the use of large funded loans for the extension of the municipal plant. Stimulated by the high favour of municipal securities as a form of private investment and by the easier terms upon which municipal loans can be negotiated, American cities have shown no hesitation in borrowing upon long time the funds required for desirable improvements properly chargeable to current expenditure, but for which there existed no likelihood of an ordinary budgetary provision.

The budgetary procedure of the American city has been a crude adjustment of a local tax rate to the anticipated expenditure by a variously constituted ways and means committee of the municipal council. The utility of a low tax rate as political capital has commonly resulted in an impossible reduction of departmental estimates (subsequently corrected by extra-budgetary appropriations), or by a deliberate over-estimate of municipal income—with the common result of a floating debt, ultimately funded as a permanent deficit.

The probable tendencies of American municipal finance in the several particulars indicated are: (1) Continued progressive increase in expenditure; (2) a more efficient administration of the general property tax; (3) longer use of sources of local revenue, other than district taxation; (4) relative stability in funded indebtedness; (5) systematisation of budgetary procedure.

2. *Municipal Trading and Profits.* *By* ROBERT DONALD.

There should be no reason to object to Municipal trading, from a commercial point of view, as the figures in a recent Government return show that the average annual profit on Municipal water, gas, and electricity works, markets, tramways, and workmen's dwellings amounts to 4¼ per cent. on the capital invested.

The chief opposition to Municipal trading last Session of Parliament arose with electricity supply. It will be found that Municipalities produce electricity at a lower cost and supply it at lower prices than do companies. A comparison between twenty-one Municipal and twenty-one company undertakings, including in the latter the large London concerns and the companies of Birmingham, Leeds, and Sheffield, where the supply has been recently Municipalised, gives the following result:—

Cost of production per unit—Municipalities, 1·87*d.*; Companies, 2·71*d.*
Average price per unit to consumer—Companies, 5½*d.*; Municipalities, 4½*d.*
Profit on mean capital—Companies, 7½ per cent.; Municipalities, 7¼ per cent.

Thus municipalities produce electricity at ¾*d.* less per unit than companies, sell it at 1*d.* less per unit, and earn only ¼ per cent. less profit.

Municipalities as a rule supply gas of a higher illuminating power than companies and at a lower price. A comparison between a representative number of Municipal and privately managed Gas Works shows that the average price of the Municipal gas is less by 3*d.* per 1,000 cubic feet, the candle power is higher, and the average profit on capital employed only 1 per cent. less than that obtained by companies.

The direct operation of tramways by Corporations has been done under easy conditions as regards capital expenditure, and has at once led to increased traffic.

There has been a readier response to public demands, a reduction of fares, and better treatment of employés—all of which have combined to make Municipal tramways very successful from a business point of view.

Municipal trading compares well with private enterprise. But it is not enough to show profits from Municipal trading, as it is suggested that Municipalities have no business to make profits. These are chiefly the people who would like the profits for themselves. But there are other reasons, based on economical grounds, why the aim of Municipalities should be to provide the cheapest services at cost price rather than seek profit. The system of relieving general local taxation out of the surplus revenues of gas, water, and tramway and other undertakings has been necessary in order to demonstrate the business capacity of Municipal bodies; but the policy is not one which best serves a community. When a town draws profit from gas, water, or electricity supplies, it is simply levying so much direct taxation on the users of these commodities for the benefit of the general community. The consumers might justly say that since the Municipality became the sole providers of gas and electricity, it deprived them of the advantages of competition, and should supply the cheapest possible article.

Whether municipalities should make a profit is left largely to their own discretion. It is becoming the practice not to make trading profits from water supply, and only a small margin of profit is sought on artisans' and labourers' dwellings and lodging houses. The practice of Parliament tends towards restricting profits. Profit from electricity supply works, for instance, is limited to 5 per cent. All surplus above that should be devoted to reducing charges. In Scotland, profit-making in connection with water or gas supplies is rendered impossible by the General Acts, which provide that surpluses go to reduce charges. No town has advanced so far in Municipal organisation as Glasgow, and no town stands higher for the efficiency of its administration or the civic spirit of its citizens; and nowhere else, taken all round, are charges for Municipal services so low; nor has any other town carried out so systematically the policy of little profit.

It will be found that in the towns where the civic spirit is the keenest and healthiest, where Municipal institutions are most largely developed, there the profit sought is least and the administration is the best.

3. *The Single Tax.* *By* WILLIAM SMART, *M.A., LL.D., Adam Smith Professor of Political Economy in the University of Glasgow.*[1]

In the universal division and co-operation of industry by which the national dividend is produced and distributed, as 'at once the net product of and the sole source of payment for all the instruments of production within the country,' the economic position of the Government is this. The Government services, imperial and local, are a part of this dividend, purveyed by a certain class of the citizens just as ordinary goods and services are purveyed by other classes; they are paid for partly by fees, but principally by taxation. This is disguised by the definition of a tax as a 'compulsory contribution;' but, on analysis, the compulsory contribution is seen to be nothing else than a payment for definite services rendered to the citizens generally, the price paid by the individual citizen being, not a competitive price, but an equality of sacrifice price.

The Single Tax, on the other hand, is an outcome of Henry George's theory that the cause of poverty in progressive societies is private property in land. Of the two alternatives, to formally confiscate the land without any compensation or to confiscate its rent, he chose the latter. This would, of course, give the Government an immense revenue, and taxation would be unnecessary.

Evidently this is not a rival system of taxation to ours, as the Impôt Unique might have been, but an alternative plan of confiscation. Instead of the old constitutional connection, by which every citizen has a stake and a voice in the

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[1] The paper was published *in extenso* in the *Glasgow Herald*, September 16.

economy and good management of the Government revenue because he pays annually his due share of it, we have in the Single Tax a method by which the Government acquires an estate of its own by confiscating the property of one class.

4. *The State as Investor.* *By* EDWIN CANNAN, *M.A.*

If an indebted individual has more capital than he is able to use in his particular business, the general rule is that his best investment is repayment of his debts. The same rule applies to a state. So till within recent years it was never doubted that the proper investment of the National Sinking Fund and the Post Office Savings Bank deposits was in the redemption, or (what comes to the same thing) the purchase of Government obligations. But under the conversion scheme of 1888, consols became irredeemable till 1923, and there is now no portion of the funded debt which can be redeemed before 1905. The effect of this, combined with the fall in the market rate of interest, which began not long after 1888, and continued till last year, has been to keep consols and other portions of the funded debt at prices considerably above par. When a stock is temporarily irredeemable and meanwhile above par, the general rule that repayment of debt is the best investment of surplus capital need not be applicable. Whether it is the best or not depends on the magnitude of the premium.

Supposing the premium to be high enough to drive the State to other investments, we have in the obligations of local authorities an excellent security entirely under the control of the State. It has been objected that municipal and county stocks could not be bought by the million without raising the price to a prohibitive height, and this is true. But no such objection applies to lending new capital when it is required. This has already been done to the extent of forty millions, and it might be done to a much larger extent if the minimum rate of interest were slightly reduced and the scale under which higher rates are charged for loans of longer duration were altogether abolished. The scale is defended on the ground that it is desirable to discourage loans for long periods. But as a matter of fact it is not desirable to discourage loans properly authorised for long periods, and the scale does not discourage them.

5. *The Mercantile System.* *By* Professor G. J. STOKES.

The policy of Free-trade receives no support from the analogy either of the individual or of the family. At first sight the collective national expenditure seems more in need of systematic guidance than individual expenditure.

The principles of the Mercantile System may be considered in relation to (1) the end in view; (2) the means employed.

The end in view was the accumulation of money or of the precious metals. Mill's criticisms on the doctrine that the wealth of a country consists in money err in two respects, in the sense in which he regards money as a part of wealth and in that in which he regards other articles of wealth as distinguishable from money. Mill really shares the error of the Mercantile doctrines. The Mercantile doctrine was relatively justified in its aim of creating a reserve of purchasing power in a country. The means employed were attention to the balance of trade. The real citadel of the Free-trade argument consists in the effect on prices of an artificial enlargement of the currency. In consequence of this the Mercantile System defeated itself in seeking to control the balance of trade. If, however, we substitute the policy of accumulating Immaterial Imports for that of the Mercantile System, the arguments in favour of Protection acquire a new significance. In so far as the interest on foreign securities is not accumulated, it is desirable that it should be paid in certain kinds of products. The financial needs of the state fix a lower limit for the accumulation of immaterial imports. The larger the area embraced under our political and financial polity the better is it for the nation and for mankind.

SATURDAY, SEPTEMBER 16.

The following papers were read:—

1. *Agricultural Wages in the United Kingdom from* 1770 *to* 1895.
By A. L. BOWLEY, *M.A.*, *F.S.S.*

The paper completes an investigation of which the preliminary results have been published in the 'Statistical Journal.' The first question dealt with is the relation between nominal weekly wages and annual earnings. The following imaginary budget of receipts shows the nature of the question and is typical:

	s.		£	*s.*
Winter wages	9	for 30 weeks	13	10
Summer wages	11	,, 15 ,,	8	5
Hay Harvest	13	,, 2 ,,	1	6
Corn Harvest	21	,, 5 ,,	5	5
Task work makes up for time lost in bad weather and yields in addition			1	0
Cheap rent, free beer, and smaller perquisites; general average 6*d*. per week			1	6
Annual Income			30	12

Equivalent to 11*s*. 9*d*. per week.

Average of summer and winter weekly rates 10

Excess of weekly earnings over wages, 1*s*. 9*d*. or 17 per cent.

There seems no good reason for holding that this resulting difference of 17 per cent. has altered much in the period.

The method of interpolating figures for dates as to which no direct calculations are available is illustrated by diagram.

The general result is shown in the following tables:

Annual Earnings of Agricultural Labourers.

	England and Wales £	Scotland £	Ireland £	United Kingdom. £
1770	20	9	9	13
1810	41	28	10	34
1830	30	19	8	17
1860	34	36	10	27
1892	40	49	25	37

2. *Note sur la situation agricole d'un canton du Pas-de-Calais. Par un* Membre de la Société d'Économie Sociale de France.

MONDAY, SEPTEMBER 18.

The following Papers were read:—

1. *The Census*, 1901. *By* MISS C. E. COLLET

2. *The Course of Average Wages between* 1790 *and* 1860.
By GEORGE HY. WOOD, *F.S.S.*

The object of this paper is to measure the course of wages, both real and nominal, between 1790 and 1860. Mr. Bowley has measured wages between 1840 and 1891,[1] and the present investigation is in part complementary to Mr. Bowley's work. The method of arrangement, however, is different from his, as he measured wages in industries, whereas wages are in this instance measured in towns. The year 1840 has been taken as 100, and the averages are simple arithmetical averages of the figures collected. Twenty-three towns are selected, and the wages for at least thirty-five separate industries are to be found in the tables on which the calculations are based. The index number so obtained is as follows:—

1790	1795	1800	1805	1810	1816	1820	1824	1831	1840	1845	1850	1855	1860
72	82	93	104	122	115	109	112	103	**100**	99	102	116	116

To solve the problem of real wages it is necessary to have an index number of retail prices, and one has been calculated, being the average course of retail prices in ten large towns corrected by the average cost of articles composing a typical workman's budget of the period 1831. The index number of retail prices and Jevons's Index number of wholesale prices for the same period are:—

—	1790	1795	1800	1805	1810	1816	1820	1824	1831	1840	1845	1850	1855	1860
Index number—Retail prices .	74	101	130	134	140	121	117	102	96	**100**	93	92	102	99
Jevons's number — Wholesale prices	100	134	162	140	163	105	116	101	94	**100**	85	73	92	91

With these numbers as the basis of the calculation, the variations of real wages over the period are:—

—	1790	1795	1800	1805	1810	1816	1820	1824	1831	1840	1845	1850	1855	1860
1 by Index number of retail prices	96	81	71	77	87	94	92	108	108	**100**	106	110	114	116
2 by Jevons's number of wholesale prices	72	61	57	74	75	109	94	111	110	**100**	116	137	126	127

The figures obtained by using Jevons's number are given to show what would have been the variations in purchasing power of wages if prices paid by the wage-earner varied directly with the course of wholesale prices, as compared with what were the actual variations as shown by the index number denoting the course of retail prices. Over the whole period the net gain in real wages was 20 per cent., but the gain denoted by use of Jevons's number is 76 per cent., showing that the use of wholesale price index numbers when calculating real wages, or variations on purchasing power of money wages, is not justifiable, as it does not represent the actual variations on prices paid by the consumer.

3. *The Regulation of Wages by Lists in the Spinning Industry.*

By S. J. CHAPMAN.

The Paper dealt briefly with the following subjects:—

1. The origin and development of lists in the spinning industry.
2. The difference in the structure of the various lists in use, and in the results given by each.
3. The mode of applying the lists.
4. The scope of the lists, possibilities of further development, and the proposed universal list.
5. The adoption of the system of lists in other branches of the cotton industry.

The object of the Paper was to supplement the information about spinning lists already given in the British Association Report on the subject in 1887.

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[1] *Report*, 1898, p. 970.

4. *The Teaching University of London and its Faculty of Economics.*
By Sir PHILIP MAGNUS.

Types of British Universities—Statistics of University Education in Britain and Germany compared—Numbers of Students in several British and German Universities—London and Berlin compared as to population and numbers of University Students—Number of Students for whom London University should provide on basis of population—Difficulties of organising University Education in London—The necessity of a compromise and an Ideal—Graduate and Post Graduate Study—Concentration of teaching effort for advanced study and research—The faculties of the reorganised University—The two new Faculties of Engineering and Economics—Reasons for and against establishing a separate Faculty of Engineering—Meaning of 'Faculty'—The Faculty of Economics—Need of further organisation in the Teaching of Economics—The work of the Faculty—The present School of Economics—The deficiencies of the School as a High School including Commerce—How deficiencies may be supplemented—Suggestions for High School of Economics including Commerce, under directions of University in Imperial Institute—Connection between work of Imperial Institute and of Faculty of Economics—The Economic Faculties of American Universities and what they teach—In what sense the London University should be Local and in what sense Imperial on its teaching side—The classes of Students for whom it should provide—The import of the two new Faculties in connection with University and Professional Teaching—The association of Teaching Institutions with the University—Advantages of its new site.

Statistics of numbers of Day Students receiving University Education in all Faculties (including Medicine) and of Population in Great Britain and Germany.

ENGLAND.

	Students.		Students.
Oxford University	3,402	Victoria (3 Colleges)	1,913
Cambridge University	3,019		

Of whom about 300 are women.

Durham (Newcastle) 300

Colleges.	Students.	Colleges.	Students.
Birmingham (Mason University)	195	Nottingham (University)	248
Bristol (University)	209	Sheffield (University)	77

Of whom about 150 are women.

	Male Students.		Male Students.
London (University College)	704	London (Central Technical College)	230
„ (King's College)	866	„ Hospitals (about)	2,250
„ (Royal College of Science)	200		

Of whom about 530 are preparing for a London Degree.

WALES—*University of, consisting of Colleges at*

	Students.		Students.
Aberystwith	400	Cardiff	459
Bangor	315		

Of whom about 400 are women.

SCOTLAND—*Universities.*

	Students.		Students.
Aberdeen	434	Glasgow	1,953
Edinburgh	2,776	St. Andrew's (including Dundee)	300

Some of whom are women.

Population of England and Wales in	1891	29,002,525
„ „ Scotland	„ 1891	4,025,647
„ „ London	„ 1896	4,433,018

The numbers of Students are taken in nearly all cases from Returns furnished in August last by Registrars of several Colleges, and have been brought into agreement with one another, as far as possible, by reference to Returns in Education Departments' 'Reports from University Colleges, 1898.'

GERMAN EMPIRE—*Universities* (*Session* 1896–7).

	Students.		Students.
Berlin	4,705	Kiel	764
Bonn	1,992	Königsberg	683
Breslau	1,513	Leipzig	3,126
Erlangen	1,153	Marburg	1,049
Freiburg	1,544	Munich	3,706
Giessen	667	Rostock	509
Göttingen	1,195	Strassburg	1,098
Greifswald	834	Tübingen	1,310
Halle	1,635	Würzburg	1,443
Heidelberg	1,322		
Jena	786		31,004

Technical Universities (*Technische Hochschulen*).

	Students.		Students.
Aachen	363	Karlsruhe	996
Berlin	2,954	Munich	1,378
Brunswick	368	Stuttgart	910
Darmstadt	1,178		
Dresden	905		9,856
Hanover	804		

Population of German Empire	52,246,589	(1891)
„ Berlin	1,773,003	„

Population of males between the ages of 15 and 25 (1891):—

England and Wales	2,712,521
Germany	4,497,153

TUESDAY, SEPTEMBER 19.

The following Papers were read:

1. *Increase in Local Rates in England and Wales,* 1891–2 *to* 1896–7.

By MISS HEWART.

	1891–2 £	1896–7 £	Increase £
Metropolitan rates	8,316,298	10,289,755	1,973,457
Urban, Extra-Metropolitan rates	10,108,490	13,721,511	3,613,021
Urban and rural rates	8,209,943	11,025,130	2,815,187
Rural rates	1,809,388	2,431,909	622,521
Total Rates	28,444,119	37,468,305	9,024,186

Average rate in £.

	1891–2		1896–7	
	s.	d.	s.	d.
Metropolitan	5	0·3	5	9
County boroughs, municipal . . .	1	2·9	1	7·8
Non-County boroughs, municipal . .		8·6		10·7
County boroughs, Urban Sanitary . .	2	6·6		11
Non-County boroughs, Urban Sanitary .	2	6·2	2	9·4
Other urban sanitary districts . . .	2	4·5	2	10·2
Rural district councils		1·7		3·0
Total rural		8		11·4

Urban Extra-Metropolitan Rates

	1891–2	1896–7
	£	£
Boroughs, municipal authorities . .	1,426,994	1,990,074
Boroughs, school boards	1,021,993	1,651,941
Urban sanitary authorities . . .	7,658,916	10,079,084
Commissioners of baths, &c. . . .	587	412

2. *Bank Reserves.*[1] *By* George H. Pownall.

System of payment by cheque and clearing an incalculable benefit to our commerce, but needs to be based on ample *cash* reserves. Total deposits, banks United Kingdom, 810,000,000*l* to 820,000,000*l*; offices open, 5,800; cash on hand and money at call and short notice, 227,000,000*l*. Vital distinction between '*cash*' and 'money at call,' and division necessary. Tables 3 and 4 enable us to make division. Fund from which 'cash on hand and money at Bank of England' cannot exceed 77,000,000*l*; 'money at call and short notice,' 100,000,000*l*. But after deductions and adjustments, figures probably are: Total *cash* resources, English banks, 52,000,000*l*; money at call and short notice, or market credits, 125,000,000*l*. Therefore 52,000,000*l* cash total provision for meeting urgent liabilities. But the 52,000,000*l* not all *free* money. Money needed for clearing balances, London, and provincial is necessary till money. Amount needed to meet London clearing balances, 10,000,000*l*; amount needed for provincial clearings unknown. British trade conducted by cheque, clearing, transfer, set off, but *liability* to pay in gold remains.

Bankers' balances needed for clearing cannot be withdrawn. Bank of England has acted on this knowledge in times of crisis by lending all her cash reserves in support of trade while still holding large bankers' balances, needed for clearing. London bankers, agents for country bankers who look to them in time of crisis for cash to fill tills. Times of internal panic—bankers uneasy because their own *cash* provision insufficient. Bank of England keeps the only large store unemployed *cash* in British Isles. Times of crisis or panic, impossible to withdraw money from short loan market or Stock Exchange; pressure falls immediately on Bank of England.

Internal panic means protecting credit at 5,800 points, and foreign withdrawals of gold also to be satisfied.

Preparation for danger by withdrawals from short loan market would produce disaster. Our methods refined to too great an extent. Suspension of Bank Act might satisfy internal panic, but not foreign drain.

Short loan and Stock Exchange markets part of our system of finance—markets permanent, could not be disorganised without creating panic. Position assigned to 'call and short money' in balance-sheets of banks not a prudent one. Two pivots, money market, 'short money,' and Stock Exchange. If *cash* basis, national finance reasonably broad, fear of serious panic minimised—want of

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[1] Published in the *Economic Journal*, September 1899, p. 394.

sufficient basis makes bankers helpless under panic conditions. *Cash* not habitually used in England except for wages. England greatest money market world, slenderest gold basis. 'Short money' not reserve, but means of employment of funds. Crisis 1890, this point recognised by Chancellor of Exchequer as vital. Solidarity of action (1890) induced by Bank of England saved situation. Clearing system masterpiece mechanism, needs cash basis. Bank amalgamations—rise few great institutions—banking on Imperial scale means Imperial responsibilities. London banks hold vast sums, country bankers' money, at 'call and short notice.' Decline of agency system—London office head great system branches takes place of agent. Savings banks no reserves—Government policy a mistaken one—and an additional source of danger to Bank of England and national finance. Do we need larger stock of gold? If so, where should central stock be kept, and do bankers keep a sufficient percentage of loose cash?

England *the free* gold market—effect of foreign demand on—danger from foreign interference with. Responsibilities England unique—preparation to meet responsibilities quite inadequate. Relative position great foreign states. Bank of England and Bank of France in 1890. Danger foreign squeeze. No State bank in England—must adjust our insular system to meet responsibilities by legislation if need be. Varying views of bankers as to responsibility. Suggest the *habitual* holding of a percentage of deposits, say 15 per cent. in Bank of England notes. At present English banks only hold 7 per cent. Suggestions as to form of bank balance-sheets. London bankers' movement *re* cash reserves—committee should include Bank of England. Question of bankers' balances at Bank of England. Effect of the withdrawal of those balances. Costly nature of scheme to work without Bank of England. Competition of Bank of England with other banks—possible State bank. Bank of England agent of Government. Vital point holding of larger percentage of *cash*, and voluntarily may escape legislation. Suggestions for compulsory publication of balance-sheets in special form, penalties for not keeping cash, new habit needs forming. Practical considerations suggest Bank of England notes as reserve, because they are legal tenders—public understand them. Reserves thus kept would show central stock of gold in 'Issue Department' Bank of England—this of international importance, and preserves individuality of banks. Results in millions of such a scheme for establishing central stock of gold and adequate bank reserves. Effect on money market of larger reserves—greater steadiness in rates. Possibilities of our present position of 'unpreparedness,' and points to be aimed at in any measures of reform of present methods. To keep adequate *cash* reserves is a duty to the State.

3. *Indian Currency after the Report of the Commission.*

By HERMANN SCHMIDT.

The monetary enactments passed a few days ago in India may be considered the evolution of the policy adopted in 1893. This policy intended to substitute gold for silver as the money of India. It was adopted on the report of the First Indian Currency Committee of 1892–3. But the Indian Coinage and Paper Currency Act of 1893 was essentially a provisional measure. It left the settlement of a permanent rate of exchange between gold and the silver rupee in abeyance. Gold was not yet made legal tender. This defect has now been remedied upon another exhaustive investigation by a new Currency Committee. India has now a gold standard in the sense that a parity has been fixed between gold and silver, and that the mints are open to the coinage of gold and closed to the coinage of silver. But the success of the year's work is still as much in doubt as was that of the measures of 1893.

4. *The Silver Question in relation to British Trade.*
By JOHN M. MACDONALD.

WEDNESDAY, SEPTEMBER 20.

The following Papers were read:—

1. *The Results of Recent Poor Law Reform.*
By HAROLD E. MOORE, *F.S.I.*

Within the last ten years, various experiments have been made by different Boards of Guardians with approval of the Local Government Board, the object in view being either (*a*) to secure better results to the persons helped, or (*b*) to effect economy in cost of poor relief.

Four of these experiments, the results of which seem worthy of notice, are (*a*) attempts at classification of workhouse inmates; (*b*) improvements in the treatment of children who are dependent upon the Poor Rate for support, education and training; (*c*) the working of land by Boards of Guardians; and (*d*) contributing from Poor Law Funds to organisations under the control of voluntary committees, who, on such sums being contributed, receive those who have been able-bodied inmates of workhouses into the institutions under their control. In summing up the results gained by these various experiments, it is suggested as to (*a*), that classification is difficult, and not likely to be capable of great extension in existing workhouses; as to (*b*), that the treatment of children by 'village communities,' 'boarding out,' or 'scattered homes' has shown beneficial results in comparison with retaining them in workhouses or barrack schools, the 'scattered home' system having proved most desirable under usual conditions; as to (*c*), that the working of farms, as shown by the results at Sheffield and elsewhere, has been found distinctly profitable and beneficial where proper conditions have been observed in choice and management of property; as to (*d*), that much good has been effected where the institutions so assisted have been farm labour colonies, of such a character as those now in operation at Lingfield in Surrey, under the control of the Christian Union for Social Service, near Dumfries in Scotland, at Hadleigh in Essex, and elsewhere. It would seem that by reason of such farms not only has the cost of poor relief been lessened, but men restarted in an independent life.

Having regard to these results, it is suggested that the principle of the Bill submitted to Parliament last Session for creation of Aged People's Homes by Poor Law authorities should be supported, as affording a most desirable means of classification; and that further extension of the system of contributing towards the support of Farm Labour Colonies, under the control of voluntary committees, should be encouraged.

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2. *Old Age Pensions in Denmark: their Influence on Thrift and Pauperism.*
By Professor A. W. FLUX, *M.A.*

The paper deals with some of the results of the establishment of a system of Old Age Relief in Denmark. The allegation that the line between pauper and pensioner would become indistinguishable is contradicted by experience. The statement that deposits in the savings banks are falling off since the establishment of the pension system (in 1891) is not supported by the figures of deposits. These increased by 25·4 per cent. between 1882 and 1887; by 21·8 per cent. between 1887 and 1892, and by 25·0 per cent. between 1892 and 1897.

With reference to pauperism, the following figures illustrate its progress in Copenhagen:

Average number of	1886	1892	1898
Indoor Paupers	2,820	2,631	2,304
Outdoor Paupers . . .	5,194	6,889	5,905
Boarded-out Children . . .	801	768	777
Pauper Lunatics	638	729	794
Hospital Patients at the public expense	580	549	526
Total	10,033	11,566	10,306
Cost of pauperism . . .	£90,443	£109,175	£108,478

The cost to Copenhagen of Old Age Relief was 25,720*l.* in 1898, and at the end of that year there were 5,838 pensioners with 1,378 dependents. The population was estimated at 349,000 in the middle of the year.

Self-help is now directed to maintaining the qualifying independence of the poor-law for ten years, rather than vanishing. The undesirable results which have manifested themselves are almost all traceable to the lack of fixity in the amount of relief granted.

SECTION G.—MECHANICAL SCIENCE.

PRESIDENT OF THE SECTION—SIR W. H. WHITE, K.C.B., SC.D., LL.D., F.R.S.

THURSDAY, SEPTEMBER 14.

The President delivered the following Address:—

IN this Address it is proposed to review briefly the characteristic features of the progress made in steam navigation; to glance at the principal causes of advance in the speeds of steamships and in the lengths of the voyages on which such vessels can be successfully employed; and to indicate how the experience and achievement of the last sixty years bear upon the prospects of further advance.

There is reason to hope that this choice of subject is not inappropriate. From the beginning of steam navigation the British Association in its corporate capacity, by the appointment of Special Committees, and by the action of individual members, has greatly assisted the scientific treatment of steamship design. Valuable contributions bearing on the resistance offered by water to the motion of ships, the conduct and analysis of the results of steamship trials, the efficiency of propellers, and cognate subjects have been published in the Reports of the Association. Many of these have largely influenced practice, and most of them may be claimed as the work of this Section.

On this occasion no attempt will be made either to summarise or appraise the work that has been done. It must suffice to mention the names of three men to whom naval architects are deeply indebted, and whose labours are ended—Scott Russell, Rankine, and William Froude. Each of them did good work, but to Froude we owe the device and application of the method of model experiment with ships and propellers, by means of which the design of vessels of novel types and unprecedented speeds can now be undertaken with greater confidence than heretofore.

As speeds increase, each succeeding step in the ascending scale becomes more difficult, and the rate of increase in the power to be developed rapidly augments. Looking back on what has been achieved, it is impossible to overrate the courage and skill displayed by the pioneers of steam navigation, who had at first to face the unknown, and always to depend almost entirely on experience gained with actual ships, when they undertook the production of swifter vessels. Their successors of the present day have equal need to make a thorough study of the performances of steamships both in smooth water and at sea. In many ways they have to face greater difficulties than their predecessors, as ships increase in size and speed. On the other hand, they have the accumulated experience of sixty years to draw upon, the benefit of improved methods of trials of steamships, the advantage of scientific procedure in the record and analysis of such trials, and the assistance of model experiments.

Steamship design to be successful must always be based on experiment and experience as well as on scientific principles and processes. It involves problems of endless variety and great complexity. The services to be performed by steamships differ in character, and demand the production of many distinct types of ships and propelling apparatus. In all these types, however, there is one common requirement—the attainment of a specified speed. And in all types there has been a continuous demand for higher speed.

Stated broadly, the task set before the naval architect in the design of any steamship is to fulfil certain conditions of speed in a ship which shall not merely carry fuel sufficient to traverse a specified distance at that speed, but which shall carry a specified load on a limited draught of water. Speed, load, power, and fuel supply are all related; the two last have to be determined in each case. In some instances other limiting conditions are imposed affecting length, breadth, or depth. In all cases there are three separate efficiencies to be considered: those of the ship, as influenced by her form; of the propelling apparatus, including the generation of steam in the boilers and its utilisation in the engines; and of the propellers. Besides these considerations, the designer has to take account of the materials and structural arrangements which will best secure the association of lightness with strength in the hull of the vessel. He must select those types of engines and boilers best adapted for the service proposed. Here the choice must be influenced by the length of the voyage, as well as the exposure it may involve to storm and stress. Obviously the conditions to be fulfilled in an ocean-going passenger steamer of the highest speed, and in a cross-Channel steamer designed to make short runs at high speed in comparatively sheltered waters, must be radically different. And so must be the conditions in a swift sea-going cruiser of large size and great coal endurance, from those best adapted for a torpedo boat or destroyer. There is, in fact, no general rule applicable to all classes of steamships: each must be considered and dealt with independently, in the light of the latest experience and improvements. For merchant ships there is always the commercial consideration—Will it pay? For warships there is the corresponding inquiry—Will the cost be justified by the fighting power and efficiency?

Characteristics of Progress in Steam Navigation.

Looking at the results so far attained, it may be said that progress in steam navigation has been marked by the following characteristics:—

1. Growth in dimensions and weights of ships, and large increase in engine-power, as speeds have been raised.
2. Improvements in marine engineering accompanying increase of steam pressure. Economy of fuel and reduction in the weight of propelling apparatus in proportion to the power developed.
3. Improvements in the materials used in shipbuilding; better structural arrangements; relatively lighter hulls and larger carrying power.
4. Improvements in form, leading to diminished resistance and economy of power expended in propulsion.

These general statements represent well-known facts—so familiar, indeed, that their full significance is often overlooked. It would be easy to multiply illustrations, but only a few representative cases will be taken.

Transatlantic Passenger Steamers.

The Transatlantic service naturally comes first. It is a simple case, in that the distance to be covered has remained practically the same, and that for most of the swift passenger steamers cargo-carrying capacity is not a very important factor in the design.

In 1840 the Cunard steamship *Britannia,* built of wood, propelled by paddle-wheels, maintained a sea-speed of about 8½ knots. Her steam pressure was 12 lbs. per square inch. She was 207 feet long, about 2,000 tons in displacement, her engines developed about 750-horse power, and her coal consumption was about 40 tons per day, nearly 5 lbs. of coal per indicated horse-power per hour. She had a full spread of sail.

In 1871 the White Star steamship *Oceanic* (first of that name) occupied a leading position. She was iron-built, propelled by a screw, and maintained a sea-speed of about 14½ knots. The steam pressure was 65 lbs. per square inch, and the engines were on the compound principle. She was 420 feet long, about 7,200 tons in displacement, her engines developed 3,000-horse power, and she burnt about 65 tons of coal per day, or about 2 lbs. per indicated horse-power per hour. She carried a considerable spread of sail.

In 1889 the White Star steamer *Teutonic* appeared, propelled by twin screws and practically with no sail-power. She is steel-built, and maintains a sea-speed of about 20 knots. The steam pressure is 180 lbs. per square inch, and the engines are on the triple expansion principle. She is about 565 feet long, 16,000 tons displacement, 17,000-horse power indicated, with a coal consumption of about 300 tons a day, or from 1·6 to 1·7 lbs. per indicated horse-power per hour.

In 1894 the Cunard steamship *Campania* began her service, with triple expansion engines, twin screws, and no sail-power. She is about 600 feet long, 20,000 tons displacement, develops about 28,000-horse power at full speed of 22 knots, and burns about 500 tons of coal per day.

The new *Oceanic*, of the White Star Line, is just beginning her work. She is of still larger dimensions, being 685 feet in length and over 25,000 tons displacement. From the authoritative statements made, it appears that she is not intended to exceed 22 knots in speed, and that the increase in size is to be largely utilised in additional carrying power.

The latest German steamers for the Transatlantic service are also notable. A speed of 22½ knots has been maintained by the *Kaiser Wilhelm der Grosse*, which is 25 feet longer than the *Campania*. Two still larger steamers are now building. The *Deutschland* is 660 feet long and 23,000 tons displacement; her engines are to be of 33,000-horse power, and it is estimated she will average 23 knots. The other vessel is said to be 700 feet long, and her engines are to develop 36,000-horse power, giving an estimated speed of 23½ knots. All these vessels have steel hulls and twin screws. It will be noted that to gain about three knots an hour nearly 50 per cent. will have been added to the displacement of the *Teutonic*, the engine-power and coal consumption will be doubled, and the cost increased proportionately.

Sixty years of continuous effort and strenuous competition on this great 'ocean ferry' may be summarised in the following statement. Speed has been increased from 8½ to 22½ knots: the time on the voyage has been reduced to about 38 per cent. of what it was in 1840. Ships have been more than trebled in length, about doubled in breadth, and increased tenfold in displacement. The number of passengers carried by a steamship has been increased from about 100 to nearly 2,000. The engine-power has been made forty times as great. The ratio of horse-power to the weight driven has been increased fourfold. The rate of coal consumption (measured per horse-power per hour) is now only about one-third what it was in 1840. To drive 2,000 tons weight across the Atlantic at a speed of 8½ knots, about 550 tons of coal were then burnt: now, to drive 20,000 tons across at 22 knots, about 3,000 tons of coal are burnt. With the low pressure of steam and heavy slow-moving paddle-engines of 1840, each ton weight of machinery, boilers, &c., produced only about 2-horse power for continuous working at sea. With modern twin-screw engines and high steam pressure, each ton weight of propelling apparatus produces from 6- to 7-horse power. Had the old rate of coal consumption continued, instead of 3,000 tons of coal, 9,000 tons would have been required for a voyage at 22 knots. Had the engines been proportionately as heavy as those in use sixty years ago, they would have weighed about 14,000 tons. In other words, machinery, boilers, and coals would have exceeded in weight the total weight of the *Campania* as she floats to-day. There could not be a more striking illustration than this of the close relation between improvements in marine engineering and the development of steam navigation at high speeds.

Equally true is it that this development could not have been accomplished but for the use of improved materials and structural arrangements. Wood, as the principal material for the hulls of high-powered swift steamers, imposed limits upon dimensions, proportions, and powers which would have been a bar to progress. The use of iron, and later of steel, removed those limits. The percentage of the total displacement devoted to hull in a modern Atlantic liner of the largest size is not much greater than was the corresponding percentage in the wood-built *Britannia* of 1840, of one-third the length and one-tenth the total weight.

Nor must it be overlooked that with increase in dimensions have come considerable improvements in *form*, favouring economy in propulsion. This is distinct from the economy resulting from increase in *size*, which Brunel appreciated thoroughly half a century ago when he designed the *Great Britain* and the *Great Eastern*. The importance of a due relation between the lengths of the 'entrance and run' of steamships and their intended maximum speeds, and the advantages of greater length and fineness of form as speeds are increased, were strongly insisted upon by Scott Russell and Froude. Naval architects, as a matter of course, now act upon the principle, so far as other conditions permit. For it must never be forgotten that economy of propulsion is only one of many desiderata which must be kept in view in steamship design. Structural weight and strength, seaworthiness and stability, all claim attention, and may necessitate modifications in dimensions and form which do not favour the maximum economy of propulsion.

Swift Passenger Steamers for Long Voyages.

Changes similar to those described for the Transatlantic service have been in progress on all the great lines of ocean traffic. In many instances increase in size has been due not only to increase in speed, but to enlarged carrying power and the extension of the lengths of voyages. No distance is now found too great for the successful working of steamships, and the sailing fleet is rapidly diminishing in importance. So far as long-distance steaming is concerned, the most potent factor has undoubtedly been the marvellous economy of fuel that has resulted from higher steam pressures and greater expansion. In all cases, however, advances have been made possible not merely by economy of fuel, but by improvements in form, structure, and propelling apparatus, and by increased dimensions.

Did time permit, this might be illustrated by many interesting facts drawn from the records of the great steamship companies which perform the services to the Far East, Australia, South America, and the Pacific. As this is not possible, I must be content with a brief statement regarding the development of the fleet of the Peninsular and Oriental Company.

The paddle steamer *William Fawcett* of 1829 was about 75 feet long, 200 tons displacement, of 60 nominal horse-power (probably about 120 indicated horse-power), and in favourable weather steamed at a speed of 8 knots. Her hull was of wood, and, like all the steamers of that date, she had considerable sail-power.

In 1853 the *Himalaya* iron-built screw steamer of this line was described as 'of larger dimensions than any then afloat, and of extraordinary speed.' She was about 340 feet long, over 4,000 tons load displacement, 2,000 indicated horse-power on trial, with an average sea-speed of about 12 knots. The steam pressure was 14 lbs. per square inch, and the daily coal consumption about 70 tons. This vessel was transferred to the Royal Navy and did good service as a troopship for forty years.

In 1893 another *Himalaya* was added to the company's fleet. She was steel-built, nearly 470 feet long and 12,000 tons load displacement, with over 8,000 indicated horse-power and a capability to sustain 17 to 18 knots at sea, on a daily consumption of about 140 tons of coal. The steam pressure is 160 lbs. per square inch, and the engines are of the triple expansion type.

Comparing the two *Himalayas*, it will be seen that in forty years the length has been increased about 40 per cent., displacement trebled, horse-power quadrupled, and speed increased about 50 per cent. The proportion of horse-power to displacement has only been increased as three to four, enlarged dimensions having secured relative economy in propulsion. The rate of coal consumption has been probably reduced to about one-third of that in the earlier ship.

The latest steamers of the line are of still larger dimensions, being 500 feet long and of proportionately greater displacement. It is stated that the *Himalaya* of 1853 cost 132,000*l.* complete for sea; the corresponding outlay on her successors is not published, but it is probably twice as great.

On the service to the Cape similar developments have taken place. Forty years ago vessels less than 200 feet long and about 7 knots performed the service, whereas the latest additions to the fleets exceed 500 feet in length, and can, if required, be driven at 17 to 18 knots, ranking in size and power next to the great Transatlantic liners.

Commercial considerations necessarily regulate what is undertaken in the construction of merchant steamers, including the swift vessels employed in the conveyance of passengers and mails. The investment of 600,000*l.* to 700,000*l.* in a single vessel like a great Transatlantic liner is obviously a serious matter for private owners; and even the investment of half that amount in a steamer of less dimensions and speed is not to be lightly undertaken. It is a significant fact that, whereas fifteen years ago nearly all the largest and swiftest ocean steamers were British built and owned, at the present time there is serious competition in this class by German, American, and French companies. It is alleged that this change has resulted from the relatively large subsidies paid by foreign Governments to the owners of swift steamers; and that British owners, being handicapped in this way, cannot continue the competition in size and speed on equal terms unless similarly assisted. This is not the place to enter into any discussion of such matters, but they obviously involve greater considerations than the profit of shipowners, and have a bearing on the naval defence of the Empire. In 1887 the Government recognised this fact, and made arrangements for the subvention and armament of a number of the best mercantile steamships for use as auxiliary cruisers. Since then other nations have adopted the policy, and given such encouragement to their shipowners that the numbers of swift steamers suitable for employment as cruisers have been largely increased. Not long since the First Lord of the Admiralty announced to Parliament that the whole subject was again under consideration.

Cargo and Passenger Steamers.

Cargo steamers, no less than passenger steamers, have been affected by the improvements mentioned. Remarkable developments have occurred recently not merely in the purely cargo-carrier, but in the construction of vessels of large size and good speed carrying very great weights of cargo and considerable numbers of passengers. The much-decried 'ocean tramp' of the present day exceeds in speed the passenger and mail steamer of fifty years ago. Within ten years vessels in which cargo-carrying is the chief element of commercial success have been increased in length from 300 or 400 feet to 500 or 600 feet; in gross register tonnage from 5,000 to over 13,000 tons; and in speed from 10 or 12 knots to 15 or 16 knots. Vessels are now building for the Atlantic service which can carry 12,000 to 13,000 tons deadweight, in addition to passengers, while possessing a sea-speed as high as that of the swiftest mail steamers afloat in 1880. Other vessels of large carrying power and good speed are running on much longer voyages, such as to the Cape and Australia. In order to work these ships successfully very complete organisation is necessary for the collection, embarcation, and discharge of cargo. The enterprise and skill of shipowners have proved equal to this new departure, as they have in all other developments of steamships.

How much further progress will be made in the sizes and speeds of these mixed cargo and passenger steamers cannot be foreseen. The limits will be fixed by commercial considerations, and not by the capability of the shipbuilder.

In passing, it may be noted that while the lengths and breadths of steamships have been greatly increased, there has been but a moderate increase in draught.

Draught of water is, of course, practically determined by the depths available in the ports and docks frequented, or in the Suez Canal for vessels trading to the East. From the naval architect's point of view, increase in draught is most desirable as favouring increase of carrying power and economy of propulsion. This fact has been strongly represented by shipowners and ship-designers, and not without result. The responsible authorities of many of the principal ports and of the Suez Canal have taken action towards giving greater depth.

Other changes have become necessary on the part of dock and port authorities in consequence of the progress made in shipbuilding. Docks and dock-entrances have had to be increased in size, more powerful lifting appliances provided, and large expenditure incurred. There is no escape from these changes if the trade of a port is to be maintained. The chief lesson to be learnt from past experience is that when works of this character are planned it is wise to provide a large margin beyond the requirements of existing ships.

Cross-Channel Steamers.

The conditions to be fulfilled in vessels designed to steam at high speed for limited periods differ essentially from those holding good in ocean-going steamers. None the less interest attaches, however, to cross-Channel steamers, and in no class has more notable progress been made. It is much to be desired that at this meeting some competent authority should have presented to the Association an epitome of the history of the steam packet service between Dover and the Continent. I cannot attempt it. So far as I am informed, the first steamer was placed on this route in 1821, was of 90 tons burden, 30-horse power nominal, and maintained a speed of 7 to 8 knots. She was built by Denny of Dumbarton, engined by David Napier, and named the *Rob Roy*. It is interesting to note that the lineal successors of the builder of this pioneer vessel have produced some of the most recent and swiftest additions to the cross-Channel service.

In 1861–2 a notable advance was made by the building of vessels which were then remarkable for structure and speed, although small and slow when compared with vessels now running. Their designers realised that lightness of hull was of supreme importance, and with great trouble and expense obtained steel of suitable quality. The machinery was of special design and relatively light for the power developed. A small weight of coal and cargo had to be carried, and the draught of water was kept to about 7 feet. Under then existing conditions it was a veritable triumph to attain speeds of 15 to 16 knots in vessels only 190 feet long, less than 25 feet broad, and under 350 tons in displacement. To raise the trial speed to 20 or 21 knots in later vessels performing the same service, whose design includes the improvements of a quarter of a century, it has been found necessary to adopt lengths exceeding 320 feet and breadths of about 35 feet, with engines developing 4,500 to 6,000 indicated horse-power, and with very great increase in coal consumption and cost. On other cross-Channel services between Dover and the Continent still larger and more powerful paddle-steamers are employed.

Another interesting contrast is to be found in the comparison of the steamers running between Holyhead and Kingstown in 1860 and at the present time. The *Leinster* of 1860 was 328 feet long, 35 feet broad, and rather less than 13 feet draught. Her trial displacement was under 2,000 tons, and with 4,750 horse-power she made 17¾ knots. She had a steam pressure of 25 lbs. per square inch; and was propelled by paddle wheels driven by slow-moving engines of long stroke. Her successor of 1896 is about 30 feet greater length, 6½ feet greater breadth, and about 10 per cent. greater displacement. The steam pressure is 170 lbs. per square inch. Forced draught is used in the stokeholds. Twin screws are adopted, driven by quick-running vertical engines of the triple expansion type. Very great economy of coal consumption is thus secured as compared with the earlier vessel, and much lighter propelling apparatus in proportion to the power, which is from 8,000- to 9,000-horse power at the full speed of 23 knots. The hull is built of steel, and is proportionately lighter.

This is a typical case, and illustrates the effect of improvements in shipbuilding and engineering in thirty-five years. The later ship probably requires to carry no greater load of coal than, if so great as, her predecessor, although her engine-power is nearly double. The weight devoted to propelling machinery and boilers is probably not so great. Thanks to the use of steel instead of iron, and to improved structural arrangements, the weight of hull is reduced in comparison with dimensions, and a longer ship is produced better adapted to the higher speed. Messrs. Laird of Birkenhead, who built three of the *Leinster* class forty years ago, and have built all the new vessels, are to be congratulated on their complete success.

Between such vessels designed for short runs at high speed and requiring therefore to carry little coal, while the load carried exclusive of coal is trifling, and an ocean-going steamer of the same average speed designed to make passages of 3,000 miles, there can obviously be little in common. But equal technical skill is required to secure the efficient performance of both services. In the cross-Channel vessel, running from port to port, and under constant observation, conditions of working in engine and boiler rooms, as well as relative lightness in scantlings of hull, can be accepted, which would be impossible of application in a sea-going ship. These circumstances in association with the small load carried explain the apparent gain in speed of the smaller vessel in relation to her dimensions.

Increase in Size and Speed of Warships.

Turning from sea-going ships of the mercantile marine to warships, one finds equally notable facts in regard to increase in speed, associated with enlargement in dimensions and advance in propelling apparatus, materials of construction, structural arrangements, and form.

Up to 1860 a measured-mile speed of 12 to 13 knots was considered sufficient for battleships and the largest classes of cruisers. All these vessels possessed good sail-power and used it freely as an auxiliary to steam, or as an alternative when cruising or making passages.

When armoured battleships were built (1859) the speeds on measured-mile trials were raised to 14 or 14½ knots, and so remained for about twenty years. Since 1880 the speeds of battleships have been gradually increased, and in the latest types the measured-mile speed required is 19 knots.

Up to 1870 the corresponding speeds in cruisers ranged from 15 to 16 knots. Ten years later the maximum speeds were 18 to 18½ knots in a few vessels. Since then trial speeds of 20 to 23 knots have been attained or are contemplated.

There is, of course, a radical distinction between these measured-mile performances of warships and the average sea-speeds of merchant steamers above described. But for purposes of comparison between warships of different dates, measured mile trials may fairly be taken as the standard. For long-distance steaming the power developed would necessarily be much below that obtained for short periods, and with everything at its best. This is frankly recognised by all who are conversant with the warship design, and fully allowed for in estimates of sea-speeds. On the other hand, it is possible to point to sea trials made with recent types where relatively high speeds have been maintained for long periods. For example, the battleship *Royal Sovereign* has maintained an average speed of 15 knots from Plymouth to Gibraltar, and the *Renown* has maintained an equal speed from Bermuda to Spithead. As instances of good steaming by cruisers, reference may be made to 60-hour trials with the *Terrible* when she averaged over 20 knots, and to the run home from Gibraltar to the Nore by the *Diadem* when she exceeded 19 knots. Vessels of the *Pelorus* class of only 2,100 tons displacement have made long runs at sea averaging over 17 knots. Results such as these represent a substantial advance in speed of Her Majesty's ships in recent years.

Similar progress has been made in foreign warships built abroad as well as in this country. It is not proposed to give any facts for these vessels, or to compare them with results obtained by similar classes of ships in the Royal Navy. Apart from full knowledge of the conditions under which speed trials are made, a mere statement of speeds attained is of no service. One requires to be informed accurately respecting the duration of the trial, the manner in which engines and boilers are worked, the extent to which boilers are 'forced,' or the proportion of heating surface to power indicated, the care taken to eliminate the influence of tide or current, the mode in which the observations of speed are made, and other details, before any fair or exact comparison is possible between ships. For present purposes, therefore, it is preferable to confine the illustrations of increase in speed in warships to results obtained under Admiralty conditions, and which are fairly comparable.

A great increase in size has accompanied this increase in speed, but it has resulted from other changes in modern types, as well as from the rise in speed. Modern battleships are of 13,000 to 15,000 tons, and modern cruisers of 10,000 to 14,000 tons, not merely because they are faster than their predecessors, but because they have greater powers of offence and defence and possess greater coal endurance. Only a detailed analysis, which cannot now be attempted, could show what is the actual influence of these several changes upon size and cost, and how greatly the improvements made in marine engineering and shipbuilding have tended to keep down the growth in dimensions consequent on increase in load carried, speed attained, and distance traversed.

It will be noted also that, large as are the dimensions of many classes of modern warships, they are all smaller in length and displacement than the largest mercantile steamers above described. There is no doubt a popular belief that the contrary is true, and that warships exceed merchant ships in tonnage This arises from the fact that merchant ships are ordinarily described not by their displacement tonnage, but by their 'registered tonnage,' which is far less than their displacement. As a matter of fact, the largest battleships are only of about two-thirds the displacement of the largest passenger steamers, and from 200 to 300 feet shorter. The largest cruisers are from 100 to 200 feet shorter than the largest passenger steamers, and about 60 per cent. of their displacement. In breadth the warships exceed the largest merchant steamers by 5 to 10 feet. This difference in form and proportions is the result of radical differences in the vertical distribution of weights carried, and is essential to the proper stability of the warships. Here we find an illustration of the general principle underlying all ship-designing. In selecting the forms and proportions of a new ship, considerations of economical propulsion cannot stand alone. They must be associated with other considerations, such as stability, protection, and manœuvring power, and in the final result economy of propulsion may have to be sacrificed, to some extent, in order to secure other essential qualities.

Advantages of Increased Dimensions.

Before passing on, it may be interesting to illustrate the gain in economy of propulsion resulting from increase in dimensions by means of the following table, which gives particulars of a number of typical cruisers, all of comparatively recent design:—

—	No. 1	No. 2	No. 3	No. 4	No. 5
Length (feet)	280	300	360	435	500
Breadth (feet)	35	43	60	69	71
Mean draught (feet) . . .	13	16½	23¾	24½	26¼
Displacement (tons) . . .	1,800	3,400	7,400	11,000	14,200
Indicated horse-power for 20 knots	6,000	9,000	11,000	14,000	15,500
Indicated horse-power per ton of displacement	3·33	2·65	1·48	1·27	1·09

The figures given are the results of actual trials, and embody therefore the efficiencies of propelling machinery, propellers, and forms of the individual ships. Even so they are instructive. Comparing the first and last, for example, it will be seen that, while the displacement is increased nearly *eightfold,* the power for

20 knots is only increased about 2·6 times. If the same types of engines and boilers had been adopted in these two vessels—which was not the case, of course—the weights of propelling apparatus and coal for a given distance would have been proportional to the respective powers; that is to say, the larger vessel would have been equipped with only 2·6 times the weight carried by the smaller. On the other hand, roughly speaking, the *disposable weights*, after providing for hulls and fittings in these two vessels, might be considered to be proportional to their displacements. As a matter of fact, this assumption is distinctly in favour of the smaller ship. Adopting it, the larger vessel would have about *eight* times the disposable weight of the smaller; while the demand for propelling apparatus and fuel would be only *2·6 times* that of the smaller vessel. There would therefore be an enormous margin of carrying power in comparison with displacement in the larger vessel. This might be devoted, and in fact was devoted, partly to the attainment of a speed considerably exceeding 20 knots (which was a maximum for the smaller vessel), partly to increased coal endurance, and partly to protection and armament.

Another interesting comparison may be made between vessels Nos. 4 and 5 in the preceding table, by tracing the growth in power necessary to drive the vessels at speeds ranging from 10 knots up to 22 knots.

—	No. 4	No. 5
10 knots	1,500-horse-power	1,800-horse-power
12 „	2,500 „ „	3,100 „ „
14 „	4,000 „ „	5,000 „ „
16 „	6,000 „ „	7,500 „ „
18 „	9,000 „ „	11,000 „ „
20 „	14,000 „ „	15,500 „ „
22 „	23,000 „ „	23,000 „ „

It will be noted that up to the speed of 18 knots there is a fairly constant ratio between the powers required to drive the two ships. As the speeds are increased the larger ship gains, and at 22 knots the same power is required in both ships. The smaller vessel, as a matter of fact, was designed for a maximum speed of 20½ knots, and the larger for 22 knots. Unless other qualities had been sacrificed, neither space nor weight could have been found in the smaller vessel for machinery and coals corresponding to 22 knots. The figures are interesting, however, as illustrations of the principle that economy of propulsion is favoured by increase in dimensions as speeds are raised.

Going a step further, it may be assumed that in unsheathed cruisers of this class about 40 per cent. of the displacement will be required for the hull and fittings, so that the balance or 'disposable weight' would be about 60 per cent.; say 6,600 tons for the smaller vessel, and 8,500 tons for the larger, a gain of nearly 2,000 tons for the latter. If the speed of 22 knots were secured in both ships, with machinery and boilers of the same type, the larger ship would therefore have about 2,000 tons greater weight available for coals, armament, armour, and equipment.

These illustrations of well-known principles have been given simply for the assistance of those not familiar with the subject, and they need not be carried further. More general treatment of the subject, based on experimental and theoretical investigation, will be found in text-books of naval architecture, but would be out of place in this Address.

Swift Torpedo Vessels.

Torpedo flotillas are comparatively recent additions to war fleets. The first torpedo boat was built by Mr. Thornycroft for the Norwegian Navy in 1873, and the same gentleman built the first torpedo boat for the Royal Navy in 1877. The construction of the larger class, known as 'torpedo-boat destroyers,' dates from 1893. These various classes furnish some of the most notable examples extant of the attainment of extraordinarily high speeds, for short periods and in smooth water, by vessels of small dimensions. Their qualities and performances, therefore, merit examination.

Mr. Thornycroft may justly be considered the pioneer in this class of work. Greatly impressed by the combination of lightness and power embodied in railway locomotives, Mr. Thornycroft applied similar principles to the propulsion of small boats, and obtained remarkably high speeds. His work became more widely known when the results were published of a series of trials, conducted in 1872 by Sir Frederick Bramwell on a small vessel named the *Miranda.* She was only 45 feet long and weighed 4 tons, yet she exceeded 16 knots on trial. The Norwegian torpedo boat built in 1873 was 57 feet long, 7½ tons, and of 15 knots; the first English torpedo boat of 1877 was 81 feet long, 29 tons, and attained 18½ knots.

Mr. Yarrow also undertook the construction of small swift vessels at a very early date, and has greatly distinguished himself throughout the development of the torpedo flotilla. Messrs. White, of Cowes, previously well known as builders of steamboats for use on board ships, extended their operations to the construction of torpedo boats. These three firms for a considerable time practically monopolised this special class of work in this country. Abroad they had able competitors in Normand in France, Schichau in Germany, and Herreshoff in the United States. Keen competition led to successive improvements and rapid rise in speed. During the last six years the demand for a fleet of about 100 destroyers, to be built in the shortest possible time, involved the necessity for increasing the sources of supply. At the invitation of the Admiralty, a considerable number of the leading shipbuilding and engineering firms have undertaken and successfully carried through the construction of destroyers varying from 26 to 33 knots in speed, although the work was necessarily of a novel character, involving many difficulties.

As the speeds of torpedo vessels have risen, so have their dimensions increased. Within the class the law shown to hold good in larger vessels applies equally. In 1877 a first-class torpedo boat was 81 feet long, under 30 tons weight, developed 400 horse-power, and steamed 18½ knots. Ten years later the corresponding class of boat was 135 feet long, 125 tons weight, developed 1,500 horse-power, and steamed 23 knots. In 1897 it had grown to 150 feet in length, 140 to 150 tons, 2,000 horse-power, and 26 knots.

Destroyers are not yet of seven years' standing, but they come under the rule. The first examples (1893) were 180 feet long, 240 tons, 4,000 horse-power, and 26 to 27 knots. They were followed by 30-knot vessels, 200 to 210 feet long, 280 to 300 tons, 5,500 to 6,000 horse-power. Vessels now in construction are to attain 32 to 33 knots, their lengths being about 230 feet, displacements 360 to 380 tons, and engine-power 8,000 to 10,000 horse-power.

Cost has gone up with size and power, and the limit of progress in this direction will probably be fixed by financial considerations, rather than by constructive difficulties, great as these become as speeds rise.

It may be interesting to summarise the distinctive features of torpedo-vessel design.

1. The propelling apparatus is excessively light in proportion to the maximum power developed. Water-tube boilers are now universally adopted, and on speed trials they are 'forced' to a considerable extent. High steam pressures are used. The engines are run at a high rate of revolution—often at 400 revolutions per minute. Great care is taken in every detail to economise weight. Speed trials at maximum power only extend over three hours. On such trials in a destroyer each ton weight of propelling apparatus produces about 45 indicated horse-power. Some idea of the relative lightness of the destroyer's machinery and boilers will be obtained when it is stated that in a large modern cruiser with water-tube boilers, high steam pressure, and quick-running engines, the maximum power obtained on an eight hours' trial corresponds to about 12 indicated horse-power per ton of engines, boilers, &c. That is to say, the proportion of power to weight of propelling apparatus is from three and a half to four times as great in the destroyer as it is in the cruiser.

2. A very large percentage of the total weight (or displacement) of a torpedo vessel is assigned to propelling apparatus. In a destroyer of 30 knots trial-speed, nearly one-half the total weight is devoted to machinery, boilers, &c. In the swiftest cruisers of large size the corresponding allocation of weight is less than 20 per cent. of the displacement, and in the largest and fastest mail steamers it is about 20 to 25 per cent.

3. The torpedo vessel carries a relatively small load of fuel, equipment, &c. Taking a 30-knot destroyer, for example, the speed trials are made with a load not exceeding 12 to 14 per cent. of the displacement. In a swift cruiser the corresponding load would be from 40 to 45 per cent., or proportionately more than three times as great. What this difference means may be illustrated by two statements. If the load in a destroyer were trebled and the vessel correspondingly increased in draught and weight, the speed attained with the same maximum power would be about three knots less. If, on the other hand, the vessel were designed to attain 30 knots on trial with the heavier load, her displacement would probably be increased about 70 to 80 per cent.

4. The hull and fittings of the torpedo vessel are exceedingly light in relation to the dimensions and engine-power. For many parts of the structure steel of high tensile strength is used. Throughout, the utmost care is taken to economise weight. In small vessels, for special service, many conditions can be accepted which would be inadmissible in larger sea-going vessels. The result of all this care is the production of hull-structures having ample *general* strength for their special service. Lightness of scantling, of course, involves small *local* strength against collision, grounding, and other accident. Experience proves, however, that this involves no serious risk or difficulty.

These conditions are essential to the attainment of very high speeds for short periods. They resemble the conditions ruling the design of cross-Channel steamers, so far as relative lightness of propelling apparatus, small load, and light scantlings are concerned. The essential differences lie in the requirements for passenger accommodation as compared with the requirements for armament of the torpedo vessel. No one has yet proposed to extend the torpedo-vessel system to sea-going ships of large dimensions. Very similar conditions for the propelling apparatus have been accepted in a few cruisers of considerable dimensions, wherein high speeds for short periods were required. It is, however, unquestionable that in many ways, and particularly in regard to machinery design, the construction of torpedo vessels has greatly influenced that of larger ships.

One important consideration must not be overlooked. For short-distance steaming at high speeds economy in coal consumption is of little practical importance, and it is all-important to secure lightness of propelling apparatus in relation to power. For long-distance steaming, on the contrary, economy in coal consumption is of primary importance; and savings in weight of propelling apparatus, even of considerable amount, may be undesirable if they involve increased coal consumption. Differences of opinion prevail as to the real economy of fuel obtainable with boilers and engines such as are fitted in torpedo vessels. Claims are made for some vessels which represent remarkable economy. Only enlarged experience can settle these questions.

Endurance is also an important quality in sea-going ships of large size, not merely in structures, but in propelling apparatus. The extreme lightness essential in torpedo vessels obviously does not favour endurance if high powers are frequently or continuously required. Still, it cannot be denied that the results obtained in torpedo vessels show such a wide departure from those usual in sea-going ships as to suggest the possibility of some intermediate type of propelling apparatus applicable to large sea-going ships and securing sufficient durability and economy of fuel in association with further savings of weight.

The Parsons Turbo-Motor.

The steam turbo-motor introduced by Mr. Charles Parsons is to be described by the inventor during these meetings; but it is impossible for me to pass it over in this review without a brief notice. This rotary engine, with its very high rate of revolution, reduces the weights of machinery, shafting, and propellers greatly below the weight required in the quickest-running engines of the reciprocating type. This reduction in the proportion of weight to power carries with it, of course, the possibility of higher speed in a vessel of given dimensions; and when large powers are employed the absolute gain is very great. An illustration of this has been given by Mr. Parsons in the *Turbinia.* That remarkable vessel is 100 feet long and of 44½ tons displacement, but she has attained 33 to 34 knots in short runs. There are three shafts, each carrying three screw propellers, each shaft driven by a steam turbine making over 2,000 revolutions at full speed, when more than 2,000 horse-power is developed. A water-tube boiler of special design supplies steam of 175 lbs. pressure, and is exceptionally light for the steam produced, being highly forced. The whole weight of machinery and boilers is 22 tons: in other words, about 100 horse-power (indicated) is produced for each ton weight of propelling apparatus. This is rather more than twice the proportion of power to weight as compared with the lightest machinery and boilers fitted in torpedo boats and destroyers. It will be noted that in the *Turbinia,* as in the destroyers, about half the total weight is devoted to propelling apparatus; and in both instances the load carried is relatively small. The secret of the extraordinary speed is to be found in the extreme lightness of propelling apparatus, and small load.

No doubt in the *Turbinia* lightness has been pushed further than it would be in vessels of larger size and greater power. In such vessels a lower rate of revolution would probably be accepted, additional motors would be fitted for manœuvring and going astern, boilers of relatively greater weight would be adopted, and other changes made. But, after making ample allowance for all such increases in weight, it is unquestionable that considerable economies must be possible with rotary engines. Two other vessels of the destroyer type with turbo-motors (one for the Royal Navy) are now approaching completion. Their trials will be of great interest, as they will furnish a direct comparison with vessels of similar size and form, fitted with similar boilers and driven by reciprocating engines.

On the side of coal consumption Mr. Parsons claims at least equality with the best triple expansion engines. Into the other advantages attending the use of rotary engines it is not necessary now to enter.

Reference must be made, however, to one matter in which Mr. Parsons has done valuable and original work. In torpedo vessels of high speed the choice of the most efficient propellers has always been a matter of difficulty, and the solution of the problem has in many instances involved extensive experimental trials. By means of alterations in propellers alone, very large increases in speed have been effected; and even now there are difficulties to be faced. When Mr. Parsons adopted the extraordinary speed of revolution just named for the *Turbinia,* he went far beyond all experience and precedent and had to face unknown conditions. He has found the solution, after much patient and original investigation, in the use of multiple screws of small diameter. His results in this direction are of general interest to all who have to deal with screw propulsion.

Such radical changes in propelling machinery as are involved in the adoption of turbo-motors must necessarily be subjected to thorough test before they will be widely adopted. The experiment which the Admiralty are making is not on a small scale as regards power. Although it is made in a destroyer, about 10,000-horse-power will probably be developed and a correspondingly high speed attained. It may well happen that from this experiment very far-reaching effects may follow. Mr. Parsons himself has prepared many designs illustrating various applications of the system to sea-going, cross-Channel, and special service vessels. Where shallowness of draught is unavoidable the small diameter of the screws possible with the quick-running turbines is clearly an important matter.

Comparisons between Large and Small Vessels.

It has been shown that the attainment of very high speeds by vessels of small size involves many conditions not applicable to large sea-going steamships. But it is equally true that in many ways the trials of small swift vessels constitute model experiments from which interesting information may be obtained as to what would be involved in driving ships of large size at speeds much exceeding any of which we have experience. When the progressive steam-trials of such small vessels can be studied side by side with experiments made on models to determine their resistance at various speeds, then the fullest information is obtained and the best guide to progress secured. This advantage, as has been said, we owe to William Froude.

His contributions to the Reports of the British Association are classics in the literature of the resistance and propulsion of ships. In 1874 he practically exhausted the subject of frictional resistance so far as it is known; and his Presidential Address to this Section in 1875 dealt fully and lucidly with the modern or stream-line theory of resistance. No doubt there would be advantage in extending Froude's experiments on frictional resistance to greater lengths and to ship-shaped forms. It is probable also that dynamometric determinations of the resistance experienced by ships of modern forms and considerable size when towed at various speeds would be of value if they could be conducted. These extensions of what Froude accomplished are not easily carried out; and in this country the pressure of work on shipbuilding for the Royal Navy has, for many years past, taxed to the utmost limits the capacity of the Admiralty experimental establishment so ably superintended by Mr. R. E. Froude, allowing little scope for purely scientific investigations, and making it difficult to deal with the numerous experiments incidental to the designs of actual ships. Now that Holland, Russia, Italy, and the United States have equipped experimental establishments, while Germany and France are taking steps in that direction, we may hope for extensions of purely scientific work and additions to our knowledge. In this direction, however, I am bound to say that much might be done if experimental establishments capable of dealing with questions of a general nature relating to resistance and propulsion were added to the equipment of some of our universities and colleges. Engineering laboratories have been multiplied, but there is as yet no example of a model experimental tank, devoted to instruction and research.

It is impossible, and possibly is unnecessary, to attempt in this Address any account of Froude's 'scale of comparison' between ships and models at 'corresponding speeds.' But it may be of interest to give a few illustrations of the working of this method, in the form of a contrast between a destroyer of 300 tons, 212 feet long, capable of steaming 30 knots an hour, and a vessel of similar form enlarged to 765 feet in length and 14,100 tons. The ratio of dimensions is here about 3·61 : 1; the ratio of displacements is 47 : 1; and the ratio of corresponding speeds is 1·9 : 1.

To 12 knots in the small vessel would correspond 22·8 knots in the large vessel; and the resistance experienced by the large vessel at 22·8 knots (neglecting a correction for friction) should be forty-seven times that of the small vessel at 12 knots. By experiment, this resistance for the small vessel was found to be 1·8 tons. Hence, for the large vessel at 22·8 knots the resistance should be 84·6 tons. This would correspond to an 'effective horse-power' of over 13,000, or to about 26,000 indicated horse-power. The frictional correction would reduce this to about 25,000 horse-power, or about 1·8 horse-power per ton. Now turning to the destroyer, it is found experimentally that at 22·8 knots she experiences a resistance of about 11 tons, corresponding to an effective horse-power of over 1,700, and an indicated horse-power of about 3,000: say 10 horse-power per ton, or nearly five and a half times the power per ton required in the larger vessel. This illustrates the economy of propulsion arising from increased dimensions.

Applying the same process to a speed of 30 knots in the large ship, the corresponding speed in the small ship is 15·8 knots. Her resistance at that speed is experimentally determined to be 3·5 tons, and the resistance of the large ship at 30 knots (neglecting frictional correction) is about 165 tons. The effective horse-power of the large ship at 30 knots is, therefore, about 34,000, corresponding to 68,000 horse-power indicated. Allowing for the frictional correction, this would drop to about 62,000 horse-power, or 4·4 horse-power per ton. For the destroyer at 30 knots the resistance is about 17½ tons; the effective horse-power is 3,600, and the indicated horse-power about 6,000, or 20 horse-power per ton, nearly five times as great as the corresponding power for the large ship. But while the destroyer under her trial conditions actually reaches 30 knots, it is certain that in the large ship neither weight nor space could be found for machinery and boilers of the power required for 30 knots, and of the types usually adopted in large cruisers, in association with an adequate supply of fuel. The explanation of the methods by which the high speed is reached in the destroyer has already been given. Her propelling apparatus is about one-fourth as heavy in relation to its maximum power, and her load is only about one-third as great in relation to the displacement, when compared with the corresponding features in a swift modern cruiser.

It will, of course, be understood that in practice, under existing conditions, a cruiser of 14,000 tons would not be made 765 feet long, but probably about 500 feet. The hypothetical cruiser has been introduced simply for purposes of comparison with the destroyer.

The earlier theories of resistance assumed that the resistance experienced by ships varied as the square of the speed. We now know that the frictional resistances of clean-painted surfaces of considerable length vary as the 1·83 power of the speed. This seems a small difference, but it is sensible in its effects, causing a reduction of 32 per cent. at 10 knots, nearly 40 per cent. at 20 knots, and 42 per cent. at 25 knots. On the other hand, it is now known that the laws of variation of the residual or wave-making resistance may depart very widely from the law of the square of the speed, and it may be interesting to trace for the typical destroyer how the resistance actually varies.

Take first the *total resistance.* Up to 11 knots it varies nearly as the square of the speed; at 16 knots it has reached the cube; from 18 to 20 knots it varies as the 3·3 power. Then the index begins to diminish: at 22 knots it is 2·7; at 25 knots it has fallen to the square, and from thence to 30 knots it varies, practically, as does the frictional resistance.

The residual resistance varies as the square of the speed up to 11 knots, as the cube at 12½ to 13 knots, as the fourth power about 14½ knots, and at a higher rate than the fifth power at 18 knots. Then the index begins to fall, reaching the square at 24 knots, and falling still lower at higher speeds.

It will be seen, therefore, that when this small vessel has been driven up to 24 or 25 knots by a large relative expenditure of power, further increments of speed are obtained with less proportionate additions to the power.

Passing from the destroyer to the cruiser of similar form but of 14,100 tons, and once more applying the ‘scale of comparison,’ it will be seen that to 25 knots in the destroyer corresponds a speed of 47½ knots in the large vessel. In other words, the cruiser would not reach the condition where further increments of speed are obtained with comparatively moderate additions of power until she exceeded 47 knots, which is an impossible speed for such a vessel under existing conditions. The highest speeds that could be reached by the cruiser with propelling apparatus of the lightest type yet fitted in large sea-going ships would correspond to speeds in the destroyer, for which the resistance is varying as the highest power of the speed. These are suggestive facts.

Frictional resistance, as is well known, is a most important matter in all classes of ships and at all speeds. Even in the typical destroyer this is so. At 12 knots the friction with clean-painted bottom represents 80 per cent. of the total resistance; at 16 knots 70 per cent.; at 20 knots a little less than 50 per cent.; and at 30 knots 45 per cent. If the coefficient of friction were doubled and the maximum power developed with equal efficiency, a loss of speed of fully 4 knots would result.

In the cruiser of similar form the friction represents 90 per cent. at 12 knots, 85 per cent. at 16 knots, nearly 80 per cent. at 20 knots, and over 70 per cent. at 23 knots. If the coefficient of friction were doubled at 23 knots and the corresponding power developed with equal efficiency, the loss of speed would approximate to 4 knots.

These illustrations only confirm general experience that clean bottoms are essential to economical propulsion and the maintenance of speed, and that frequent docking is necessary in vessels with bare iron or steel skins, which foul in a comparatively short time.

Possibilities of further Increase in Speed.

From the facts above mentioned it is obvious that the increase in speed which has been effected is the result of many improvements, and has been accompanied by large additions to size, engine-power, and cost. These facts do not discourage the 'inventor,' who finds a favourite field of operation in schemes for attaining speeds of 50 to 60 knots at sea in vessels of moderate size. Sometimes the key to this remarkable advance is found in devices for reducing surface-friction by the use of wonderful lubricants to be applied to the wetted surfaces of ships, or by interposing a layer of air between the skins of ships and the surrounding water, or other departures from ordinary practice. If these gentlemen would 'condescend to figures,' their estimates, or guesses, would be less sanguine. In many cases the proposals made would fail to produce any sensible reduction in resistance; in others they would increase resistance.

Other proposals rest upon the idea that resistance may be largely reduced by adopting novel forms, departing widely from ordinary ship shapes. Very often small-scale experiments, made in an unscientific and inaccurate manner, are adduced as proofs of the advantages claimed. In other instances mere assertion is thought sufficient. Ordinarily no regard is had to other considerations, such as internal capacity, structural weight and strength, stability and seaworthiness. Most of these proposals do not merit serious consideration. Any which seem worth investigation can be dealt with simply and effectively by the method of model experiments. A striking example of this method will be found in the unusual form of a Parliamentary Paper (No. 313, of 1873), containing a Report made by Mr. William Froude to the Admiralty. Those interested in the subject will find therein much matter of special interest in connection with the conditions attending abnormally high speeds. It must suffice now to say that ship-shaped forms are not likely to be superseded at present.

The most prolific 'inventions' are those connected with supposed improvements in propellers. One constantly meets with schemes guaranteed by the proposers to give largely increased efficiency and corresponding additions to speed. Variations in the numbers and forms of screws or paddles, the use of jets of water or air expelled by special apparatus through suitable openings, the employment of explosives, imitations of the fins of fishes, and numberless other departures from established practice are constantly being proposed. As a rule the 'inventors' have no intimate knowledge of the subject they treat, which is confessedly one of great difficulty. When experiments are adduced in support of proposals they are almost always found to be inconclusive and inaccurate. More or less mathematical demonstrations find favour with other inventors, but they are not more satisfactory than the experiments. An air of great precision commonly pervades the statements made as to possible increase in efficiency or speed. I have known cases where probable speeds with novel propellers have been estimated (or guessed) to the third place of decimals. In one such instance a trial was made with the new propeller, with the result that instead of a gain in efficiency there was a serious loss of speed. Very few of the proposals made have merit enough to be subjected to trial. None of them can possibly give the benefits claimed.

It need hardly be added that in speaking thus of so-called 'inventors' there is no suggestion that improvement has reached its limit, or that further discovery is not to be made. On the contrary, in regard to the forms of ships and propellers continuous investigation is proceeding and successive advances are being made. From the nature of the case, however, the difficulties to be surmounted increase as speeds rise; and a thorough mastery of the past history and present condition of the problems of steamship design and propulsion is required as a preparation for fruitful work in the nature of further advance.

It would be idle to attempt any prediction as to the characteristic features of ocean navigation sixty years hence. Radical changes may well be made within that period. Confining attention to the immediate future, it seems probable that the lines of advance which I have endeavoured to indicate will remain in use. Further reductions may be anticipated in the weight of propelling apparatus and fuel in proportion to the power developed; further savings in the weight of the hulls, arising from the use of stronger materials and improved structural arrangements; improvements in form; and enlargement in dimensions. If greater draughts of water can be made possible, so much the better for carrying power and speed. For merchant vessels commercial considerations must govern the final decision; for warships the needs of naval warfare will prevail. It is certain that scientific methods of procedure and the use of model experiments on ships and propellers will become of increased importance.

Already avenues for further progress are being opened. For example, the use of water-tube boilers in recent cruisers and battleships of the Royal Navy has resulted in saving *one-third* of the weight necessary with cylindrical boilers of the ordinary type to obtain the same power, with natural draught in the stokeholds. Differences of opinion prevail, no doubt, as to the policy of adopting particular types of water-tube boilers; but the weight of opinion is distinctly in favour of some type of water-tube boiler in association with the high steam pressures now in use. Greater safety, quicker steam-raising and other advantages, as well as economy of weight, can thus be secured. Some types of water-tube boilers would give greater saving in weight than the particular type used in the foregoing comparison with cylindrical boilers.

Differences of opinion prevail also as to the upper limit of steam pressure which can with advantage be used, taking into account all the conditions in both engines and boilers. From the nature of the case, increases in pressure beyond the 160 to 180 lbs. per square inch commonly reached with cylindrical boilers cannot have anything like the same effect upon economy of fuel as the corresponding increases have had, starting from a lower pressure. Some authorities do not favour any excess above 250 lbs. per square inch on the boilers; others would go as high as 300 lbs., and some still higher.

Passing to the engine-rooms, the use of higher steam-pressures and greater rates of revolution may, and probably will, produce reductions in weight compared with power. The use of stronger materials, improved designs, better balance of the moving parts, and close attention to details have tended in the same direction without sacrifice of strength. Necessarily there must be a sufficient margin to secure both strength and endurance in the motive power of steamships. Existing arrangements are the outgrowth of large experience, and new departures must be carefully scrutinised.

The use of rotary engines, of which Mr. Parsons's turbo-motor is the leading example at present, gives the prospect of still further economies of weight. Mr. Parsons is disposed to think that he could about halve the weights now required for the engines, shafting, and propellers of an Atlantic liner while securing proper strength and durability. If this could be done in association with the use of water-tube boilers, it would effect a revolution in the design of this class of vessel, permitting higher speeds to be reached without exceeding the dimensions of existing ships.

It does not appear probable that, with coal as the fuel, water-tube boilers will surpass in economy the cylindrical boilers now in use; and skilled stoking seems essential if water-tube boilers are to be equal to the other type in rate of coal consumption. The general principle holds good that as more perfect mechanical appliances are introduced, so more skilled and disciplined management is required in order that the full benefits may be obtained. In all steamship performance the 'human factor' is of great importance, but its importance increases as the appliances become more complex. In engine-rooms the fact has been recognised and the want met. There is no reason why it should not be similarly dealt with in the boiler-rooms.

Liquid fuel is already substituted for coal in many steamships. When sufficient quantities can be obtained it has many obvious advantages over coal, reducing greatly manual labour in embarking supplies, conveying it to the boilers and using it as fuel. Possibly its advocates have claimed for it greater economical advantages over coal than can be supported by the results of extended experiment. Even if the saving in weight for equal evaporation is put as low as 30 per cent. of the corresponding weight of coal, it would amount to 1,000 tons on a first-class Atlantic liner. This saving might be utilised in greater power and higher speed, or in increased load. There would be a substantial saving on the stokehold staff. At present it does not appear that adequate supplies of liquid fuel are available. Competent authorities here and abroad are giving attention to this question, and to the development of supplies. If the want can be met at prices justifying the use of liquid fuel, there will undoubtedly be a movement in that direction.

Stronger materials for the construction of hulls are already available. They are, however, as yet but little used, except for special classes of vessels. Mild steel has taken the place of iron, and effected considerable savings of weight. Alloys of steel with nickel and other metals are now made which give strength and rigidity much superior to mild steel, in association with ample ductility. For destroyers and torpedo boats this stronger material is now largely used. It has also been adopted for certain important parts of the structures of recent ships in the Royal Navy. Of course the stronger material is more costly, but its use enables sensible economies of weight to be made. It has been estimated, for example, that in an Atlantic liner of 20 knots average speed about 1,000 tons could be saved by using nickel steel instead of mild steel. This saving would suffice to raise the average speed more than a knot, without varying the dimensions of the ship.

Alloys of aluminium have also been used for the hulls or portions of the hulls of yachts, torpedo-boats, and small vessels. Considerable savings in weight have thus been effected. On the other hand, these alloys have been seriously corroded when exposed to the action of sea-water, and on that account are not likely to be extensively used. Other alloys will probably be found which will be free from this defect, and yet unite lightness with strength to a remarkable degree.

Other examples might be given of the fact that the metallurgist has by no means exhausted his resources, and that the shipbuilder may look to him for continued help in the struggle to reduce the weights of floating structures.

It is unnecessary to amplify what has already been said as to possible increase in the efficiency and types of propellers. With limited draught, as speeds increase and greater powers have to be utilised, multiple propellers will probably come into use. Mr. Parsons has shown how such problems may be dealt with; and other investigators have done valuable work in the same direction.

In view of what has happened and is still happening, it is practically certain that the dimensions of steamships have not yet attained a maximum.

Thanks to mechanical appliances, the largest ships built or to be built can be readily steered and worked. In this particular, difficulties have diminished in recent years, notwithstanding the great growth in dimensions.

Increase in length and weight favours the better maintenance of speed at sea. The tendency, therefore, will be to even greater regularity of service than at present. Quicker passages will to some extent diminish risks, and the chance of breakdown will be lessened if multiple propellers are used. Even now, with twin screws, the risk of total breakdown is extremely small.

Whatever may be the size and power of steamships, there must come times at sea when they must slow down and wait for better weather. But the larger and longer the vessel, the fewer will be the occasions when this precaution need be exercised.

It must never be forgotten that as ships grow in size, speed, and cost, so the responsibilities of those in charge increase. The captain of a modern steamship needs remarkable qualities to perform his multifarious duties efficiently. The chief engineer must have great powers of organisation, as well as good technical knowledge, to control and utilise most advantageously the men and machinery in his charge. Apart from the ceaseless care, watchfulness, and skill of officers and men, the finest ships and most perfect machinery are of little avail. The 'human factor' is often forgotten, but is all-important. Let us hope that in the future as in the past, as responsibilities increase so will the men be found to bear them.

The following Papers were read:—

1. *The Dover Harbour Works.* *By* J. C. Coode, *M.Inst.C.E., and* W. Matthews, *M.Inst.C.E.* See Reports, p. 479.

[Ordered to be printed *in extenso.*]

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2. *On Non-Flammable Wood and its Use on Warships.*

By E. Marshall Fox.

The one serious defect of wood as a material of construction is the danger from fire that always attends its use. Efforts to eliminate this danger have repeatedly been made. Faraday demonstrated that many chemicals possessed the property, when impregnated into the pores of the wood, of reducing the inflammability of the same.

Among the fire-proofing chemicals used from time to time have been: tungstate of soda, boracic acid, sulphate of ammonia, sulphate of magnesia, chloride of zinc.

Fire as an element of naval warfare is traceable as far back as 190 B.C., when, according to Livy, the Rhodians made use of fireships, or vessels filled with combustibles, set adrift among the hostile fleet. Repeatedly since that early date fireships have played a not unimportant part in naval warfare.

With the advent of ironclads the utility of fireships passed away, but the naval battles of the Chinese and Japanese War in 1894 showed conclusively that in a new form fire was still a serious factor in naval engagements, three Chinese warships being burned to the water's edge owing to their woodwork being set ablaze from the shot and shell of the attacking fleet. It was this object lesson that induced the naval authorities of the United States in 1895 to look about for a remedy to prevent the wood of their warships from burning. Experiments with wood impregnated with fire-proofing chemicals were made by the Government of that country, with the result that two cruisers and two battleships then under construction were fitted out with non-flammable wood. After some sixteen months of service trial, a re-examination of the subject was officially ordered, owing to reports that the treated wood corroded metals, absorbed moisture, and failed to properly retain paint. The examination resulted in the continuance of its use and extension to other American warships.

In 1897, H.M. Admiralty commenced the investigation of non-flammable wood, and after various tests specified it for the new royal yacht, the new battleships, cruisers, and torpedo-boat destroyers now being constructed.

The process by which wood is rendered non-inflammable consists in placing it in cylinders of steel, closing the same tightly, and submitting to alternate applications of heat and steam, after which the air is exhausted and the fire-proofing solution—one of the ingredients of which is phosphate of ammonia—admitted. Pressure pumps are then applied, forcing the liquid into the pores of the wood. The degrees of steaming, vacuum, and pressure vary according to the character of the wood. All kinds of wood are not amenable to the process—some because of the large quantity of resin or oil they contain, and irregular fibres resist thorough impregnation. Teak, Austrian oak, Norway spruce, and American pitch-pine, are particularly resistent, while yellow deal, white pine, mahogany, ash, elm, birch, cherry, and English oak lend themselves readily to the treatment. In the softer woods timber from three to four inches in thickness has been impregnated successfully, but in the harder woods rarely more than two inches can be impregnated throughout. For all practical purposes, it has been found that impregnation for one inch all round renders the wood non-flammable throughout. The amount of solution taken up by the softer woods is greater than that absorbed by the harder woods. White pine takes more than twice its original weight, while mahogany, oak, and teak only take up about 75 per cent. of original weight. After the wood has become thoroughly impregnated the next step is to evaporate the aqueous portion of the solution from the wood, leaving the resultant crystals deposited in the pores. The wood is then dried in a kiln at an even temperature not exceeding 120° F., having a free circulation of dry air. The time required for proper drying varies from three to seven weeks, depending upon the thickness of the wood. After the wood is thoroughly dry it is ready for use, and will be found to be flame- and fire-resisting, merely carbonising at the point of contact with fire.

The resistance of treated wood to the passage of electricity is decreased, while the heat-resisting properties are increased. A piece of yellow pine an inch thick placed over the flame of a Bunsen burner, having on its upper surface some grains of gunpowder, will not impart in four hours sufficient heat through the wood to ignite the gunpowder.

Experience has shown that care must be taken to have the treated wood thoroughly dry before paint is applied.

The wisdom of the American Government in having the woodwork of its ships of war made non-flammable was well exemplified during their recent war with Spain, when, as is well known, several of the Spanish ships at Manilla and Santiago de Cuba were burnt to the water's edge by the woodwork of the same being set on fire from the bursting of the American shell, while more than one American ship, having non-flammable wood on board, although shot through and through, received no injury from fire.

FRIDAY, SEPTEMBER 15.

The following Report and Papers were read:—

1. *Report on Small Screw Gauges.*—See Reports, p. 464.

2. *A Short History of the Engineering Works of the Suez Canal to the Present Time.* *By* Sir CHARLES HARTLEY, *K.C.M.G.*

3. *Fast Cross-Channel Steamers driven by Steam Turbines.*
By Hon. C. A. PARSONS, *F.R.S.*

4. *The Niclausse Water-Tube Boiler.*
By MARK ROBINSON, *M.Inst.C.E.*

5. *On the Discharge of Torpedoes below Water.*
By Captain E. W. LLOYD, *of Elswick.*

Torpedoes have not in actual warfare, up to the present, had any direct influence, but they are retained as part of the armament of large ships, as no Government likes to take the initiative in discarding them. As recent wars have shown that torpedoes fired from above-water apparatus are a source of great danger to their possessors, the necessity for discharge below the water has become apparent. This necessity has been well met by the introduction of the Elswick Submerged Torpedo Tube. This tube has been designed with a view to firing torpedoes from the broadside of a ship travelling at high speeds. Discharge is preferably done by means of cordite, and it is only necessary to press a firing key in the conning tower for the shield to be run out, the torpedo ejected, and the shield returned. During the discharge, the ship travelling at a speed of 17 knots, the torpedo is subjected to a total pressure of about 5·2 tons, and the shield or spoon of the torpedo tube has to be made strong enough to support it against this strain.

SATURDAY, SEPTEMBER 16.

The following Paper was read:—

1. *Erection of the New Alexander III. Bridge in Paris.*
By M. A. Alby, *of Paris.*

[Ordered to be printed *in extenso.*]

See Reports p. 469.

MONDAY, SEPTEMBER 18.

The following Papers were read:—

1. *Electrical Machinery on Board Ship.*
By A. Siemens, *M.Inst.C.E.*

2. *On the Electric Conductivity and Magnetic Properties of an Extensive Series of Alloys of Iron, prepared by* R. A. Hadfield. *By* Professor W. F. Barrett, *F.R.S., and* W. Brown, *B.Sc.*

During the last five years the authors have been engaged in the determination of the physical properties of upwards of 100 alloys of iron, many of them entirely new, and some of them presenting remarkable physical characteristics. This splendid series of alloys or 'steels' has been prepared at considerable expenditure by the liberality of Mr. Hadfield, M.I.C.E., Managing Director of the Hecla Steel Works, Sheffield, whose researches on the mechanical properties of many of these alloys are well known. Mr. Hadfield has also had a chemical analysis of the alloys made in the laboratory attached to his works; the paper may therefore be said to be a joint contribution by three authors.

The *first part* of the paper deals with the *electric conductivity* of these alloys. For the purposes of measurement the specimens were rolled into rods rather over a metre long and about half a centimetre diameter, and after their conductivity was measured in the unannealed condition they were then carefully annealed and re-determined. Annealing was found to increase the conductivity in the case of all the alloys. The potential method of measurement of conductivity was employed, a comparison being made with a standard rod of pure copper, of known conductivity, and also with a standard rod of the purest commercial iron. Full details of the method of measurement and the results obtained will be found in the forthcoming volume of the Transactions of the Royal Society of Dublin.

In all the specimens the conductivity decreases as the percentage of the added element increases, at first rapidly and then very slowly. But the effect of different elements on the conductivity of the alloy varies largely. The addition of even small quantities of carbon, silicon, manganese, chromium, or aluminium lowers the conductivity of iron considerably, whereas corresponding quantities of nickel, copper, and tungsten have a much less effect. The conductivity of the aluminium steels is extremely low, a particular specimen having 5½ per cent. of aluminium (with only 0·2 of carbon and the same amount of silicon) had a conductivity of only 2·16, pure copper being taken as 100, or a specific resistance of 75 microhms per c.c., the specimen had also the low temperature coefficient of 0·063 per cent. per degree Cent. It was a beautiful alloy and very ductile. But the highest resistance was found among the nickel manganese steels. One specimen having 25 per cent. of nickel and 5 per cent. of manganese with 1 per cent. of carbon, was found to have the extraordinary specific resistance of 97½ microhms per c.c. at 15° C. and a temperature coefficient of 0·085 per cent. per degree Cent. This alloy also was easily worked and drawn into wire, but was harder and less ductile than the aluminium alloy just mentioned.

The *second* part of the paper deals with the magnetic properties of the alloys; complete **B** and **H** curves were made in the case of a large number of the specimens. The magnetometric method of measurement was employed, each specimen being taken through a magnetic cycle, with a maximum magnetising force of 45 C.G.S. units. The induction, the retentivity and coercivity of each specimen are shown by the curves, and the permeability for a given magnetising force was estimated in each case. Mr. R. L. Wills, who, with Mr. R. G. Allen, assisted in the experiments, has also measured the areas enclosed by the curves, and thus determined the energy dissipated per cycle in ergs per cubic cent. Some elements were found to affect the hysteresis very differently to others and to very different extents, depending upon the percentage of the element present. Annealing in the case of some of the nickel and of the chromium-nickel and chromium-manganese alloys converted a practically non-magnetic alloy into a strongly magnetic one. For magnetising forces up to about 8 C.G.S. units, the addition of 2¼ per cent. of aluminium actually increases the permeability of iron; very small percentages of nickel also have the same effect for lower magnetising forces. As the percentage of nickel increases, the induction and permeability rapidly decrease and the hysteresis increases, but between 24½ and 31½ per cent. of nickel in the alloy the hysteresis falls, owing to the rapid decrease in coercive force between these percentages. The 31 per cent. nickel steel had in fact an exceptionally low coercive force, and a permeability greater than the best iron for very low magnetising forces. Mechanical tests, made by Mr. Hadfield, show a similar result, the curve representing the tensile strength of nickel steels rising rapidly from 7 to a 12 per cent. nickel steel, then remaining nearly stationary till 20 per cent. is reached, after which it falls rapidly to the highest per cent. nickel steel tried, viz. 31½ per cent. This is exactly analogous to the curve representing the coercive force of nickel steels. These interesting results were obtained independently. Still more remarkable was the magnetic effect produced by silicon when alloyed with iron and steel; this is now under investigation.

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3. *Some Recent Applications of Electro-Metallurgy to Mechanical Engineering.* *By* SHERARD COWPER-COLES, *Assoc.M.Inst.C.E., M.I.M.E., M.I.E.E.*

The author commenced by pointing out the prominent position electro-metallurgy is now taking in many workshops, and enumerated the uses to which electro-metallurgy is being applied. He then proceeded to give a description of an electro-galvanising plant as used for coating the tubes of water-tube boilers and the plates of torpedo-boat destroyers, and also gave details of the anode and cathode bars used for suspending the electrodes, and information as to the thickness of zinc applied and the current density and voltage employed. Estimates were given as to the cost and output of various-sized plants, and the advantages of electro-galvanising over hot galvanising were compared. The regenerative or recuperative process and methods of circulation were also described.

Particulars were then given of various electro-chemical processes for cleaning iron and removing magnetic oxide and scale, and a model was shown of a magnetic scale collector for collecting the scale from the acid solution after its removal from the iron or steel, so as to prevent the further unnecessary waste of acid. Experiments made in this direction tended to show that a considerable proportion of the acid is consumed by dissolving the scale after it has left the iron or steel.

An electrolytic process for the manufacture of reflectors was then described, suitable for making parabolic reflectors for search-lights. The various steps of the process were given in detail. Briefly, the process consists in using a glass convex mould on which is chemically deposited a coating of metallic silver, and then polished so as to ensure the copper backing being adherent to the silver. The mould thus prepared is placed in a suitable ring and frame and immersed in an electrolyte of copper sulphate, the mould being rotated in a horizontal position, the number of revolutions being about fifteen per minute. The copper adheres firmly to the silver, and together they form the reflector, which is subsequently separated from the glass mould by placing the whole in cold or lukewarm water, and then gradually raising the temperature of the water to 120° F., when the metal reflector will leave the glass mould, due to the unequal expansion of the two. The concave surface of the reflector obtained is an exact reproduction of the surface of the mould and has the same brilliant polish, and requires no further treatment to answer all the purposes of a reflector with the exception that it must be coated with a film of some suitable metal to prevent it tarnishing. Palladium is found to answer this purpose best, as a bright coating can be deposited rapidly to any desired thickness. Palladium resists tarnishing and the heat of an arc to a wonderful degree.

4. *Signalling without Contact, a New System of Railway Signalling.*
By WILFRED S. BOULT, *Assoc.M.Inst.C.E.*

5. *Our Lighthouses of the English Channel in* 1899.
By J. KENWARD, *C.E., F.S.A.*

This Paper dealt with the Sea Lights and Lightships of the English Channel; enumerated them from West to East; described their origin, characteristics, and intensities; referred incidentally to certain French Lights on the opposite coast; reviewed the various illuminants of gas, oil, and electricity, as also sound-signals; and suggested the probable condition of lighthouses in the near future.

TUESDAY, SEPTEMBER 19.

The following Papers were read:—

1. *Recent Experiences with Steam on Common Roads.*
By JOHN I. THORNYCROFT, *F.R.S.*

Introduction.—Hancock's vehicles; difficulties of early builders; revival of interest during past few years; the Locomotives on Highways Act, 1896; objections to the present tare limits; current French practice; the Lancashire lurries; suggested amendment in the law as to tare limits; case of a vehicle transporting ten tons net; House of Commons Committee, 1832, extract from Report; experience on Russian railways; motor vehicles with trailers.

The Thornycroft Vehicles.—(1) One-ton steam van; description; the air condenser; advantages and disadvantages of air condensers; air condensers with radiating gills and circulating fan. (2) The Chiswick dust carts; description; the boiler; engine; gearing; steering; air condenser. (3) The steel tip-wagon; construction; annular boiler; engine; speed of vehicle; availability for different services; wheels; steel disc wheels; latest practice in wheels; felloe drive. (4) The passenger carriage; belt differential gear; action of belt gear; belt adhesion to pulleys; further experiments. (5) The brewer's dray; performance in actual service; cost of running; controlling arrangements; boiler; engine; feed-heater; superheater. (6) The chainless steam wagons; traction engine practice in transmission gearing; description of the chainless drive; the spring drive; speed; hill-climbing power; two-speed gear; free engine.

Summary of leading features in latest designs.—The motor vehicle; boiler; engine; feed-pump; injector; steering-gear; variety of service; choice of fuel; the driver; the repair shed; table of results; comments on table of results; concluding remarks.

2. *The Dymchurch Wall and Reclamation of Romney Marsh.*
By Edward Case, *Assoc. M.Inst.C.E., F.R.G.S.*

Commencing from the time of the Romans, the author traced the history of the reclamation and protection of Romney Marsh down to the reign of Henry III., when the charter was first granted, and thence to the year 1562, during which period the charter was repeatedly confirmed.

Originally the sea was retained within its limits by a shingle beach; but in course of time this natural means of protection failed, and the breaches, which occurred in places, had to be closed up by earth banks. As the shores gradually wasted these artificial banks had to be extended, until at last they became the one continuous embankment, known as the Dymchurch Wall.

Romney Marsh, depending, as it does, on the Dymchurch Wall for immunity from inundation by the sea, lies from 4 to 10 feet below the level of ordinary spring tides. Including the adjoining marshes, it consists of some 60,000 acres of very valuable arable and pasture land. The problem of sea defence, thus presented, is doubtless the most important one that has ever arisen in the British Isles.

The Dymchurch Wall, as it now stands, is about four miles in length. Its top, 20 feet wide, stands 10 to 13 feet above ordinary spring tides. On its inland side is an earth slope of 1½ to 1; on the seaward side a curved stone parapet, 6 feet deep, and thence down to the shore level an apron, graded 5 to 1 and 7 to 1, and comprising about 40 acres of stone pitching. Since the early part of the eighteenth century it has been persistently threatened by the sea; and on numerous occasions it has been subjected to damage, entailing the expenditure of vast sums of money on restoration.

The encroachment of the sea was attributed by the author to the denudation of the shore near high water-mark, due to the growth of Dungeness Point, which caused the silting up of the bay and destroyed the uniform inclination of the foreshore. The commonly received opinion, that the travel of shore material is arrested by promontories, was not accepted by him. He further showed that this denudation was hastened by the form of the pitched apron, and by the existence of high groynes. The author had arrived at the conclusion, from numerous sections, that the natural inclination of a foreshore is elliptical, and maintained that this should be kept in view in designing and constructing sea defence works. The author's low groynes at Dymchurch, which have been in course of erection during the past five years, are based on this principle. Unlike high groynes, they have no scouring effect on the shore, but on the contrary are the instruments by which the destructive forces of the sea have been utilised for the accumulation of material. The foot of the apron is now protected by a covering of sand, a natural inclination of repose exists in the shore, and both erosion and encroachment have ceased.

The author illustrated his paper by a map of the coast-line and three cross sections of the shore.

3. *An Instrument for Gauging the Circularity of Boiler Furnaces and Cylinders, producing a Diagram.* *By* T. Messenger, *A.M.I.C.E.*

Hitherto furnaces have generally been gauged for distortion by a diameter gauge, which is not so satisfactory as gauging radially, *i.e.* from a fixed point.

The Author having this object in view:—

Firstly, designed that part of the instrument for fixing a pin as nearly in the centre of furnace as possible by arranging three telescopic legs at equal angles apart, viz. 120°, the points of these legs being caused to radiate outwards or inwards simultaneously from the centre pin; so that when the points of these three legs rest on the inner surface, and are locked there, the centre pin will always be in the centre of these points. To do this in a suitable frame, a centre wheel is mounted on the pin, which gears into three other wheels, or segments of wheels, and similar segments on the spindles of these gear into racks on the three telescopic legs, thus compelling them to radiate outwards or inwards simultaneously.

Secondly, the centre pin is arranged to receive a small drawing board to attach a sheet of paper to.

Thirdly, this centre pin also forms a pivot on which to mount a telescopic pencil arm, having a roller at its outer end, the pencil being near its inner end. This arm being moved round on the pivot, the roller will move inwards or outwards if the furnace is deformed, and the pencil, following the movements of the roller, and describing a small circle, will also move inwards or outwards, thus delineating on the paper the deformities full size, but, as these are shown on the small circle, they will apparently be greatly magnified, and so may easily be read by the eye, thus enabling the commencement of deformities to be easily detected long before it would be otherwise observed; for if the roundness of a furnace is once destroyed, the defect accentuates itself under ordinary working conditions. The possibility of the gradual, but at last probably excessive, if not also dangerous, distortion of furnaces might be guarded against, and the cause removed, if only the first sign of the circularity of the furnace being defective were discovered.

The diagram will completely delineate the actual shape of the furnace around the whole of its circumference, and so enable the boilermaker, when setting a furnace into truth, to know exactly where to deal with these defects.

These diagrams should be taken when furnaces are new, before and after the hydraulic test is put on, and retained for future reference when furnaces are from time to time examined with this gauge.

The instrument itself was shown.

4. *Experiments on the Thrust and Power of Air-Propellers.*

By William George Walker, *M.I.M.E., A.M.I.C.E.*

The first set of experiments were made with air-propellers of 2, 3, and 4 feet in diameter. The following laws were proved for top speeds up to 15,000 feet per minute.

The thrust varies as the square of the number of revolutions, also as the area. The horse-power varies as the cube of the revolutions, and for small angles as the square of the angle of pitch. In the case of the four-foot diameter air-propeller, a thrust of 15 lbs. per horse-power, at a top speed of 15,000 feet per minute, was obtained.

Experiments were then carried out on air-propellers of 30 feet in diameter. They were made as light as possible, and weighed about 150 lbs. each, designed for giving a thrust of 1,000 lbs. The area of the four blades was 360 square feet. At forty revolutions per minute, a thrust of 120 lbs. was obtained with about four horse-power. A Mangin type of propeller was employed, the blades being fixed one behind the other, and connected together by diagonal struts and ties; the object in placing a blade immediately behind another one is to increase the strength and stiffness of the blades. The blades are made of solid drawn steel tubes, and of diameters varying from $\frac{5}{8}$ inch to 1 inch.

The 30-foot air-propeller was tried at progressive revolutions, varying from 10 to 100 revolutions; also at different angles, varying from 4° to 20°.

SECTION H.—ANTHROPOLOGY.

PRESIDENT OF THE SECTION—C. H. READ, F.S.A.

THURSDAY, SEPTEMBER 14.

The President delivered the following Address:

THE difficulties that beset the President of this Section in preparing an address are chiefly such as arise from the great breadth of our subject. It is thought by some, on the one hand, to comprehend every phase of human activity, so that if a communication does not fall within the scope of any other of the Sections into which the British Association is divided, it must of necessity belong to that of anthropology. On the other hand, there are many men, wanting neither in intelligence nor education, who seem incapable of grasping its general extent, but, mistaking a part for the whole, are fully content with the conclusions that naturally result from such a parochial method of reasoning. The Oxford don who stated, a year or two ago, his belief that anthropology rested on a foundation of romance can only have arrived at this opinion by some such inadequate process, and the conclusion necessarily fails to carry conviction. The statement was, however, singularly ill-advised, for anthropology gives way to no other branch of science in its reliance upon facts for its existence and its conclusions. Had the reproach been that the facts were often of a dry and repellent character we might have pleaded extenuating circumstances, but I fear it must have been admitted that there was some justice in the complaint, though we could fairly point to instances where master minds had made even the dry bones of anthropology live, and that without trenching upon the domain of romance.

It is not, however, my purpose to-day to enter upon a general defence of anthropology as a branch of science. It has taken far too firm a hold upon the popular mind to need any such help. I intend rather to treat of one or two special subjects with which I am in daily relation, in order to see whether some practical means cannot be found to bring about a state of things more satisfactory than that at present existing.

The first of these branches is that of the prehistoric antiquities of our own country. It will not be denied that there can be no more legitimate subject of study than the remains of the inhabitants of our islands from the earliest appearance of man up to the time when written history comes to the aid of the archæologist. There is no civilised nation which has not devoted some part of its energies to such studies, and many of them under far less favourable circumstances than ours. The chiefest of our advantages is to be found in the small extent of the area to be explored—an area ridiculously small when compared with that of most of the Continental nations, or with the resources at our command for its exploration. The natural attractions of our islands, moreover, have also had a great influence on our Continental neighbours, so that their incursions have not been few, and no small number of them decided to remain in a country where the necessaries of life were obtainable under such agreeable conditions. The effect of these incursions, so far as our present subject is concerned, is that there is to be found in the British Islands a greater variety of prehistoric and later remains than is seen in most European countries, a fact which should add considerably to the interest of their exploration. At the same time also it must be borne in mind that it is by such researches alone that we can arrive at any true understanding of the conditions of life, the habits and religious beliefs, or the physical characters of the varied races who inhabited Britain in early times.

It may seem unnecessary to urge, in face of these facts, that all such memorials of the past should be, in the first place, preserved; and, in the second, that any examination of them should be undertaken only by properly qualified persons. Unfortunately, however, it has never been more necessary than it is at the present time to insist upon both points, and the fact that these prehistoric remains are scattered impartially over the whole country, with the exception, perhaps, of the sites of ancient forests, makes it almost impossible to devise any special measures for their preservation. An additional difficulty is to be found in the fact that many ancient remains, such as the barrows of the early Bronze Age, are altogether unrecognised as such, and in the process of cultivation have been ploughed down almost to the level of the surrounding surface, until at last the plough scatters the bones and other relics unnoted over the field, and one more document is gone that might have served in the task of reconstructing the history of early man in Britain.

Such accidental and casual destruction is, however, probably unavoidable, and, being so, it is scarcely profitable to dwell upon it. We can, perhaps, with more advantage protest against wilful destruction, whether it be wanton mischief or misplaced archæological zeal. An enlightened public opinion is our only protection against the first of these, and will avail against the second also, but we are surely entitled to look for more active measures in preventing the destruction of archæological monuments in the name of archæology itself. It is a far more common occurrence than is generally realised for a tumulus to be opened by persons totally unqualified for the task either by experience or reading. An account may then be printed in the local journal or newspaper. When such accounts do appear it is often painfully obvious that an accidental and later burial has been mistaken for the principal interment, while the latter has been altogether overlooked, and no useful record has been kept of the relative positions of the various objects found. The loss that science has suffered by this indiscriminate and ill-judged exploration is difficult to estimate, for it should be borne in mind that an ancient burial, once explored, is destroyed for future searchers—no second examination can produce results of any value, though individual objects overlooked by chance may repay the energy of the later comers. So much varied knowledge is, in fact, required for the proper elucidation of the ordinary contents of a British barrow that it is almost impossible for any single person to perform the task unaided. A wide experience in physical anthropology must be combined with an acquaintance fully as wide with the ordinary conditions of such interments and the nature, material, and relative positions of the accompanying relics, all of which must be brought to bear, with discriminating judgment, on the facts laid bare by the digger's spade. Added to this, the greatest precaution is needed that nothing of value be overlooked. In some soils, such as a stiff clay, it is almost impossible to guard against such a casualty, especially when the barrow is of large size and vast masses of earth have to be moved. The amount of profitable care that may be bestowed on scientific work of this character can nowhere be better seen, I am glad to say, than in our own country, in the handsome volumes produced by General Pitt-Rivers as a record of his investigations in the history of the early inhabitants of Dorsetshire. The memoirs contained in them are unsurpassed for scientific thoroughness, and they will probably long stand as the model of what archæological investigation should be. It is very seldom, however, that circumstances conspire so favourably towards a desired end as in the case of General Pitt-Rivers, where a scientific training is joined to the love of research, and finally ample means give full scope for its practice under entirely favourable conditions. While it is, perhaps, too much to expect that all explorations of this character should be carried through with the same minute attention to detail that characterises General Pitt-Rivers's diggings, yet his memoirs should be thoroughly studied before any work of the same kind is entered upon, and should be kept before the mind as the ideal to be attained. It is not too much to say that a diligent study of the works of the two foremost explorers of prehistoric remains in this country—Canon Greenwell and General Pitt-Rivers—will of itself suffice to qualify any intelligent antiquary to conduct the exploration of any like remains. At the same time, it must not be forgotten that exploration is one thing and a useful record of it is another, and here the explorer would do well to invite the co-operation of specialists if he would get the full value out of his work, and there is generally little difficulty in getting such help.

I have ventured to point out, in moderate terms, the dangers to which a large number of our prehistoric sites are liable, and to state under what conditions they should be investigated. It is not unreasonable to expect, if the danger is so obvious, that a remedy should be forthcoming to meet it. In most of the Continental States it would be easy to institute a scheme of State control by which such sites would vest in the Government to just such an extent as would be necessary to prevent their being destroyed, and such a scheme might be cheerfully accepted and applied with success in any country but our own. Here, however we are so accustomed to rely upon individual influence and exertion in matters of this kind that an appeal to the Government is scarcely thought of; while, on the other hand, the rights of property are fortunately so safeguarded by our tradition and law that nothing but a futile Act of Parliament would have the least chance of passing. Moreover, experience teaches us that it is not to State control that we must look. The Ancient Monuments Bill, which was intended to protect a special class of monuments, and was framed with a full regard to the rights of owners, still stands in the Statute Book, but for years past it has had no effective value whatever. That being so, we must look to private organisations, and preferably to those already in existence, for some effectual moral influence and control, and, in my judgment, the appeal could best be made to the local scientific societies. Many of these are very active in their operations, and could well bear an addition to their labours; others, less active, might become more energetic if they had a definite programme. The plan I would propose is this:—Each society should record on the large scale Ordnance map every tumulus or earthwork within the county, and at the same time keep a register of the sites with numbers referring to the map, and in this register should be noted the names of the owner and tenant of the property, as well as any details which would be of use in exploring the tumuli. I am well aware that a survey of this kind has been begun by the Society of Antiquaries of London, and is still in progress; but this is of a far more comprehensive character, and is, moreover, primarily intended for publication. The more limited survey I now advocate would in no way interfere with it, but, on the contrary, would provide material for the other larger scheme. Once the local society is in possession of the necessary information just referred to, it would be the duty of its executive to exercise a beneficent control over any operations affecting the tumuli, and it may safely be said that such control could in no way be brought to bear so easily and effectively as through a local society.

Some of the arguments in favour of some such protection for our unconsidered ancient monuments have been already briefly stated, and, in conclusion, I would only urge this in their favour, that while the more beautiful monuments of later and historic times are but little likely to want defenders, the less attractive early remains are apt to disappear not so much from want of appreciation as from want of knowledge, and I would repeat that it is from them alone that we can reconstitute the life-story of those who lived in what we may, with truth, call our dark ages.

I will now ask you to turn your attention to another matter in which it seems to me that this country has opportunities of an unusually favourable kind. I refer to the collection of anthropological material from races which still remain in a fairly primitive state. It is somewhat trite to allude to the extent of our Empire and the vast number of races either subject to our rule or who look to us for guidance and protection. The number may be variously computed according to the bias, philological or physical, of the observer, but it will not be contested that our opportunities are without precedent in history, nor that they greatly exceed those of any existing nation. That being so, it may not be useless to see how far these opportunities are utilised. While it will not be denied that the Indian Government and the Governments of some of our colonies have done excellent work in the direction of anthropological research and publication, and that exhaustive reports from our colonial officials are frequently received and afterwards entombed in parliamentary papers, yet it is equally clear that work of this kind is not a part of our administrative system, but rather the protest of the intelligent official mind against the monotony of routine. The material, the opportunity, as well as the intelligence and will to use both, are already in existence, and all that is now wanted is that the last should be encouraged and the work be done on a systematic plan, and, as far as may be, focussed on some centre where it may be available for present and future use. It was for this end that I ventured to bring before the British Association at the Liverpool meeting a scheme for the establishment of a central Bureau of Ethnology for Greater Britain. Frequent appeals had been made to me by officials of all kinds in distant parts of the Empire to tell them what kind of research work they could most usefully undertake, and it seemed a pity not to reduce so much energy and goodwill into a system. Hence the Bureau of Ethnology. The Council of the Association, on the recommendation of the Committee, invited the Trustees of the British Museum to undertake the working of the Bureau; this they have accepted, with the result that if the Treasury will grant the small yearly outlay it will be under my own supervision. If I had foreseen this ending I might have hesitated before starting a hare the chasing of which will be no sinecure.

It was considered necessary, before attempting to begin the work of the Bureau by communicating with commissioners and other officials in the various Colonies and Protectorates, to lay the matter before Lord Salisbury and to invite his approval of the scheme. The whole correspondence will appear in the Report of the present meeting, but I may be pardoned for quoting one paragraph of the circular letter from the Foreign Office to the several African Protectorates. It is as follows: 'Lord Salisbury is of opinion that Her Majesty's officers should be encouraged to furnish any information desired by the Bureau, so far as their duties will allow of their doing so, and I am to request you to inform the officers under your administration accordingly.' When it is remembered that this is strictly official phraseology, its tenor may be considered entirely satisfactory, and there can be little doubt that other departments of the Government will recognise the utility of the Bureau in the same liberal spirit. Thus we shall have within a short time an organisation which will systematically gather the records of the many races which are either disappearing before the advancing white man, or, what is equally fatal from the anthropological point of view, are rapidly adopting the white man's habits and forgetting their own.

The Bureau of Ethnology, however, will only perform a part of the task that has to be done. While there is no doubt of the value of knowledge as to the religious beliefs and customs of existing savages, it is surely of equal importance that anthropological and ethnological collections should be gathered together with the same energy. The spear of the savage is, in fact, far more likely to be replaced by the rifle than is his religion to give way to ours. Thus the spear will disappear long before the religion is forgotten. It may be said that we have collections of this kind in plenty, and it is true that in the British Museum, at Oxford, Cambridge, Liverpool, and Salisbury, there are indeed excellent collections of ethnology, while at the College of Surgeons and the Natural History Museum there are illustrations of physical anthropology in great quantity. Whatever might be the result if all these were brought together, there can be no question that no one of them meets the requirements of the time. Here also there is a want of a system that shall at once be worthy of our Empire and so devised as to serve the ends of the student. Where, if not in England, should be found the completest collections of all the races of the Empire? It must be admitted, however, not only that we have no national collection of the kind, but that other nations are ahead of us in this matter. This could be readily understood if their sources of supply were at all comparable to ours. But this is, of course, very far from being the case. The sources are ours in great part, and if we stand inactive it is not unlikely that some will be exhausted when we do come to draw upon them. It is, perhaps, better to give here a case in point rather than to rely on general statements. In the summer of last year I arranged, with the approval of the Trustees, that Mr. Dalton, one of the officers of my department, should make a tour of inspection of the ethnographical museums of Germany, with a definite object in view, but at the same time that he should make a general survey of their system and resources as compared with our own. The report which he drew up on his return was printed and has recently been communicated to the newspapers; it is therefore not necessary to allude to it now, except to quote one instance confirming my statement that it is to a great extent from our colonies that material is being drawn. Mr. Dalton says: 'On a moderate estimate the Berlin collections are six or seven times as extensive as ours. To mention a single point, the British province of Assam is represented in Berlin by a whole room and in London by a single case.' But even this, forcible though it is, does not adequately represent the vast difference between the material at the disposal of the two countries. For it is the habit of the collectors for the German museums to procure duplicates or triplicates of every object, for the purposes of exchange or study. It is thus not unlikely that the whole room referred to represents only a part of the Berlin collection from the British province of Assam. In making these observations, I should be sorry if it were thought that I wish to advocate a dog-in-the-manger policy, or that I consider it either desirable or politic to place any restriction upon scientific work in our colonial possessions, even if such restrictions were possible. I would prefer to look at the matter from an entirely different point of view. If the German people, who are admittedly practical and businesslike, think it worth while, with their limited colonies, to spend so much time and money on the establishment of a royal museum of ethnography, how much more is it our duty to establish and maintain one, and on a scale that shall bear some relation to the magnitude of our Empire. The value of such museums is by no means confined to the scientific inquirer, but they may equally be made to serve the purpose of the trader and the public at large.

How can we best obtain such a museum? That is the question that we have to answer. It is scarcely profitable to expect that the Government will be stirred to emulation by the description of the size and resources of the Museum für Völkerkunde in Berlin. In the British Museum there is at the present time only the most limited accommodation even for the collections already housed there, and I am well aware that these form a very inadequate representation of the subject.

It may be thought that the solution of this difficulty is easy. It is well known that the Government has purchased the rest of the block of land on which the British Museum stands, and it may seem that such a liberal extension as this will form should be enough for, at any rate, a generation or two, and that a little additional building would meet immediate wants, and enable the collections, now so painfully crowded, to be set out in an instructive and interesting way. I admit that if the whole of the contemplated buildings were at this moment complete, and at least double as much space given to the ethnographical collections as they occupy at present, the difficulty would be much simplified. The collections could at any rate be then displayed far more worthily and usefully. Even this, however, would hardly meet the case, even if there were a certainty of the buildings being immediately begun. Such works as these, however, can only be executed in sections during the course of each financial year. Thus, even if a Chancellor of the Exchequer could be found to fall in entirely with the views of the Trustees, it would still be an appreciable number of years before the completion of the entire range of galleries that is contemplated. For this reason alone I do not look forward to obtaining the space that is even now urgently wanted for some time. Meanwhile the natural and legitimate increase of the collections at the rate of about 1 to 2 per cent. per annum still goes on, and the original difficulty of want of room would still face us, though in a lesser degree. This estimate of the rate of increase may seem a high one; but it should not be forgotten that the science is new, and that it is only within the last few years that such collections have been made on scientific lines, instead of being governed only by the attractive character or rarity of the object. The gaps that exist in such a series as that of the British Museum, made in great part on the old lines, are relatively more numerous than would be the case in museums more recently founded. Another reason, equally cogent, for allowing far more room than is required for the mere exhibition of the objects is that, in my judgment, ethnographical collections, to be of real value, need elucidation by means of models, maps, and explanatory descriptions, to a far greater extent than do works of art, which to the trained eye speak eloquently for themselves. Such helps to understanding necessitate a considerable amount of space, though the outlay is fully justified by their obvious utility, and in any general scheme of rearrangement of the national collection they should be considered an essential feature.

There is yet another factor to be considered. It has been the fashion in this country to consider remains illustrating the physical characters of man to belong to natural history, while the productions of primitive and uncultured races generally find a place on the antiquarian side. Thus the skull of a Maori will be found at the natural history branch of the British Museum, while all the productions of the Maori are three miles distant in Bloomsbury. Such an arrangement can perhaps be defended on logical grounds, but its practical working leaves much to desire, and the arguments for a fusion of the two are undoubtedly strong. For instance, the student of one branch would be unlikely to study it alone without acquiring a knowledge of the other, while the explorers to whom we look for collections usually give their attention to both classes of anthropological material. Here again, in such a case, there would be a call for still more space at Bloomsbury.

If I may be permitted to add one more to the requirements of what should be an attainable ideal, I should like to say that courses of lectures on anthropology delivered in the same building that contains the collections would form a fitting crown to such a scheme for a really Imperial museum of anthropology as I have endeavoured to sketch. There is but one chair of anthropology in this country, and admirably as that is filled by Professor Tylor, he would himself be the first to admit that there is ample room and ample material to justify the creation of a second professorship.

It will be admitted that if my premisses are well founded the conclusion must necessarily be that we cannot look to the British Museum to furnish us eventually with the needful area and other resources for the installation of a worthy museum of anthropology. The difficulties are far too great for the Trustees to overcome, unless by the aid of such an exhibition of popular enthusiasm as I fear our branch of science cannot at present command. Failing the British Museum, which may be called the natural home of such a collection, we must look elsewhere for the necessary conditions, and I think they are to be found, although it is possible that, however favourable these conditions may seem from our point of view, difficulties may already exist or arise later.

It is not the first time that a scheme has been thought out for the establishment of a museum or kindred institution which should represent our colonies and India. In the year 1877 the Royal Colonial Institute made a vigorous effort in this direction, and, in combination with the various chambers of commerce throughout the country, advocated the building of an 'Imperial Museum for the Colonies and India' on the Thames Embankment, with the then existing India Museum as a nucleus. The arguments then brought forward were in the main commercial, but they are, if anything, more forcible now than they were twenty years ago. The competition with foreign countries has become keener on the one hand, while the bonds between the colonies and the parent country are notoriously closer and more firm than at any previous time. No moment could thus be more opportune than the present for the foundation of a really Imperial Institution to represent our vast Colonial Empire.

The last sentence has, perhaps, given an indication of my solution of the question. The Imperial Institute at South Kensington has now been in existence for some time, and has passed through various phases. But its most enthusiastic supporters will scarcely claim for it entire success in its mission. Whatever may be the underlying causes, it must be admitted that such popular support as it possesses is scarcely founded on the performance of its functions as an Imperial Institute. It would seem, therefore, that something more is wanted—a more definite *raison d'être*—than it has at present, and this I think it will find in being converted into such a museum of anthropology as I have indicated, but, of course, as a Government institution I am by no means an advocate of the creation of new institutions, if the old ones can adequately do their work, nor do I think that anything but ill would result from a general partition of the contents of the British Museum. The separation of the natural history from the other collections was painful, though inevitable, and no such severe operation can be performed without loss in some direction. But the removal of the ethnographical and anthropological collections from the British Museum to the galleries of the Imperial Institute would possess so many manifest advantages that the disadvantages need scarcely be considered. The Government has already taken over a portion of the building for the benefit of the University of London. The remaining portion would provide ample accommodation for the anthropological museum, as well as for the commercial side, that might properly and usefully be continued; its proximity to the natural history branch of the British Museum would render control by the trustees easy; the Indian collections, which formed so important a feature in the scheme of 1877, are at this moment under the same roof; and finally the University of London has but to found a chair of anthropology, and the whole of the necessary conditions of success are fulfilled.

I have but little doubt that, wherever it might be placed, the creation of a distinct department of anthropology would of itself tend to the enrichment of the collections. It must be remembered that it is only since 1883, when the Christy collection was removed to the British Museum, that the ethnographical collections there can claim any kind of completeness. Until then one small room contained the few important objects of this kind that had survived from the voyages of Cook, Wallis, and the other early voyagers. The public did not expect to find ethnography in the British Museum, and it is, in fact, only within the last few years that it has been generally realised that a gallery of ethnography exists there. If it were placed in such a building as the Imperial Institute, it would still remain part of the British Museum, and be under the guardianship of its Trustees; but it would obviously command more attention and support from the public than can be expected while it remains an integral part of a large institution which has as many aims as it has departments.

I began this address by stating that it would have a practical application. I trust that to others it may seem that what I have ventured to suggest is not only possible of achievement, but would also be beneficial to the branch of science that we represent. I should like to add that, as far as possible, I have tried to state the case as it would appear to one who regarded the situation from an entirely independent standpoint, and wishing only to discover the most practical solution of what must be admitted to be a difficult question. My allegiance to the British Museum, however, may well have tinged my views, unnoticed by myself. There are many other subjects that might well have formed the subject of an address at the present time. On such occasions as these, however, it is, I think, advisable to select a subject with especial reference to the needs of the time, and I know of nothing that is at the present moment more urgent in this particular direction, and in my judgment it will tend greatly towards the true advancement of science, the object we all have at heart.

The following Reports and Papers were read:—

1. *Report on the New Edition of 'Anthropological Notes and Queries.'*[1]

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2. *Report on Photographs of Anthropological Interest.*
See Reports, p. 592.

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3. *The Presidential Address was delivered.* See p. 861.

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4. *The Personal Equation in Anthropometry.* *By* Dr. J. G. GARSON.

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5. *Finger Prints of Young Children.* *By* FRANCIS GALTON, *D.C.L., F.R.S.*

At the times when I published my book on 'Finger Prints,' and subsequent works on the same subject, no material existed for determining the age at which the patterns of the ridges on the fingers and their numerous details became first established. The ridges were known to be traceable in some degree long before birth, but it was not known whether they had acquired, even in early childhood, that strange complexity of distribution which I showed to be permanent from youth upwards. The wish to complete my work by investigating this interesting physiological point was sharpened by a request for an opinion on the following case. The police authorities in —— (I will not say what country) received information that a baby who was heir to a great title and estate might be kidnapped for the sake of extorting ransom. Such cases have occurred in history, and it is needless to insist on the miserable doubts and legal difficulties that would arise if a stolen infant should be restored after the lapse of some time without satisfactory identification. I was asked whether prints of the fingers of a baby would serve for ever afterwards to identify him, and to prove that he was not a changeling.

An American lady—Mrs. John Gardiner, of Boulder, Colorado—kindly volunteered to collect finger prints of infants for me. The following remarks are confined to those of her own child Dorothy, whose fingers she printed every day after that of her birth for a short time, then less frequently, and afterwards yearly, the child being now 4½ years old. By selecting the best of the numerous specimens of the earlier dates, I compiled three sets of all the ten fingers. In the first set the age of the child lay between 9 days and a month. In the second, between 1 month and 6 weeks; in the third, between 5 and 7 months. In addition, I have a fourth set taken at 17 months, a fifth at 2½ years, and a sixth at 4½ years.

It is easy to those who have learnt the art, and who have the necessary materials, to print with sharpness the fingers of children who have attained six years of age or upwards; but it is exceedingly difficult to print the fingers of babies. Far more delicate printing is needed on account of the low relief of the ridges and the minuteness of the pattern. At the same time, babies are most difficult to deal with, the persistent closing of their fists being not the least of the difficulties. The result is that many undecipherable blurs are made before one moderate success is attained, and, at the best, the print is made by a mere dab of the finger, rolled impressions being practically impossible. Consequently the first four sets are all more or less blotted, and none show more than a small part of that surface which it is desirable to print.

The fifth and sixth sets are clear though pale, for it was necessary to spread the ink very thinly to avoid blots; otherwise they are perfectly suited for comparisons. The two sets agree in every detail, and show the same order of complexity that is found in the ridges of adult persons; so, subject to the possibility of some minute after change, I should infer that the print of a child's fingers at the age of 2½ years would serve to identify him ever after. It will be interesting

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[1] The book was published in November.

after the lapse of some years to ascertain whether this is the case with Miss Dorothy Gardiner.

The first four sets are much more difficult to deal with. I have scrutinised them, and compared them several times with the last two sets and with one another, and my conclusions are as follows:—

(1) The *type* of the pattern is never doubtful to a practised eye. To an unpractised eye the result of a slight twist of the finger at the moment of printing, which gives a specious air of circularity, might convey the false impression of a whorl to what was really an arch or a loop. (2) The character of the core is defined within narrow limits, but not always accurately. Thus in one instance, the core of a loop in the 2½ and 4½ year sets was a clear 'staple.' At 17 months the staple was connected to the curve next above it by a small isthmus; in babyhood the staple and the ridge were joined—whether by a blot or in reality I cannot say. (3) A similar absence of distinction between ridges that are afterwards clearly separated is often found near the V point. It is thus impossible to count the number of ridges with accuracy that lie between the core and the V, and the entry has often to take such a form at 9 + ? the ? proving to be any number between one and perhaps eight ridges. It is, however, a great point to be assured that the real number is *not less* than 9. (4) The doubt (as I pointed out in my book) which is always attached to the exact way in which a new ridge arises is greatly increased in these prints. No weight should be assigned to the character of the junction or ending, but only to the fact that somehow a new ridge has become interpolated.

The study of these prints is an excellent discipline in the art of decipherment. I have counted sixty-eight details in the prints of these ten fingers that can be identified throughout all six sets, unless obliterated in some one of them by a blot. In the majority of cases the identity is unquestionable; in the others it may be trusted within narrow limits. I have therefore little doubt that the prints of all ten fingers of a baby, if taken as clearly as those I have dealt with, would suffice for after identification by an expert, but by an expert only.

It should be added that I have had as yet no opportunity of taking finger prints from infants who are two or even more months younger than babies ordinarily are at the time of their births—I mean such as are now successfully reared in warmed glass cases. These premature infants are passive, and in that respect easy to deal with, but they are tiny creatures who require great tenderness in handling. I think that the impressions most likely to succeed would be those that their greasy fingers might leave on a highly polished metal plate, to be afterwards photographed under suitable illumination.

6. *Finger Prints and the Detection of Crime in India, describing the System of classifying Finger Prints and how all the great Departments in India have brought Finger Prints into use. By* E. R. Henry, *C.S.I., Inspector-General of Police, Bengal Civil Service.*

The author refers to the importance of fixing human personality so that no efforts made to confuse it subsequently may prove availing. Of this problem the Bertillon system offered first scientific solution. But experience has shown that the 'Personal Equation' error of measures predominates so much as to vitiate seriously the correctness of the recorded results under that system. Finger prints, on the other hand, being absolute impressions taken from body under conditions which eliminate error in transcribing or recording, the 'Personal Equation' error is reduced to a minimum. Taking the impressions of all ten digits occupies only a fraction of the time required for measuring, while search is more exhaustive and many times more rapid. This new system has been introduced on a most extensive scale throughout British India, where the Postal, Survey, Registration, Medical, Pensions, Emigration, Police, Opium, and other great Departments have adopted it, and the Legislature has recognised it by passing, with the strong approval of all representative bodies consulted, an Act to amend the Law of Evidence so as to make relevant the testimony of Finger-print Experts.

The main difficulty hitherto experienced had been that of providing an effective system of classification. But this difficulty has been overcome. A thin film of printer's ink is spread over a piece of flat tin, and each finger in turn is pressed on the film, and after being thus inked is pressed on paper where a clear, sharp impression is left. Fingers are impressed in their natural order of thumb, index, middle, ring, and little, those of the right hand being above, and the corresponding digit of the left hand below them.

All impressions must be either arches, loops, whorls, or composites—there is a great preponderance of loops and whorls. In primary classification arches are included under loops, and composites under whorls, and therefore, for purposes of primary classification, an impression must be either a loop or whorl. The digits are taken in the following pairs: (1) right thumb and right index; (2) right middle and right ring; (3) right little and left thumb; (4) left index and left middle; (5) left ring and left little finger. Taking first pair and denoting loop by L and whorl by W, we get the following arrangements. Right thumb may be L and right index L; right thumb may be L and right index W; right thumb may be W and right index L; and right thumb may be W and right index W. So there are four, and not more than four, arrangements possible. Similarly, in second pair, there are four such arrangements, which, taken with those of the first pair, yield 16 combinations; taking the third pair we get 64 combinations, and by adding the fourth and fifth pairs, this number rises to 256 and 1,024. Now 1,024 equals 32 squared; in other words, a cabinet containing 32 sets of 32 pigeon-holes arranged vertically would provide all the locations required. A diagram shows how this works in practice. But the following rule is very simple. The first of each pair is shown as numerator, the second of each pair as denominator, yielding for the five sets of pairs some such formula as the following: $\frac{L}{W}$; $\frac{W}{L}$; $\frac{L}{L}$; $\frac{W}{W}$; $\frac{L}{W}$. A whorl in the first pair counts 16, in the second pair 8, in the third 4, in the fourth 2, in the fifth 1. No numerical value is given to a loop. Substituting these values in the formula we get $\frac{0}{16}$; $\frac{8}{0}$; $\frac{0}{0}$; $\frac{2}{2}$; $\frac{0}{1}=\frac{10}{19}$. Add 1 to both numerator and denominator and invert the fraction which becomes $\frac{20}{11}$, and this is the Primary classification number, and represents that the card containing these impressions will be found on the twentieth pigeon-hole of the eleventh vertical row. The Secondary classification required to break up accumulations is equally simple, and the search formula or legend for each card can be prepared rapidly without any key and brings search down to groups of very small volume.

FRIDAY, SEPTEMBER 15.

The following Report and Papers were read:—

1. *Report on the Expedition to Torres Straits and New Guinea.*

See Reports, p. 585.

2. *The Linguistic Results of the Cambridge Expedition to Torres Straits and New Guinea.* *By* SIDNEY H. RAY.—See Reports, p. 598.

3. *Notes on Savage Music.* *By* C. S. MYERS.—See Reports, p. 591.

4. *Seclusion of Girls at Mabuiag, Torres Straits.* *By* C. G. SELIGMANN. See Reports, p. 590.

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5. *Notes on the Club Houses and Dubus of British New Guinea.* *By* C. G. SELIGMANN.—See Reports, p. 591.

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6. *Notes on the Otati Tribe, North Queensland.* *By* C. G. SELIGMANN.

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7. *Contributions to Comparative Psychology from Torres Straits and New Guinea.*—See Reports, p. 586.

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8. Professor HADDON exhibited Photographs from Torres Straits and British New Guinea.

SATURDAY, SEPTEMBER 16.

The following Papers and Report were read:—

1. *Some New Observations and a Suggestion on Stonehenge.*
By ALFRED EDDOWES, *M.D., M.R.C.P.*

The author believes that the thirty large upright stones, with their intervals, indicate that the circle was divided into sixty equal parts; that the Grooved Stone (which is the best selected, worked, and preserved stone in the whole ruin, but has never hitherto received the attention it deserved) was used for supporting a pole in a definite and permanent manner; and that the signs of wear at the mouth of the groove, together with the two worn horizontal hollows or waists, and the dimples on the convex back of the stone, indicate not only *where*, but *how*, this pole was fixed. Such a pole would form the pointer of a sun-dial for daily observation, or—what was more important—an indicator of the time of year, by the length of its shadow. The levelled avenue (along which the sun's shadow would fall about 3 P.M.) and the flat 'slaughter-stone' with its arrow-head marking, seem to the author to support his view.

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2. *Interim Report on Investigations of the Age of Stone Circles.*

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3. *Notes on the Discovery of Stone Implements in Pitcairn's Island.*
By J. ALLEN-BROWN, *F.G.S., F.R.G.S.*

The implements were obtained in Pitcairn Island by Lieutenant Gerald Pike, R.N., during the cruise of H.M.S. *Comus* in 1897–8, and the greater part of them are in his possession.

They are made of the compact volcanic rock of the island, and were discovered about a foot below the surface.

One class consists of small celts chipped and partially ground, with the sides worked to a ridge, and resemble those discovered at Tahiti and in some other islands of the Pacific. Another class consists of large chipped and ground axes with long narrow shank and widespread cutting edge. Other forms again are a long clublike chisel, well smoothed and shaped as if for a handle grip at the butt-end, and a plain cylindrical club, such as might be used for beating Tapu cloth, though the modern Tapu clubs are of wood, and square in section.

4. *On the Occurrence of 'Celtic' Types of Fibula of the Hallstatt and La Tène Periods in Tunisia and Eastern Algeria.* By ARTHUR J. EVANS, *M.A., F.S.A.*

In the course of a recent journey through Tunisia and Eastern Algeria, the author found repeated evidence that a form of 'Late Celtic' fibula, answering to a well-known 'Middle La Tène' type of continental archæologists, was in use among the ancient Numidians. Three examples of this were described; two from near Constantine (the ancient *Cirta*), and one from a dolmen near El-Kef (*Sicca Venerea*). The author traced the origin of this type in the lands about the head of the Adriatic, and its subsequent diffusion on European soil. Attention was called to the new materials for the chronology of this and other allied forms, supplied by Bianchetti's excavations in the Gaulish cemeteries of Ornavasso near the Lago Maggiore, where a large series of tombs were approximately dated by the presence of coins.

The author also described some examples of earlier fibulæ found at Carthage, and in a dolmen near Guyotville in Algeria. Two of the forms are parallel to those found in the early cemetery of Fusco near Syracuse, and may have been due to the same Corinthian influence which during the sixth, seventh, and eighth centuries seems to have been predominant at Carthage itself. Another Carthaginian fibula is identical with a Hallstatt type, and is the prototype of the 'cross-bow' form so widely distributed throughout the north, when it gave birth to a long succession of derivative forms reaching down in Gothland and elsewhere to mediæval times. In the case of both the earlier and later African examples there is thus an indication pointing to the ancient course of the amber trade by the Adriatic coast. The appearance of Celtic types of fibula among the Numidians finds its complement in the discovery of large hoards of Carthaginian and Numidian coins on the transit line of this commerce between the Save and the Adriatic. Attention was further called to the appearance of 'Late Celtic' forms of Fibula in the Carthaginian Dominion of Western Sicily.

5. *On Irish Copper Celts.* By GEORGE COFFEY.

Celts, apparently of unalloyed copper, though rare compared with those of bronze, have been found in considerable numbers in Ireland. Thirty specimens are described or mentioned in the Catalogue of the Museum of the Royal Irish Academy, published in 1861. The Academy's Collection (now in the National Museum, Dublin) at present numbers eighty-two examples.

Copper celts are not confined to any particular district: examples are recorded from the counties of Donegal, Londonderry, Antrim, Cavan, Mayo, Galway, Louth, Tipperary, Waterford, Cork—localities embracing the extreme north and south, and east and west of the island.

One specimen was analysed by J. W. Mallet in 1853: it gave copper, 98·74; tin, 1·09.[1]

During the present year Mr. J. Holmes Pollok, Royal College of Science, Dublin, kindly analysed for me eight additional specimens as shown on next page.

The analyses are fairly in line with analyses of copper celts from other parts of Europe, with the exception of W. 10. This celt is one of the best finished copper celts in the collection; the metal is, however, very soft and hardly serviceable. It is remarkable for the almost total absence of tin (0·05) and the high percentage of lead (2·74). There is not evidence to show whether the presence of the lead is intentional or accidental. It was found at Tramore, county Waterford, a rich copper district. Numerous lodes of copper and lead are exposed in the cliffs of this locality, and extensive remains of ancient workings have been found in a promontory near Tramore.

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[1] *Trans. R.I.A.* vol. xxii.

—	Londonderry	—	Cork	Galway	Tyrone	—	Waterford	—
Reference	W. 3	W. 17	1881/136	1874/38	1897/112	1896/7	W. 10	1875/20
Density .	8·833	8·698	8·430	8·749	8·862	8·811	8·987	8·705
Copper .	98·43	96·75	98·73	97 68	97·25	97·17	96·46	98·24
Arsenic .	·76	1·35	·18	·76	1·56	1·86	Trace	·13
Tin . .	Trace	·50	·10	·79	·51	·27	·05	·83
Silver .	·25	·14	·13	·18	·25	·11	—	·07
Lead .	·05	·46	·07	—	·17	·17	2·74	·12
Zinc .	—	—	—	·44	—	—	—	—
Nickel .	—	—	—	—	—	—	·21	—
Iron .	—	·07	—	—	·10	—	·25	—
Total .	99·49	99·27	99·21	99·85	99·84	99·58	99·71	99·39

The classification of the copper celts by metal is confirmed by type divisions. The copper celts are invariably of the plain flat type, without ornament, and in no instance showing even rudimentary stop ridges. Ten specimens closely resemble common forms of Irish small stone celts. Some of these might be regarded as ingots, but in four instances they have been ground to an edge for use. The examples of developed metal form are in general ruder and heavier than bronze celts. In some cases the rough surface marks of casting have not been removed, but in many instances these celts show traces of having been rubbed down over the body of the celt, after the manner of stone celts. Celts of the developed copper form can be classified under two main types.

1. More or less V-shaped; flare of cutting edge wide compared with length of celt, leading to plain bronze celt of type (Evans, fig. 28, and Wilde, fig. 247).

2. Cutting edge narrow compared with length, and in some instances nearly semicircular; sides more or less parallel, leading to long, slender, plain bronze celt of type (Evans, fig. 33). In several instances types 1 and 2 cross. In both types the butt end, in the majority of examples, is thick and squared off, showing a quadrangular section. As the types approach those of the bronze celts a thinning off of the butt end is noticeable.

The copper celts appear, therefore, to represent, apart from metal, a transition from stone to bronze types, and can be arranged in series showing development of form from stone to bronze.

From the preceding facts it would appear reasonable to conclude that, prior to a knowledge of bronze, copper was known and used for cutting implements in Ireland.

This statement is supported by a find of three copper celts, a copper tanged knife, and three copper awls, all found together at Kilbannon, county Galway (Academy Collection). One of the celts is included in the eight analysed by Mr. Pollok, 1874: 38. All these objects seem to be copper, and agree most closely in the appearance of the metal, as if made from the same piece. The awls are of early type, pointed at both ends and without shoulders, and the knife also appears to be of an early type.

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6. *Stone Moulds for New Types of Implements from Ireland.*

By G. Coffey.

MONDAY, SEPTEMBER 18.

The following Reports and Papers were read:—

1. *Final Report on the Ethnographical Survey of the United Kingdom.* See Reports, p. 493.

2. *On Recent Ethnographical Work in Scotland.*

By J. GRAY, *B.Sc.*

Preliminary observations on the physical characteristics of the people of East Aberdeenshire, begun in 1895 by the Buchan Field Club, were summarised in a paper at the Ipswich Meeting of this Association (1895, p. 831), and published more fully in the 'Transactions' of the Buchan Field Club.

A pigmentation survey of the whole of the school-children of East Aberdeenshire has since been completed, chiefly through the organising ability of Mr. Tocher, the Secretary of the Buchan Field Club, and the generous and gratuitous co-operation of the school teachers. Returns were received between October 1895 and November 1897, from over ninety schools, comprising nearly 14,000 children.

The scheme of colours for hair and eyes was practically the same as that of Dr. Beddoe; but his two darkest classes for hair were amalgamated into one. Comparison with Dr. Virchow's survey of German school children would, however, have been facilitated if blue eyes had been separated from other light eyes.

The Pigmentation of the school children (with that of adults added for comparison) is shown in the following table of average results:—

—	Hair				Eyes		
	Fair	Red	Brown	Dark	Light	Medium	Dark
Children, total	25·3	7·0	46·5	21·2	41·0	35·0	24·0
,, Boys .	23·6	6·8	48·2	21·4	41·6	35·8	22·6
,, Girls .	26·9	7·3	44·7	21·1	40·6	33·8	25·6
Adults, total .	9·5	5·7	64·1	20·7	25·4	48·6	26·0
,, Males .	9·5	5·6	66·2	18·7	26·3	50·7	22·8
,, Females .	9·8	6·4	54·8	29·0	21·6	39·0	39·4

A study of this table reveals several noteworthy facts:—

(1) About 15½ per cent. of the fair-haired children become brown-haired adults—almost exactly the same percentage that Virchow found to become brunette in Germany, and about 15 per cent. light-eyed become medium or dark-eyed.

(2) Between boys and girls the percentage of dark hair is practically equal, and the girls have only 3 per cent. excess of dark eyes; but adult females have 11 per cent. more dark hair than adult males, and 16½ per cent. more dark eyes. The darkening of the females is therefore post-natal. Ripley points out the same excessive pigmentation of the females among the Jews, and also in regions like Alsace, where a blonde race has invaded a brunette country.

A comparison with the continental districts whence, according to tradition and history, we have derived a large element in our population, namely, Schleswig-Holstein, Lüneberg, and Mecklenburg-Schwerin, the reputed original seats of the Angles and Saxons, is shown in the following table:[1]—

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[1] The Aberdeenshire 'blonde-type' (including fair hair with light grey eyes, as well as with blue) is rather larger than Virchow's (which includes only the blue eyes), but the 'brunette types' are practically the same.

—	Brunette type	Blonde type	Blonde hair	Brown hair	Light eyes	Brown eyes
Upper Bavaria	24	17	51	48	25·7	34
Schleswig-Holstein	7	43	82	18	50	16
Lüneburg	7	44	83	17	49	18
Mecklenburg-Schwerin	10	42	77	23	49	21
East Aberdeenshire	20·4	16·2	25·3	67·7	41	24

The three North German districts are clearly much more blonde than East Aberdeenshire. Germany, as Virchow's survey has shown, gets more brunette and less blonde from north to south; but we must go to its extreme southern frontier—*i.e.* to Upper Bavaria—before we find a district approximating in pigmentation to East Aberdeenshire.

It is noteworthy that whereas in Germany (especially in North Germany) there is always more blonde hair than blue eyes, in Aberdeenshire the reverse is the case. Of this, two explanations are possible: (1) that the immigrants from Germany were not pure blondes, but of a mixed variety with brown hair and blue eyes; or (2) that pure blonde immigrants found here a population with brown eyes, and hair so black as to resist depigmentation longer than the brown eyes.

The maps of different elements show blonde areas on the accessible parts of the coast, and brunette areas on the inaccessible parts.

The Stature of 169 persons measured at Mintlaw in 1895 averaged 5 feet 8½ inches (which is about the average for Scotland), with three distinct peaks of maximum frequency at 5 feet 7½ inches, 5 feet 9 inches, and 5 feet 11½ inches. Of thirteen persons of 5 feet 11½ inches in height, nine were dark, three brown, and one fair-haired, the other two heights comprise equal numbers of fair and dark.

The Head Measurements show cephalic indices lying almost entirely between 74 and 84, with peaks of maximum frequency at 77 and 79. These indices do not give a satisfactory analysis into race groups; but on plotting the head-measurements on a chart with the length and breadth as co-ordinates, the people are separated into three groups, coinciding very closely with Beddoe's average dimensions plotted on the same chart; of (1) Italians and Row-grave-men; (2) Danes; (3) Hanoverians. The Danish group is the most numerous, the Italian coming next, and the Hanoverian last. Mixed groups also appear on the chart, having the length of one typical group, and the breadth of another.

3. *Report on the Mental and Physical Condition of Children in Elementary Schools.* See Reports, p. 489.

4. *On Recent Anthropometrical Work in Egypt.*

By D. MacIver, *B.A.*

The author gives examples of the ways in which anthropometry may aid archæological investigation, and points out the unusually favourable conditions for such anthropometrical work which exist in Egypt. He gives a summary of the series of Egyptian measurements at present available, of the difficulties which have arisen in their interpretation, and of some new methods of publishing measurements specially designed to meet them.

Details are given of three important series of specimens from Egypt, viz.:

(1) Prehistoric Series; from the excavations of 1898-9.
(2) VI. to XII. Dynasties; from the excavations of 1898.
(3) XII. to XVI. or XVII. Dynasties; from the excavations of 1898-9.

These series are considered (*a*) separately, with the object of ascertaining the race type represented in each; (*b*) in comparison with one another, to show their affinities and differences. The paper concludes with a note on the light which such comparison throws on Egyptian history.

5. *Notes on a Collection of* 1,000 *Egyptian Crania.*
By Professor A. MACALISTER, *F.R.S.*

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6. *On a Pre-basi-occipital Bone in a New Hebridean Skull, and an anomalous Atlanto-occipital Joint in a Moriori.* *By* Professor A. MACALISTER, *F.R.S.*

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7. *Notes on Colour Selection in Man.* *By* Dr. J. BEDDOE, *F.R.S.*

The author notes the prevalence of light colours of eyes and hair in those who follow occupations which have to do with animals, *e.g.* butchers, grooms, and carters, and the opposite in some sedentary occupations; and seeks an explanation.

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8. *Report on the Lake Village of Glastonbury.* See Reports, p. 594.

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9. *Sequences of Prehistoric Remains.*
By Professor W. M. FLINDERS PETRIE.

In written history the value of chronology lies almost entirely in its defining the sequence of events; and if the order of changes in a civilisation can be fixed, the reference to a scale of years is but a secondary matter.

Hitherto, only very vague and general terms, covering large periods, have been used in naming prehistoric remains; and those terms referring to places and not to age. The very incomplete records of discoveries make such terms the best that can be usually attained.

But if we possessed a perfect record of an unlimited number of contemporary groups of objects (as from tombs), all of which objects have had a time of invention, popularity, and decay, and in use overlapped each other, it is clear that with patience it would be possible to arrange all the series of groups in their order of time, and so establish definite sequences among the various objects. Such a task would be like that of reconstructing the order of an alphabet from torn-up fragments which contained only two or three letters each, or settling the sequence of scattered geological beds from the remains found in each.

If then a sequence can be established, a scale of notation is needed. As a scale of years is impossible, a scale of equal activities is the most reasonable. This may be reached by placing all the available material in order (from tombs, houses, &c.) and then dividing it into a scale of equal parts. Such a scale, though not equal in time, will yet give a fair unit for measuring a civilisation.

From the records of the excavations that my party have made in Egypt, we have the contents of some thousands of prehistoric tombs exactly known. Every type of vase, of stone or pottery, is defined in a *corpus* containing over a thousand forms, so that merely a letter and a number defines precisely what was found. Thus, all the complexity of variations can be dealt with rigorously in a workable condition.

The practical process for dealing with this material is by writing out the contents of each grave on one slip of card; and then sorting the cards into such order that there shall be the minimum dispersion of each type number.

The methods of sorting the cards into the original order of the graves (as nearly as possible), depend on various principles.

1. Any certain superposition of graves, one later than another.
2. Any clear and unquestionable series of changes of form or of manufacture. (These two principles serve to fix the order of our scale, whether going forward or backward in time.)
3. Statistical methods; sorting graves by the relative proportions of types in

common with ages before or after them. This is the way to place a large quantity of material roughly in order.

4. Method of style, serves to group in sequence the forms which are clearly intermediate between others, after their approximate place is already fixed by statistics.

5. Method of compression. The earliest and latest examples of each type to be examined, to see if it be possible to concentrate them. Such inquiry always results in revealing a tension between two or more types; either one must be earlier or another later than in other cases, proved by their occurring together on one slip. The range of similar types helps to decide this.

Practically a range in prehistoric Egypt of perhaps a thousand years (may be half or double of that) is broken up into a scale of fifty parts of equal activities; and we can define the age of every type of object found in that scale, as 38 to 41, 53 to 65, &c.; these numbers may be termed sequence dates, or S.D.

Pottery is the best material for study. But all other forms in stone, metal, ivory, &c., are useful evidence, though more liable to transmission and to copying.

We reach thus a system for the exact definition of all that we can learn on prehistoric times: a system which can be applied to all countries where enough material can be studied, and which will enable us to exactly state any correlation discovered between the civilisation of different lands, when a sequence date of one country can be proved equal to a given sequence date elsewhere.

10. *On the Sources of the Alphabet.*

By Professor W. M. FLINDERS PETRIE.

The large series of signs used in Egypt about 2500 B.C. is now shown—by such signs existing as far back as 5000 B.C.—to be independent of the hieroglyphic system or any derivatives of that. Similar signs in Crete show this system to have extended to the Mediterranean by about 2000 B.C.

On looking at the more extended forms of the Greek alphabet found in Karia and Spain, about 60 signs are seen in use, representing about 43 sounds. Three-quarters of these signs are common to the system found in Egypt and Crete.

The only conclusion at present seems to be that signs were in use from 5000 B.C. onward, and developed by 2500 B.C. to over 100 in Egypt, of which half survived in the fuller alphabets of Karia and Spain. The compression and systematising of these signs were due to 27 of them being adopted for a numerical system by the Phœnicians, and thus the *alpha beta* order was enforced by commerce on all the Mediterranean. This accounts in the only satisfactory way for the confusion of the early Greek alphabets, and is a view forced on us by the prevalence of these same signs long before Phœnician commerce.

TUESDAY, SEPTEMBER 19.

1. *Notes on the Yaraikanna Tribe, Cape York, North Queensland.*

By Dr. A. C. HADDON, *F.R.S.*—See Reports, p. 585.

2. *Report on the Ethnological Survey of Canada.*—See Reports, p. 497.

3. *Primitive Rites of Disposal of the Dead, as illustrated by Survivals in Modern India.*

By WILLIAM CROOKE, B.A.

The author discussed—

(*a*) Customs connected with the preservation of the corpse, such as various forms of mummification; (*b*) platform burial; (*c*) direct exposure of the dead to beasts of prey; (*d*) general exposure of the dead; (*e*) the question of the priority of burial to cremation; (*f*) transitions from burial to cremation, and *vice versâ*; (*g*) disposal of those dying in a state of taboo; (*h*) shelf or niche burial; (*i*) crouched or sitting burial; (*j*) disinterment of the corpse; (*k*) jar or urn burial; and (*l*) dismemberment of the corpse.

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4. *Pre-animistic Religion.* *By* R. R. MARETT, *M.A.*

General Thesis.—The term Religion denotes a state of mind embracing emotional and ideal constituents, whereof the former constitute the universal and constant, the latter the particular and variant element. Self-interpretation in ideal terms on the part of the religious emotion of the savage has found most complete and definite expression in Animism, the 'Belief in Spiritual Beings.' Animism, however, as compared with 'Supernaturalism,' namely, that state of feeling almost uncoloured by ideas which is the primary form taken by man's Awe of the Supernatural (or extraordinary), is but as the strongest sapling in a thicket of heterogeneous growths, which, in the struggle for existence, has come to overshadow the rest and give a character to the whole. The vagueness of primitive 'supernaturalistic' utterance is illustrated by, *e.g.*, *andriamanitra* (Malagasy), *ngai* (Masai), *mana* (Melanesians), *wakan* (North American Indians), *kalou* (Fijians). A 'pre-animistic' validity as manifestations of religion thus attaches to a variety of special observances and cults; and it may therefore be interesting in the case of some of the more important of these to distinguish between the original basis of 'supernaturalistic' veneration and the animistic interpretation that as the result of successful competition with other modes of explanatory conception (notably 'Animatism,' namely, the attribution of life and will, but not of soul or spirit, to material objects and forces) is thereon superimposed in accordance with the tendency of the religious consciousness towards doctrinal uniformity. The author illustrates his thesis as follows:—

A. *In regard to the Inanimate.*—(1) Selected instances show the transition through 'Animatism' and 'animatistic' mythology to Animism in the interpretation of the religious awe felt in relation to extraordinary manifestations on the part of Nature-Powers; (2) the cult of the Bull-roarer displays an almost complete absence of animistic conceptions in regard to the veneration of *Daramulun*, *Mungun-ngaur*, *Turndun*, *Baiamai* (Kurnai, Murrings, Kamilaroi, &c.); (3) in Stone-worship; sympathetic magic in connection with the use of 'guardian stones,' &c., generates explanatory conceptions tending towards an animistic form.

B. *In regard to the Subanimate and Animate.*—(1) Plant and Animal Worships show how Totemistic Magic and, apart from Totemism, the desire for magical communion with extraordinary animals, invite explanations which need not be animistic, though they tend to become so. (2) Among observances connected with the phenomena of human life: (*a*) dream and trance are the special parent-soil of Animism; (*b*) awe of the Dead Body, as such, is due to the instinct of self-preservation, an influence which cooperates with the theory of the self-existent soul to bring about the ascription of the 'potency' of human remains to that of the surviving spirit; (*c*) Diseases taking the form of seizure, and those of a convulsive nature, lend themselves almost directly to animistic interpretation; those ascribable to Witchcraft are not necessarily so explained, though the idea of Infection tends this way; the awe of Blood, notably of an issue of blood, is analogous to the awe of the Dead Body, and a crucial proof that 'supernaturalistic' veneration may, in regard to certain maladies, assert itself strongly in the absence of animistic colouring.

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5. *The Thirty-seven Nats (or Spirits) of the Burmese.*
By Colonel R. C. TEMPLE, *C.I.E.*

The belief in the Nats, or supernatural beings who interfere in the affairs of mankind, is universal among all the native inhabitants of Burma of every race and religion. Every writer about the Burmese and their customs mentions the Nats. The subject is, however, still but vaguely understood. The Nats are of three distinct kinds: (1) the supernatural beings due to the Buddhist cosmogony; (2) the supernatural beings familiar to the creatures, objects, and places with which man is concerned due to the prehistoric animistic beliefs of the people; (3) the supernatural beings who are ghosts and spirits of the notorious dead. Of the many orders of Nats thus created, that of the Thirty-seven Nats is by far the best known among the people. These are the ghosts of the departed royalties of fame, and their connections. About them nothing seems to have been previously published in England, and this paper is a preliminary attempt at an adequate representation of them, and of the history, real or supposed, connected with them during life. The paper was illustrated by a map in order to explain the relative position of the places chiefly connected with the very complicated political history of Burma and its numerous dynasties, so far as these are concerned with the stories related of the Thirty-seven Nats. The paper was further illustrated by a lantern slide of an image of each of the Thirty-seven Nats from the unique and authentic collection of large carvings of them in teak wood by Burmese artists in the possession of the author.

WEDNESDAY, SEPTEMBER 20.

The following Report and Papers were read:—

1. *Report on recent Excavations in the Roman City of Silchester.*

See Reports, p. 495.

2. *Two New Departures in Anthropological Method.*[1]

By W. H. R. Rivers, *M.D.*

When in Torres Straits with the Cambridge Anthropological Expedition, two methods were employed to record the colour of the skin quantitatively. Numerous records were taken with Lovibond's Tintometer, and these were fairly satisfactory, although the dark skins of the natives were found to be difficult objects to match exactly. More satisfactory matches were made with the colour top, but this method is open to the objection that the coloured paper discs used on the top are liable to fade, while the glasses used in the Tintometer have the advantage of being constant. Records were taken of the colour of various Melanesians and Polynesians, as well as of the two races of Torres Straits. The following match of the skin of the Mamus (chief) of Murray Island is given as an example:

15·0° Orange + 6·0° Yellow + 7·0° White + 332·0° Black.

The second contribution to anthropological method is the collection of social and vital statistics by means of genealogies. In Murray Island and in Mabuiag genealogies going back for three to five generations were compiled which included nearly all the present inhabitants of these islands. In working out these genealogies, the only terms of relationship used were father, mother, child, husband, and wife, and care was taken to limit them to their English sense. The trustworthiness of the genealogies was guaranteed by the fact that nearly every detail was derived independently from two or more sources. It was found that these genealogies afforded material for the exact study of numerous sociological questions; thus the system of kinship can be worked out very thoroughly by finding the native terms which any individual applies to the other members of his family, *i.e.* the subject can be investigated entirely by concrete examples, and abstract terms of relationship derived from European sources entirely avoided. The genealogies

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[1] The methods and their results will be published *in extenso* in the Report of the Expedition.

also provide a large amount of material for the study of totemism, marriage customs, naming customs, &c.

By this method, also, vital statistics can be collected of the past as well as of the present. The genealogies collected in Torres Straits supply data for the study of the size of families, the proportion of the sexes, the fertility of mixed marriages, &c. The method has the further advantage of bringing out incidentally many facts in the recent history of the people, and of giving insight into their views on various subjects. It is also eminently adapted to bring one into sympathy and friendly relations with natives.

A small amount of work on these lines was also done with natives of Tanna and Lifu living on Mabuiag; enough was done to show that the method is readily applicable to other Melanesian populations, and it is hoped that it may be found to be capable of wide application.

3. *The 'Cero' of St. Ubaldino: The Relic of a Pagan Spring Festival at Gubbio in Umbria.* *By* D. MacIver.

4. *Exhibition of Ethnographical Specimens from Somali, Galla, and Shangalla.* *By* Dr. R. Koettlitz.

5. *The Ethnography of the Lake Region of Uganda.* *By* Lieut.-Colonel J. R. L. Macdonald, *R.E.*

6. *Notes on some West African Tribes north of the Benue.* *By* Lieut. H. Pope Hennessy.

SECTION I.—PHYSIOLOGY, including EXPERIMENTAL PATHOLOGY and EXPERIMENTAL PSYCHOLOGY.

PRESIDENT OF THE SECTION—J. N. LANGLEY, D.Sc., F.R.S.

The President delivered the following Address on Friday, September 15:—

ONE might suppose that Physiology, dealing as it does for the most part with structures—such as nerves, and muscles, and glands—which every one has and has heard of, would be eminently a science the newer aspects of which every one could readily understand. And in this supposition one would be encouraged by the frequency of the references in English literature to some part of our inner mechanism. More than a century and a quarter ago we find: 'If 'tis wrote against anything, 'tis wrote an' please your worships against the spleen, in order by a more frequent and more convulsive elevation and depression of the diaphragm, and the succussations of the intercostal and abdominal muscles in laughter, to drive the gall and other bitter juices from the gall-bladder, liver, and sweetbread of his Majesty's subjects, with all the inimicitious passions which belong to them, down into their duodenums.'

It must, however, be recognised that many subjects which are most interesting to the physiologist either involve so much special knowledge, or are so beset with technical terms, that it is difficult to make clear to others even their general drift.

I am not without uneasiness that my subject to-day may be found to fall within this category. I propose to consider some relations of the nerves which pass from the brain and spinal cord, and convey impulses to the other tissues of the body—the motor or efferent nerves; and in especial the relations of those efferent nerves which run to the tissues over which we have little or no voluntary control. It is as well to say at once that none of the general conclusions which I lay before you are encrusted with universal acceptance. One or two have been subjects of controversy for the last fifty years; others are too young to have met even with contradiction. I do not propose to give you an account of the various theories which have been put forward on the questions I touch upon, nor do I propose to point out how far the views I advocate are due to others. I am concerned only to state what seems to me to be the most probable view with regard to certain problems which have been emerging from obscurity in recent years.

Limitations in the Control of the Nervous System over the Tissues of the Body.—In view of the conspicuous manner in which nervous impulses affect every-day life, we are perhaps apt to over-estimate the character and range of the influence exercised directly by the nervous system.

From the early part of this century one way of regarding the body has been to consider it as made up of tissues grouped together in varying number and amount. Each tissue has its characteristic features under the microscope. We need not enter into the question as to which of the commonly recognised tissues of the body are to be regarded as forming a class by themselves, and which are to be regarded as subdivisions of a class. The point I wish to lay stress on is that in any broad classification not more than two tissues are known to be supplied with approximate completeness with efferent nerve-fibres. The striated muscular tissue, which forms, amongst other parts of the body, the muscles of the limbs and trunk, receives in all regions nerve-fibres from the brain or spinal cord. And the unstriated muscular tissue, which forms, amongst other parts of the body, the contractile part of the alimentary canal and of the blood-vessels, is in nearly, and possibly in all, regions similarly supplied.

The glandular division of epithelial tissue in some parts responds promptly and strikingly to nervous impulses, but in some parts the response is feeble, and in others no nervous impulse has been shown to reach the tissue. The connective tissue which exists all over the body, and which in its varied forms of connective tissue proper—cartilage, bone, teeth, epithelioid cells—makes so considerable part of it, is in mammals, so far as we know, destitute of efferent nerve-fibres. The epidermic cells, which form a covering for the body, the ciliated cells, the reproductive cells, do not visibly respond to any nerve stimulus. And the myriads of blood corpuscles, which in different ways are in incessant action for the general welfare, are naturally out of range of nervous impulses. According to our present state of knowledge, large portions of the organism live their own lives uninfluenced, except indirectly, by the storms and stresses of the central nervous system. No nervous impulse can pass to them to make them contract or to make them secrete, or to quicken or slacken their inherent activity. The nervous system can only influence them through the medium of some other tissue by changing the quantity or quality of the surrounding fluid.

Regarding, then, the body from the point of view of the control exercised by the nervous system on the other constituents, we have first to recognise that this control is in considerable part indirect only, that the several tissues are in varying degree under direct control, and that different parts of one tissue may be influenced by the nervous system to different extents.

Limitation in the Control of the Nervous System over the different Activities of the Cell.—Even when nervous impulses can strikingly affect the vital activity of a tissue, their action is limited. They cannot modify the activity in all the various ways in which it is modified by the inherent nature of the tissue and the character of the surrounding fluid. Thus the submaxillary gland which pours saliva into the mouth is in life ceaselessly taking in oxygen and giving out carbonic acid; it does this without pouring forth any secretion. So far as we know no nervous impulse can hasten or retard this customary life of the gland by a direct action upon it without producing other changes. The nervous system can only do this indirectly by modifying the blood supply The nervous impulse which reaches the gland cells causes them to secrete, to take up fluid on one side and to pour it out on the other, and it does not, and so far as we know it cannot, confine its influence to those changes ordinarily going on in the gland cells. The essential effect of a nerve impulse appears to be to modify the amount of energy set free as work; usually it causes work to be done, as in the contraction of a muscle, or in the secretion of fluid by a gland; sometimes it diminishes the work done, as in the cessation of a heart-beat, or the decrease of contraction of a blood-vessel. Other changes often go on side by side with this setting free of energy as work, but there is no unimpeachable instance in which these other changes take place by themselves as the result of nervous excitation. Physiologists have sought for long years in all parts of the body for nerves—calorific or frigorific nerves—which cause simply an increase or decrease of the heat set free by a tissue; and for nerves—trophic nerves—which cause simply chemical changes in the tissue associated with a setting free of heat or not. Probable as the existence of such nerves seems to be, the search for them cannot, I think, be said to have been successful.

Somatic or Voluntary Tissues.—When we look at the question of nervous control subjectively, and consider in ourselves what tissues are at our beck and call, we find that we have immediate and prompt governance over one tissue only, the one which, as we have already seen, is most universally supplied with efferent nerve-fibres—namely, the (fibrous) striated muscular tissue. The parts of the body composed of this muscular tissue we move, as we say, at will. We exercise a control over it that we cannot exercise over any other tissue. The tissue is supplied with a special system of nerves. In other vertebrates there is a tissue of similar microscopical characters, and having a similar system of nerves. And we can be certain that in all vertebrates the fibrous striated muscle and the nervous system belonging to it form a definite portion of the body which can be properly placed in a class apart from the other tissues of the body. The tissues in this class are spoken of as 'somatic' tissues, or sometimes, in view of our own sensations, as 'voluntary.' 'Voluntary' is not a word which physiologists care much to use in this context, because it readily gives rise to misconceptions. It will serve, however, if we bear in mind that the primary distinguishing characters of the system are microscopical, anatomical, and developmental; that other tissues than 'voluntary' can be put in action by the will, though in a different fashion; and that 'voluntary' tissues are also put in action involuntarily. That is to say, the word will serve if we rob it of much of its ordinary meaning.

The somatic or voluntary nervous system has in its essential features long been known. We may leave it and pass on to a more obscure field.

Autonomic or Involuntary Tissues.—In putting on one side the voluntary system, you will notice that we have disposed of one only of the several tissues, differing microscopically from one another, which go to make up the various organs of the body. Of the rest some, as we have said, either do not receive nerve-fibres from the brain and spinal cord, or, if they do, practically nothing is known about them in our own class of vertebrates—the mammalia. These I shall say a word or two about later. For the present we must confine our attention to the tissues which are known to be supplied not too illiberally with nerve-fibres. These are unstriated muscle, and its allied cardiac muscle, and certain glands. Since the voluntary striated muscle has a nervous system of its own, it might be imagined that the unstriated tissue and the glandular tissue, differing as they do, would also have separate nervous systems. This, however, is not the case. The nervous supply of these two tissues has common features and belongs to the same system. There is, unfortunately, no satisfactory term by which to designate it. On the whole the term 'autonomic' seems to me best adapted for scientific use. But it is not of the first importance for our present purpose to insist upon a proper nomenclature, so that I think I shall not do much harm if I use the familiar 'involuntary' for the unknown, or nearly unknown, 'autonomic.'

I need hardly point out how widespread are both the glandular and the unstriated muscular tissues. In man practically the whole surface of the skin is supplied with sweat-glands, lachrymal glands lie hid behind the eye, small glands are thick in the respiratory tract from the nose to the smaller bronchial tubes, and glands stretch along the whole of the digestive tract. Most of these can be set in action by nerve-fibres. There are a number of others in which such action has not been shown, so that they do not concern us at present. Unstriated muscle, forming, as it does, part of the walls of the arteries and veins, penetrates to every part of the body. It forms a large part of the coats of the stomach and intestines; it is present in the spleen and in parts of the lymphatic vessels; it is present in the iris and in other parts of the eye; it occurs in greater or less amount in different animals in the deeper layers of the skin.

Consider some of the ways in which these tissues in the several organs or structures affect the working of the body. The heart contracts and supplies the driving force for the circulation of the blood; the arteries contract less or more, here or there, and regulate the amount of the blood to each region; the digestive tract secretes solvent and disintegrating fluids in the food, churns it to pulp, absorbs some and rejects the rest; the skin-glands pour out their tiny beads of perspiration, and so aid in regulating the temperature of the body; the iris commands the aperture of the pupil and determines the amount of light falling on the retina; the ciliary muscle, by its varying contraction, brings about the focussing necessary for distinct vision.

But the involuntary tissues do not confine themselves to actions of such flagrant utility as those just mentioned. The contraction of small bundles of unstriated muscles in the skin will cause the flesh to creep; other similar small muscles are attached to the hairs; 'tis these will make

'Thy knotted and combinèd locks to part,
And each particular hair to stand on end,
Like quills upon the fretful porpentine.'

The involuntary tissues, although not under the prompt and immediate control of the will, are under the control of the higher centres of the brain. They are particularly responsive to the emotions; and in so far as we can call up emotions, we can play upon them at will. The ease with which nervous impulses pass along given tracts depends, amongst other things, upon use. And so it appears that our great-grandfathers wept and our great-grandmothers fainted with an ease which we should require assiduous practice to attain.

Further, you may note that the contraction of involuntary muscle caused by an emotion may in its turn set up nervous impulses, which pass back to the brain and give rise to vague and curious feelings, feelings often lending themselves to effective literary expression:—

'Where our heart does but relent, his melts; where our eye pities, his bowells *yearn.*

I must ask your forgiveness for mentioning so many well-known facts in the sketch which I have just given of the involuntary tissues. But I hope it will take from you all excuse for not understanding the rest of what I have to say.

The arrangement of the involuntary nervous system presents some peculiar characters. The most distinctive of these is that the nerves, after they leave the brain or spinal cord, do not run interruptedly to the periphery; they end in nerve-cells, and the nerve-cells send off the fibres which run to the periphery. The most direct proof of this lies in the fact that a certain amount of nicotine prevents the central nervous system from having any influence on the peripheral structures—*i.e.* the line is somewhere blocked; it can be shown, speaking generally, that there is no block on either side of the ganglia, so that it must be in them. The actual point of attack of the nicotine appears to be the connections made by the central nerve-fibres with the peripheral nerve-cells. Thus all nerve-impulses, which pass from the brain or spinal cord to unstriated muscle or glandular tissue, pass through an intermediate station on their way. In this, as in some other respects, the arrangement of the involuntary nervous system is more complex than that of the voluntary nervous sytem; in the latter the motor nerve-fibres run direct to the tissue and have no nerve-cells on their course. The nerve-cells which form the intermediate stations for the involuntary nerve-fibres are grouped together into ganglia; and so we may call the nerve-fibres which run from the brain or spinal cord to the nerve-cells pre-ganglionic fibres, and the nerve-fibres which run from the ganglia to the peripheral tissues post-ganglionic nerve-fibres.

The involuntary nervous system is divided into at least two subdivisions. The most extensive of these is what is called the *sympathetic nervous system.* The pre-ganglionic fibres of the sympathetic arise from a limited portion of the spinal cord. They arise from that part of the spinal cord which is in the region of the chest and the small of the back—*i.e.* roughly from the part which lies between the origin of the voluntary nerves for the arms and the origin of the voluntary nerves for the legs. The fibres given off by the ganglia of this system—*i.e.* the post-ganglionic fibres—run to the involuntary tissue in all parts of the body.

The Cranial and Sacral Systems.—The second division of the involuntary nervous system consists of two parts; one part—the cranial—arises from the brain—*i.e.* above the origin of the sympathetic; the other—the sacral—arises from the end of the spinal cord—*i.e.* below the origin of the sympathetic.

Each supplies a limited and different part of the involuntary tissue of the body, but both together supply a portion only of it. Taking the distribution broadly, they supply the muscular coats of the alimentary canal and certain structures connected developmentally with the anterior and posterior portions of it. They are especially connected with these terminal portions; they send numerous nerve-fibres to them; whereas they send but few to the intervening portion, and none at all to its blood-vessels. Thus parts of the involuntary tissue of the body receive a double supply of nerve-fibres, whilst parts receive a single supply only. Amongst the latter are all the involuntary tissues of the skin, the blood-vessels of the limbs and trunk, and of most of the viscera.

The cranial and sacral divisions of the involuntary nervous system are considered by some observers to be simply portions of the sympathetic system separated from it by the development of the nerve-centres for the arms and for the legs. I may give one reason why I do not take this view. The middle portion of the spinal cord, which is the region that sends fibres to the sympathetic, always sends fibres to a given spot by more than one nerve, and usually by four or five. The fibres passing by the several spinal nerves never differ in the kind of effect they produce, but only in the degree of effect; the difference is in quantity and never in quality. If, then, regions above and below were mere separated parts of this sympathetic region, we should expect that when one of these regions and the sympathetic region sent nerves to the same spot, the effect produced by both sets of nerves would be the same in kind, though it might differ in extent. But this is often not the case. Thus certain blood-vessels may receive nerve-fibres from four spinal nerves in the sympathetic region and from three spinal nerves in the sacral region; all the former cause contraction of the blood-vessels, all the latter cause dilation. And thus it seems to me probable that in the evolution of mammals the sympathetic nerves have developed at one time, and the cranial and sacral involuntary nerves have developed at another time.

Inhibition.—A striking feature of the involuntary nervous system is its possession of nerve-fibres, which, when excited, stop some action at the time going on. The most striking example is perhaps the cessation of the heart-beats brought about by excitation of the vagus nerve. Such nerve-fibres are called inhibitory nerve-fibres, and the stopping of the action is called inhibition.

So far as has been definitely proved inhibitory nerve-fibres only run to involuntary muscle and to nerve-cells, and to these, so far as has been certainly shown, only in particular cases. It is true that when fear or other emotion causes the tongue to cleave to the roof of the mouth, there is a cessation of the customary flow from certain glands, but this flow is itself the result of nervous impulses passing in ever rising and falling intensity from the central nerve-cells, and its cessation is due to inhibition of nerve-cells and not to inhibition of glandular cells.

The inhibition of nerve-cells has only been proved to take place in the central nervous system. When a group of nerve-cells of the central nervous system is engaged in sending out nervous impulses, other nervous impulses reaching them by way of other nerve-cells may diminish or stop their activity. The theory which is commonly advocated now to explain this inhibition makes the activity of the nerve-cells depend upon their receiving stimuli from the minute endings of other nerve-cells, and the cessation of the activity to depend upon these minute endings, either withdrawing themselves out of range, or having something interposed between them and the nerve-cells, so that the impulses can no longer pass. This theory I do not wish to discuss to-day; it is sufficient to say that if it is true, the inhibition of nerve-cells is an entirely different process from that of the inhibition of involuntary muscle.

Turning to the inhibition of involuntary muscle, there is a source of confusion which we must first guard against. Nearly all the unstriated muscle in the body is kept in a state of greater or less tone, or contraction, by the central nervous system. A diminution or cessation of this contraction may then be caused by a diminution or cessation of the activity of the central nervous system. This cessation of contraction is, of course, not what we mean by an inhibition of the unstriated muscle. It is usually spoken of as an inhibition of the nervous centre. The inhibition we mean is that which is caused by stimulating the peripheral end of a nerve outside the spinal cord.

I have said that this inhibition can only be obtained in certain cases, and it is not easy to find anything in common with regard to these cases. But on the whole it appears that the more a tissue is able to work by itself, the more likely it is to be under the control of inhibitory fibres. The heart, stomach, and the intestines work when no longer connected with the central nervous system, and these are especially liable to inhibition.

There has been a marked tendency amongst physiologists, in considering the question of inhibitory nerve-fibres, to take what may be called *the view of the equal endowment of the tissues.* Because some arteries have inhibitory nerve-fibres, therefore it is to be held as in the highest degree probable that all have. And many would go farther and say that it is therefore in the highest degree probable that all unstriated muscle, and glands, and even the voluntary muscles have such fibres. This view seems to me a mistaken one. There is hardly room for doubt that the motor fibres are supplied in most unequal measure to the unstriated muscle and glands of the body. There are veins in the body containing unstriated muscle, which show no visible contraction from any nerve stimulation. And there are a number of glands which no nerve—so far as we know—excites to secretion. Since, in the course of the evolution of the organism, a universal development of motor fibres has not occurred, it is, I think, to be expected that the development of inhibitory fibres should be still less universal. For up to a certain point the results of inhibition can be obtained in most cases without inhibitory nerve-fibres, by a simple diminution in the impulses travelling down the motor fibres. The only, and the final, test is of course experiment. But not all experiments are decisive, and theory inevitably colours interpretation. This theory of the equal endowment of the tissues has, it seems to me, caused a number of quite inconclusive experiments to be accepted as offering satisfactory evidence for the existence of inhibitory nerve-fibres.

Passing from this question, we may consider briefly how far we can get on the way to understand what occurs during inhibition. The external characteristic feature of inhibition is that a certain state of activity ceases; a muscle contracting at short intervals ceases to contract, or a muscle in a steady state of contraction loses this state. The tissue in either case becomes flabby.

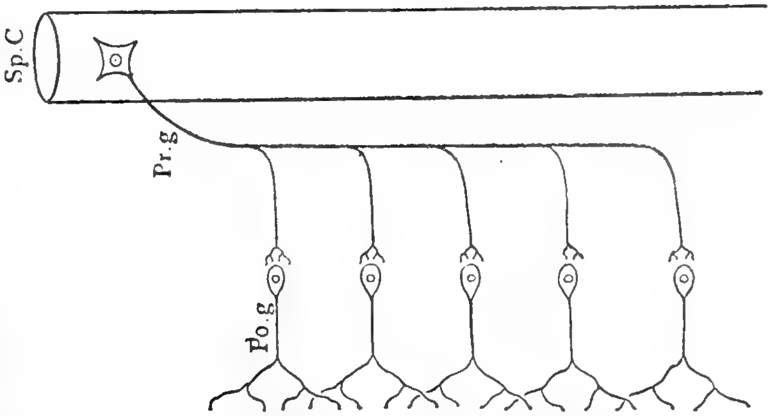
The activity of a tissue may obviously be due to its receiving some stimuli from the nervous system or to its own inherent qualities. In the former case, if the tissue were only active when receiving nervous impulses, we should naturally look to some interference with these impulses as being the cause of inhibition. The blood-vessels of the submaxillary gland appear to me to offer sufficiently clear evidence with regard to the inhibition of blood-vessels. The superior cervical ganglion is the local centre from which the nerve-fibres bringing about contraction run to the blood-vessels of the gland. When this ganglion has been removed and the nerve-fibres from it have degenerated, the vessels receive no nervous impulses causing them to contract. But stimulation of the inhibitory nerve will still cause dilation—*i.e.* inhibition of the blood-vessels. The inhibition must then be due to a direct action on the tissue, and not to an interference with other nerve-impulses. The evidence with regard to the inhibition of the beat of the heart and of the tone or peristalsis of the alimentary canal is more complex, but there is good reason to believe that the contraction is in both cases due to their inherent qualities. And if this be granted, it follows that here also inhibition must be due to a direct action upon the tissue.

The contraction of a muscle is due to a chemical change in it. In this chemical change some energy is set free as work—shown by the contraction of the muscle—and some as heat. It is conceivable that the nervous stimulus which cuases inhibition should cause all the energy set free by the chemical change to take the form of heat. In that case the inhibitory nerve would be a calorific nerve. The amount of chemical change is indicated by the amount of carbonic acid given off to the blood. No experiments have been made as to the amount of carbonic acid given off to the blood by an inhibited tissue, but it appears very unlikely that the amount is increased, and we may take this view of the action of an inhibitory nerve as improbable.

If the nervous impulse does not act in this way it must in some way stop the particular chemical change associated with contraction from taking place. It does not stop all chemical change, for blood passing through an inhibited tissue loses some of its oxygen. The simplest way for a nervous impulse to prevent a particular chemical change is to induce a different one. We have seen that the tissues which are inhibited have a great tendency to contract of themselves—that is, they form certain very unstable substances. In closely related tissues which are not inhibited this tendency exists but little or not at all. The proximate cause of inhibition might then be that the nervous stimulus causes certain molecules of the tissue to form more stable combinations. This need not be associated with any general assimilation; it would simply make the muscle adopt for a time a mode of life more like that of other closely related muscle.

Number of Relay Stations.—I have already mentioned that the nerve-fibres which pass from the central nervous system to the involuntary tissues do not run to it direct, but end in groups of nerve-cells or ganglia from which fresh nerve-fibres are given off. Now, in most cases, there are anatomically several ganglia on a nerve in its course from the spinal cord to the periphery. For example, the nerve-fibres which cause the hairs of a cat's tail to stand on end, giving the tail the appearance of a bottle brush, leave the spinal cord in the lower part of the back, and enter a nerve-strand which is beaded with ganglia. They leave this strand near the root of the tail. Between the point where the nerve-fibres enter and the point where they leave the strand there are seven or eight ganglia. The fact offers us a problem of some difficulty. With how many of these ganglia are the nerve-fibres connected? Or, in other words, how many relay stations are there; eight or one, or some intermediate number? Further, do all kinds of involuntary nerve-fibres in all parts of the body have the same number of relay stations, or do some have one, some two, some three, and so on? It would take too long to discuss this question here. But the experimental evidence is, I think, fairly decisive in favour of the simple view that the nerve-impulse passes through one relay station only. There is, however, evidence that the nerve-fibres which pass from the spinal cord branch, so that we may take the element by reduplication of which the involuntary nervous system is built up to be diagrammatically as in fig. 1.

FIG. 1.



Reflexes.—Another point of view is given by a comparison of the groups of nerve-cells of the peripheral ganglia with the groups of nerve-cells of the brain and spinal cord. The proper working of the body depends upon an agile response by the central nervous system to what is going on in the periphery. Now the peripheral ganglia are made up of nerve-cells and nerve-fibres which differ less in general characters from some of the cells of the central nervous system than these differ from one another. The nerve-cells of the spinal cord can receive impulses from many groups of nerve-cells both near and remote; they do not simply receive impulses from one quarter alone—say, the cortex of the cerebral hemispheres—but from many quarters, and notably direct from the periphery. Hence it has been supposed that the peripheral ganglia have similar wide connections, that they receive impulses direct from the periphery, that each is connected with other ganglia, and that impulses received from the periphery, or elsewhere, bring separate ganglia into co-ordinate action. And this view, which has been taken on general grounds, has been supported by microscopical observations.

The evidence against this view is of two kinds. In the first place, it can be shown that in a number of individual cases the nerve-cells of one ganglion have no connection with the nerve-cells of another ganglion, so that anything like a universal scheme of connection is out of the question. And, secondly, it can be shown that whenever an action occurs, which might be referred to such connection, it is an action which is bound to occur in consequence of some other known arrangement, and that therefore it is unnecessary to seek for a further cause.

The evidence of the first kind we need not enter into; the evidence of the second kind we may hastily touch on. If we accept the conclusion stated above, that the pre-ganglionic nerve-fibres branch and the branches run to different nerve-cells, it follows that a stimulus applied to one branch will stimulate a number of nerve-cells; this follows since a nerve-impulse set up in any part of a nerve travels over the whole of it. Thus actions, resembling reflex actions, will inevitably be obtained whenever nerve-fibres are stimulated which send branches to different ganglia. The mechanism in this case is confined to motor nerve-fibres and nerve-cells. The action, for lack of a convenient term, was spoken of by Dr. Anderson and myself simply as a reflex action. It is perhaps better to call it a *pseudo-reflex action*.

FIG. 2.

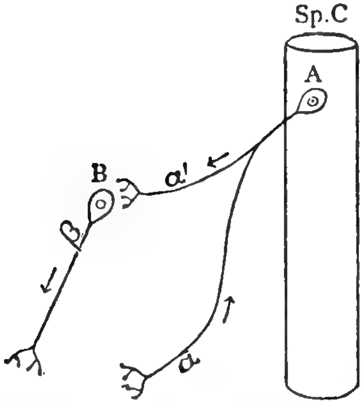


FIG. 3.

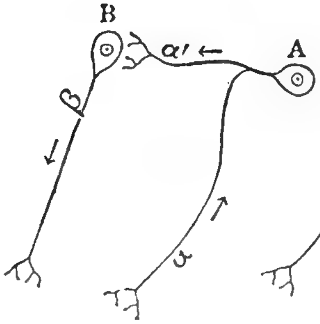
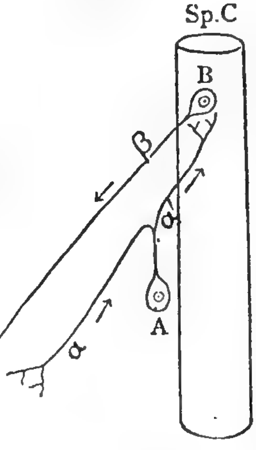


FIG. 4.



Regarded from the customary point of view, a pseudo-reflex differs widely from a reflex action. The one is brought about by stimulating an efferent or motor fibre, and the other by stimulating an afferent or sensory fibre.

But suppose we compare them from another point of view. Fig. 2 is a diagrammatic representation of a pseudo-reflex. A nervous impulse passes up one branch α of a cell A, passes to another branch α', so excites a cell B and its nerve-fibre β.

Fig. 4 is a diagrammatic representation of a simple true reflex in the voluntary muscle. A nervous impulse passes up one branch α of a cell A, passes to another branch α', so excites a cell B and its nerve-fibre β.

You see the two can be described in exactly the same terms, and both are reducible to the diagram of fig. 3. It is true that the cells A and B are not similarly situated in the two cases; in the pseudo-reflex A is in the spinal cord, and B is outside it in a peripheral ganglion; whereas in the true reflex A is outside the spinal cord, in a spinal ganglion, and B is inside the cord. But then no one has even suggested that the position of a nerve-cell determines whether an action in which it takes part is a reflex or no. So that this point is irrelevant. And so it might be urged that the one action has as good a title to be called a reflex as the other. I do not, however, wish to insist too much on this comparison. I am inclined to say, after Touchstone, 'An ill-favoured thing, sir, but mine own.'

If, as some think is the case, the spinal ganglion cell receives the nerve-impulse conveyed by the peripheral nerve process, and modifies it before passing it on to the central process, this establishes a distinguishing character for the true reflex. It would be probably an axon plus dendron reflex, the pseudo-reflex being simply an axon reflex. The important known functional difference between the reflex and the pseudo-reflex is that in the former case the nerve-endings of the primarily affected nerve-fibre are specially differentiated for receiving nerve-impulses, and in the latter case these endings are specially differentiated for imparting nerve-impulses. And, on the whole, it is probable that the pseudo-reflex is not a normal part of the working of the body, but comes into play only as it were by accident. I do not, however, regard this as quite certain.

The pseudo-reflex I have spoken of is caused by the excitation of nerve-fibres before they reach the ganglia—*i.e.* of pre-ganglionic fibres. But the fibres which are given off by the ganglia also branch, so that it appears inevitable that we should have in certain circumstances an action related to a reflex caused by a stimulation set up in one of these branches spreading to the rest—*i.e.* a spreading out of impulses in post-ganglionic fibres similar to that which occurs in pre-ganglionic fibres. Turning to the diagram, fig. 1, a nervous impulse set up in one branch—possibly by a contraction of muscle-cells to which it runs—would spread to other branches and cause contraction of the muscle-cells in connection with them. You will notice that this spreading out of impulses does not necessarily involve the stimulation of any nerve-cell; it might perhaps be distinguished as *irradiation.* It would, probably, be very local in action, unless there were overlapping of the districts supplied by the several nerve-cells, in which case a not inconsiderable spreading out of a local contraction might take place, giving rise to a peristaltic wave.

It must be pointed out that it has been assumed that in the sympathetic nervous system an impulse cannot pass from a motor fibre through the nerve-cell from which the fibre arises and affect any other nerve-fibre or nerve-cell. There is good ground for this assumption, but the experimental evidence might certainly be more complete.

To return to our main line of argument, we have good evidence that nervous impulses set up in one spot may affect regions more or less remote by a mechanism which does not involve the presence in the sympathetic system of special sensory nerve-cells with peripheral sensory nerve-endings. And so far as investigation has gone at present, I think that all the apparent reflex actions can be explained without reference to such sensory apparatus. And so I take the analogy of the peripheral ganglia with the central nervous system to be misleading, and consider that all the nerve-cells of which we have been speaking are motor nerve-cells, and that they all conform to the simple plan shown in fig. 1. Thus the whole consists of a duplication of one type; a cell in the spinal cord which branches, each branch ending in a single cell; each of these cells sends off a nerve-fibre which branches, the branches ending in a group of involuntary muscle or gland cells.

That I regard as the real working mechanism, but there are two reservations to make. All the tissues of the body may be looked upon as engaged in a life-long process of carrying out experiments, and I am prepared to believe that there are in the body what may be spoken of as the residues of these natural physiological experiments, either the beginnings of experiments which have not succeeded, or the melancholy ends of those which once partially successful have failed later. Such possibly may be the nerve-cells which have been described in sympathetic ganglia as sending their nerve-fibres to other nerve-cells.

Secondly, in this account I have not included the nerve-cells which exist in the wall of the alimentary canal, and the cells of Auerbach's and Meissner's plexuses. These 'enteric' nerve-cells belong, I hold, to a system different from that of the other peripheral nerve-cells. With regard to their connections I do not think anything can be said with certainty.

Regeneration. Specific Nerve Energy.—One other problem presented by this involuntary system we may say a few words about. You know that when a nerve in the hand or arm is cut the nerve will in proper conditions grow again; and the lost feeling and the lost power over the muscles will return. The recovery is brought about by the part of the nerve which is attached to the spinal cord growing along its old track and spreading out as before in the muscle, skin, and other tissue. At any rate that is the method for which there is most evidence. You may know also that when the nerve-fibres in the spinal cord are similarly injured, they do not recover function. Regeneration in the latter case implies that the nerve-fibres have to form fresh endings in connection with nerve-cells. If this were more difficult than the formation of nerve-endings in muscle and other non-nervous tissues, the difference which exists as regards recovery of function between the nerve-fibres of the limb, and nerve-fibres of the spinal cord, would be readily explainable. But recent experiments show that the nerve-fibres which run from the spinal cord to the peripheral ganglia—*i.e.* pre-ganglionic fibres—re-form with ease their connection with nerve-cells, so that we may probably seek in mechanical conditions for the reason of the absence of regeneration of the fibres in the spinal cord. Possibly some way may be found of improving the mechanical conditions, and so obtaining regeneration. That question, however, we need not enter into.

The regeneration of the pre-ganglionic nerves presents some very remarkable features. The nerve-fibres which end in a sympathetic ganglion are rarely, if ever, all of one kind—that is to say, they do not all produce the same effects. Thus, of those which run to the ganglion in the upper part of the neck, some cause the eyelids to move apart, some cause the pupil to dilate, some cause the face to become pale, some cause the glands of the mouth or skin to secrete, and others have other effects. These different kinds of nerve-fibres run, in large part at any rate, to different nerve-cells in the ganglion. There are in the ganglion several thousands of nerve-cells closely packed together. And it would seem hopeless for each kind of nerve-fibre as it grows again into the ganglion during regeneration to find its proper kind of nerve-cell. Nevertheless, nearly all of them succeed in doing this. The nerve-fibres which normally cause separation of the eyelids, or dilatation of the pupil, or pallor of the face, or secretion from the glands, produce the same effects after several inches of their peripheral ends have formed anew.

The fact offers at first sight a striking proof of a specific difference between the different classes of nerve-fibres and different classes of nerve-cells. Through the matted mass formed by the delicate interlacing arms of the nerve-cells, the ingrowing fibres pursue their tortuous course, passing between and about hundreds of near relations until they find their immediate stock, whom they clasp with a spray of greeting tendrils and so come to rest.

Absolute laws seem unfitted for a workaday world. For closer observation shows that the fibres have not always this marked preference for their own stock. The nerve-fibres of the cervical sympathetic, the nerve I have spoken of above, do not often go astray, at any rate so far as is known. But they do sometimes; thus it may happen that some nerve-fibres which ought to find their home with nerve-cells governing the blood-vessels, take up with nerve-cells governing the dilator structures of the pupil.

And if we turn to other nerves, greater aberrations are found. We have seen that the nerves running from the central nervous system to involuntary structures may be divided into two sets: the sympathetic nerves on the one hand, and the cranial and sacral nerves on the other. An important cranial nerve is the vagus; it causes, when in action, cessation of the heart-beat, contraction of the œsophagus, contraction or inhibition of the stomach, and various other effects. It does not send nerve-fibres to any of those structures of the head which we have seen the sympathetic ganglion at the top of the neck—the superior cervical ganglion—so liberally supplies. And yet the vagus nerve, if it has a proper opportunity of growing into the superior cervical ganglion, will do so, and there establish connections with the nerve-cells. Thus the nerve which properly exercises control over certain viscera in the thorax and abdomen is capable of exercising control over structures in the head, such as the iris, the blood-vessels, and the glands. The details of the process, with which I will not trouble you, do not afford any clear evidence that the nerve-fibres of the vagus pick and choose amongst the nerve-cells of the superior cervical ganglion; the fibres appear rather to form their terminal branches around any kind of nerve-cell, so that, in fact, the action which the nerve-fibre will in future bring about depends not on any intrinsic character of its own, but upon the nature of the action carried on by the nerve-cell. The nerve-cell may cause secretion from a gland, or contraction of a blood-vessel, or dilation of the pupil, or movement of hairs; whichever action it causes the nerve-fibre which joins it from the vagus nerve can cause for the future, and it can cause no other. In this case, then, we arrive at results which are hopelessly at variance with the view that the nerve-fibres and nerve-cells of the involuntary nervous system are divided into classes which are fundamentally different. In other words, that theory which is spoken of as the theory of specific nerve energy does not apply here.

But if this is so, how are we to account for the selective power shown by the sympathetic nerve-fibres which I have mentioned earlier? That the different classes of nerve-fibres and nerve-cells with which we are dealing have not those deep and inherent differences which are required by the theory of specific nerve-energy is, it seems to me, certain. Nevertheless, there may be some differences of a comparatively superficial nature which suffice to explain the selective activity observed. We may suppose that a re-growing nerve-fibre will in favourable circumstances join a nerve-cell, the function of which is the same as that of its original cell, but that if there are hindrances in the way of this return to normal action, and if the conditions are favourable for joining a nerve-cell acting on some other tissue, why then it will join this. It is as if it had a preference, but did not care overmuch. We might perhaps express the facts by saying that there are different varieties of pre-ganglionic fibres, but no species.

We have been speaking so far of the nerve-fibres which run from the brain and spinal cord to the peripheral nerve-cells. The nerve-fibres which run from the peripheral nerve-cells have also, there is reason to believe, a large measure of indifference as to the kind of work they perform. The limits of this indifference have yet to be investigated.

I have said earlier that in mammalia nerve-fibres are not known to run to connective-tissue cells or to epidermic cells. But in some lower vertebrates certain connective-tissue cells are under the control of the central nervous system. Thus in the frog the pigmented connective-tissue cells, which play a large part in determining the colour of the skin, can be made to contract or to rearrange their pigment granules—and so change the colour of the skin—by excitation of certain nerves. In all probability the motor nerve-fibres to the pigment-cells belong to the same class as the nerve-fibres which run to the arteries and to the glands—*i.e.* they belong to the autonomic system. We have seen that unstriated muscle-cells and gland-cells in different parts of the body are by no means equally supplied with motor nerve-fibres, and it may be that in mammals there are certain connective-tissue cells which receive motor nerve-fibres. Further, if it is true, as it well may be, that nerve-fibres which run to a gland are capable in favourable conditions of making connections with a blood-vessel, it is not beyond hope that either kind of nerve-fibre may experimentally, by offering it favourable conditions, be induced to join connective-tissue cells.

The factors which determine whether a particular tissue or part of a tissue is eventually supplied with nerve-endings, and the degree of development of these, are the factors which determine evolution in general. In the individual it is exercise of function which leads to the development of particular parts; in the race it is the utility of this development which leads to their preservation. And so it is conceivable that in some lower vertebrate at some time, the autonomic nervous system may have developed especially in connection with those tissues which appear in ourselves to be wholly unprovided with motor nerve-fibres.

I am tempted, before ending, to make a slight digression. Those who have occasion to enter into the depths of what is oddly, if generously, called the literature of a scientific subject, alone know the difficulty of emerging with an unsoured disposition. The multitudinous facts presented by each corner of Nature form in large part the scientific man's burden to-day, and restrict him more and more, willy-nilly, to a narrower and narrower specialism. But that is not the whole of his burden. Much that he is forced to read consists of records of defective experiments, confused statement of results, wearisome description of detail, and unnecessarily protracted discussion of unnecessary hypotheses. The publication of such matter is a serious injury to the man of science; it absorbs the scanty funds of his libraries, and steals away his poor hours of leisure.

Here I bring my remarks to a close. I have endeavoured to give as clearly as possible what seem to me to be the conclusions which logically follow from certain data, but I would not have you believe that I regard them as representing more than the immediate point of view. As the wise man said: 'Hardly do we guess aright at things that are upon earth, and with labour do we find the things that are before us.'

THURSDAY, SEPTEMBER 14.

The following Reports were read:—

1. *Report on the Influence of Drugs upon the Vascular System.*

See Reports, p. 608.

2. *Report on the Physiological Effects of Peptone and its Precursors when introduced into the Circulation.*—See Reports, p. 605.

3. *Report on the Electrical Changes accompanying the Discharge of the Respiratory Centre.*—See Reports, p. 599.

4. *Report on the Comparative Histology of the Cerebral Cortex.*

See Reports, p. 603.

5. *Interim Report on the Histological Changes in the Nerve Cells.*

6. *Report on the Micro-chemistry of Cells.*—See Reports, p. 609.

7. *Interim Report on the Histology of the Suprarenal Capsules.*

See Reports, p. 598.

FRIDAY, SEPTEMBER 15.

The President's Address was delivered.—See p. 881.

The following Papers were read:—

1. *Autointoxication as the Cause of Pancreatic Diabetes.*

By IVOR L. TUCKETT, *M.A.*

In all my experiments I have estimated the reducing power of the blood and urine, reckoned as glucose; so that when the degree of hyperglycæmia or glycosuria is mentioned, all that is meant by the expression is that the blood or urine respectively contains so much reducing material, estimated as glucose. My method in extracting the sugar from the blood has consisted in boiling with sodium sulphate, as described by Pavy in his book on 'The Physiology of the Carbohydrates.' The reducing power of the blood and urine I have estimated by the ammoniated Fehling's solution recommended by Pavy, and described in the same book. I have convinced myself of its accuracy, as in the estimation of standard solutions of sugar I have always obtained a value correct to the first two places of decimals.

I have obtained the following results:—

1. That if the thoracic lymph from a dog which has been starved a day is injected into the portal system of a cat, no glycosuria results, nor is there any hyperglycæmia beyond the degree which sometimes results from the use of anæsthetics, that is from about ·2 per cent. to ·28 per cent.

2. That if the thoracic lymph from a digesting dog is injected into the portal system of a cat, glycosuria of a degree varying from 1 per cent. to 9 per cent. and hyperglycæmia of a degree varying from ·3 per cent. to ·9 per cent. result.

3. That if thoracic lymph from a digesting dog be injected into the systemic circulation of a cat, hyperglycæmia and glycosuria again result, though not in as high a degree as after portal injections; that is, hyperglycæmia of a degree from ·3 per cent. to ·5 per cent., and glycosuria of a degree from 1 to 3·75 per cent.

4. That if the thoracic lymph from a digesting cat be injected into its own splenic vein, hyperglycæmia and glycosuria result.

5. That the mere injection of a few bubbles of air with a little normal salt solution into the portal system of a cat is followed by glycosuria; while the injection of salt solution or of serum from dog's blood is followed by no glycosuria and by no hyperglycæmia, beyond the slight degree due to the anæsthetics employed.

6. That, as Biedl proved, the mere formation of a fistula of the thoracic duct in a dog is followed by glycosuria; and whereas he only experimented on the dog, and usually obtained glycosuria of a degree not above 2 per cent. and never more than 5·8 per cent, I have also obtained this result in the cat; and in a dog which had been starved thirty-six hours I obtained glycosuria of a degree of 10·52 per cent.

My explanation of these various results is that the internal secretion of the pancreas passes into the blood chiefly *viâ* the thoracic lymph, while some toxic substance, formed probably in the intestine, is present in the thoracic lymph during digestion, but is absent therefrom during starvation, though it probably is present also in the portal blood both during digestion and starvation. This toxic body and the internal secretion of the pancreas are antagonistic to one another In the absence of the internal secretion of the pancreas, this substance has a toxic action on the glycogenic tissues of the body whereby they cannot, to the same extent as normal, form glycogen out of sugar, and probably are stimulated to convert glycogen into sugar.

Thus the injection of thoracic lymph from a digesting dog causes glycosuria because it contains the toxic substance. On the other hand, leading the thoracic lymph away from a fasting dog is followed by glycosuria, because, the internal secretion of the pancreas being thus removed, the toxic substance in the blood is given free play.

I attribute the glycosuria following the mere injection of a few bubbles of air into the portal circulation of a cat to the fact that this air very largely accumulates in the veins of the pancreas; as a result of which the pancreas is probably crippled in forming its internal secretion.

Though the above explanation is nothing more than a supposition, yet it has very great probability in its favour, because it harmonises the glycosuria caused by interference with the thoracic duct with the glycosuria following excision of the pancreas; and thus gets rid of the necessity of our calling the former 'a new form of experimental diabetes,' as was done by Biedl.

It further explains all my results and, as far as I can see, is not opposed to any of the numerous observations recorded in the literature of diabetes, which is very extensive.

Pancreatic diabetes thus consists, in my view, of the balance between this toxic substance and the internal secretion of the pancreas being upset; and I should be inclined to explain the majority of cases of human diabetes similarly, seeing that several observers have proved that the internal secretion of the pancreas is under nervous influences.

What this toxic substance is, I do not know. How exactly it exerts its action is also uncertain; but my experiments tend to show, that if the liver contains no glycogen, not only is excision of the pancreas not followed by glycosuria, but also injection of thoracic lymph from a digesting dog causes no glycosuria.

2. *The Physiological Effects of Extracts of the Pituitary Body.*[1]

By Professor E. A. SCHÄFER *and* SWALE VINCENT.

1. Extracts of the pituitary body, when intravenously injected, have a marked effect upon the blood-pressure, producing, according to the nature of the extract, either a marked rise or a marked fall. The pituitary body contains, therefore, two active substances, one *pressor* and the other *depressor*. Of these the pressor substance is soluble in salt solution and insoluble in absolute alchol and ether: the depressor substance is soluble in salt solution, in absolute alcohol, and in ether. The active substances are not destroyed by boiling, and are dialysable.

2. The pressor substance produces its action both upon the heart and upon the peripheral arteries (confirmatory of Oliver and Schäfer); the depressor substance probably mainly on the arterioles. The action of the pressor substance is a prolonged one (confirmatory of Oliver and Schäfer), and during the period of its action a second dose is inactive or nearly so (confirmatory of Howell). The action of the depressor substance is evanescent, and can be repeated at short intervals.

3 The pressor effect of the extract may be accompanied by cardiac slowing. This is probably in large part incidental to the contraction of arterioles and rise of aortic pressure, but is in part due to direct action upon the peripheral cardiac mechanism (confirmatory of Oliver and Schäfer, Howell, and Cleghorn).

4. The active substances are contained only in the infundibular, not in the hypophysial part of the pituitary body (confirmatory of Howell).

5. Subcutaneous injection of the extracts in small mammals causes paralytic symptoms similar to those obtained by injecting suprarenal extract.

6. The characteristic effects produced by extracts of the infundibular body are probably not due to the grey nervous matter of which this is largely composed (confirmatory of Howell).

3. *On the Theory of Hearing.* *By* A. A. GRAY.

SATURDAY, SEPTEMBER 16.

The following Papers were read:—

1. *On the Resonance of Nerve and Muscle.* *By* Dr. F. C. BUSCH.

[*From the Physiological Institute of the University of Bern*].

It is known and shown in the work of N. Wedensky,[2] that the pitch of an artificial muscle tone (Helmholtz) corresponds to the frequency of the stimuli which are given to the nerve or to the muscle directly.

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[1] A more extended account will be found in the *Journ. of Physiol.* vol. xxv. p. 1.

[2] Du Bois-Reymond's *Arch.*, 1883, p. 313.

Bernstein and Schoenlein as well as Wedensky, who used Kronecker's tone-inductorium, found that when the frequency of stimuli exceeded 1,000 per second, the muscle tone no longer corresponded with the frequency of stimuli, but a lower tone was given out.

It seems to H. Kronecker, that the tone of the interruptor governing a moderate frequency of stimuli, would not only be reproduced in the muscle with the same pitch, but also with the same timbre and quality.

We desired to know, whether the tones from two interruptors vibrating at different rates could be heard in the doubly stimulated muscle.

The gastrocnemius muscle of the rabbit, irritated directly or through the sciatic nerve, was used for stimulation with opening induction shocks of different frequencies, in some cases of 60 and 100 per second, and in others of 100 and 200 per second.

With the same intensity of current from both interruptors, in most instances, the high tone was heard in the muscle by means of a solid stethoscope, at first stronger than the lower tone; but the low tone remained audible longer than the high tone.

In several instances, however, the low tone became inaudible before the higher tone.

The same result followed if the nerve was clamped in two pairs of electrodes, the one proximal and the other distal.

When the nerve was stimulated through the proximal electrodes, the tone was weaker than when it was stimulated through the distal electrodes, although the intensity of the current, and the frequency of the stimuli remained the same in both places.

When the cerebrum of the rabbit had been eliminated, and the cervical cord stimulated with induction shocks of different frequencies, there could be heard for several seconds the deep natural muscle tone.

Stimulation of the lumbar cord gave, in consequence of the spreading of derived currents to the nerve roots, the artificial muscle tone.

In another similar experiment, we heard the deep natural muscle tone for several seconds only. When a frequency of 100 stimuli per second was used alone, and with the same intensity of current as before, namely 10,000 units (with three Daniell cells, the position of the secondary coil on a convenient scale of induction machine), a strong and increasing tetanus followed, and a loud and distinct tone was heard which increased in strength as long as the stimulus lasted. This note was one tone higher than that of the tuning-fork interruptor. The same was heard when the lumbar cord, and when the muscle itself was stimulated.

In the dog whose cervical cord was stimulated we heard the deep natural muscle tone, as well with 100 stimuli per second as with 60.

When the 'action currents' of the muscle stimulated by different frequencies were made audible with the aid of the telephone, the same results were obtained as when we listened to the muscle directly.

The higher tone became inaudible before the lower tone.

2. *The Propagation of Impulses in the Rabbit's Heart.* *By* H. KRONECKER *and* Dr. F. C. BUSCH. [*From the Physiological Institute at Bern.*]

W. His, jun., has cited only one fact in support of the myogene nature of the adult heart pulse.

At the Third Physiological Congress in Bern [1] he communicated the observation that simple muscle fascicles could be demonstrated between the septum atriorum and the septum ventriculorum of rabbits' hearts, and that through these fascicles, impulses were conducted from the auricles to the ventricles.

We have, in a number of rabbits, cut through the septum atriorum near the septum of the ventricles, from the dorsal side of the heart where His and Romberg

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[1] *Centralblatt f. Physiologie*, ix. p 469

have placed their conducting fibres. After this lesion the auricles and ventricles continued to beat in coordination as before. After cutting most of the apex away from the base, but still leaving a large number of connecting fibres, the apex ceased to beat while the base continued to pulsate.

If now the septum ventriculorum of the base was incised in several places, the base either ceased to beat entirely or the bases of the two ventricles pulsated incoordinately.

These facts cannot be explained by the theory of the myogene nature of the heart pulsation.

Also, we cannot understand, however slow the conduction in a muscle may be, how the pause between the contraction of the auricles and the ventricles can be thus explained.

It is also impossible to explain by the myogene theory the fibrillation of the dog's heart after a mechanical lesion of a very small region in the septum ventriculorum, where we must place the vasomotor centre of the coronary arteries.

3. *Concerning Fibrillation and Pulsation of the Dog's Heart. By* Dr. F. C. BUSCH. [*From the Physiological Institute of the University of Bern.*]

Dr. Busch observed the excised dog's heart, which was still beating weakly after being cut out, to pulsate when perfused through the large descending branch of the left coronary artery with a mixture of equal parts of defibrinated dog's blood and 0·6 per cent. salt solution at 38° C.

The contractions were at first irregular and weak, but became regular, stronger, and more frequent as the perfusion continued.

When the muscle was tetanised, it fibrillated only during the excitation.

This result agrees with observations made by Porter.

In other cases we found that the part of the dog's heart which was perfused with a mixture of equal parts of defibrinated calves' blood and 0·6 per cent. salt solution, fibrillated for twenty minutes, and then pulsated for seven to forty minutes, at first irregularly, then regularly, then at long intervals, and finally only upon stimulation. If, however, the ventricle was fed through a coronary artery in a normal manner with normal dog's blood, by means of uniting the coronary directly with the femoral or carotid of another dog, the pulsations continued only so long as the coordination apparatus was not disturbed.

As soon as the vasomotor centre in the septum ventriculorum was stimulated either through a stab or through electrical excitation, the ventricle began to fibrillate and continued without recovery.

If, after the circulation of normal blood, various abnormal mixtures were used, the same heart began, in most cases, to pulsate, more or less regularly.

In one instance we saw the dog's heart which was being perfused with normal blood, fibrillate for twenty-three minutes, and then, upon perfusing with equal parts of warmed defibrinated blood from the same dog and 0·6 per cent. salt solution, to continue fibrillation for fifty-eight minutes more.

Perfusion with simple normal salt solution failed to preserve either fibrillation or pulsation. The parts perfused became œdematous, and failed to beat, while neighbouring parts, not supplied with salt solution, continued to contract.

A flap of the left ventricle which had been dissected away from the rest of the wall so as to remain connected only by muscle at its base, and by its artery and veins, pulsated with a slower rhythm than the rest of the heart.

After the vessels supplying this flap had been tied, the ventricle was caused caused to fibrillate; the flap continued to pulsate as before.

In another case the flap fibrillated with the ventricle, but resumed pulsations after the ligature of its vessels.

In the third similar experiment, the flap continued to fibrillate after the ligature of its vessels.

4. *On the Effects of Successive Stimulation of the Visceromotor and Vasomotor Nerves of the Intestine.* *By* J. L. Bunch, *D.Sc., M.D.*

When the contractions of the circular and longitudinal coats of the same segment of small intestine are recorded together, stimulation either of the vagus or of the splanchnic produces the same effect on both coats, but when the contractions of two different segments are recorded, the circular coat of one and the longitudinal coat of the other, the result of stimulation is not necessarily the same on both. Successive stimulation of the vagus and splanchnic nerves with the same strength of current shows some differences according to the order in which the two nerves are stimulated. Though the effect produced by a preliminary stimulation of the splanchnic can be modified or even overcome by subsequent excitation of the vagus, when such excitation normally gives rise to an effect opposed to that brought about by the splanchnic, a reversal of the order of stimulation does not give rise to a similar result, and a secondary stimulation of the splanchnic cannot, as a rule, equally modify the effect produced by preliminary vagus excitation.

The vasomotor effects which François Franck and Hallion have ascribed to the vagus, I have, in a somewhat prolonged series of experiments, been unable to confirm.

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5. *On Stimulation and Excitability of the Anæmic Brain.* *By* William J. Gies. [*From the Physiological Institute of the University of Bern.*]

The research indicated by this subject was conducted in the Physiological Institute at Bern, upon the suggestion and under the constant direction of Professor Kronecker. Our aim was to determine definitely the sequence of events during perfusion of various so-called indifferent solutions through the brain, the data thus obtained to afford a starting-point for future research with such liquids as may be found to exert specific and characteristic influences.

In this report I shall present only the briefest outline of the experiments and the results obtained.

The animals employed were toads, frogs, rabbits, and dogs.

The solutions used were various strengths of pure sodium chloride, Ringer's solution and Howell's modification of it; Schücking's solution, both of calcium and sodium saccharate, and serum.

The perfusion in the cold-blooded animals was conducted with the least possible pressure through the abdominal vein. All of the various solutions already enumerated, except the serum, were used. We made thirteen experiments (seven with toads and six with frogs), each of which continued for a period of two to eight hours, with a total transfusate of 250 to 1,600 c.c.

During the period of perfusion the following functions gradually weakened and then usually disappeared in this order: (*a*) Respiration; (*b*) Skin reflex; (*c*) Lid reflex; (*d*) Nose reflex; (*e*) Heart beat.

The time of disappearances of these functions varied with the total length of the experiments, and apparently also with the amount of fluid transfused.

Convulsive extension of the limbs occurred in all of the experiments in the earlier stages, but toward the close of each, and before the reflex movements of the eyelids ceased, no such manifestations could be induced.

In passing it should be noted that:

(*a*) All of the animals became edematous; even those in which perfusion took place at the lowest possible pressures and for the shortest periods.

(*b*) Also, that it was impossible to entirely remove the blood corpuscles, even when the perfusion continued uninterruptedly for eight hours, and as much as 1,600 c.c. of fluid had slowly passed through the body. In all cases the fluid flowing from the canula, and particularly that pressed from the heart and brain, contained quite an appreciable number of red and white corpuscles.

We carried out fourteen experiments with rabbits and three with dogs, all of the previously mentioned fluids having been used.

Ligaturing, either in the neck or in the chest, the arteries to the brain, before, or simultaneously with, the beginning of the perfusion, brought on convulsions immediately. Even when the perfusion had been begun shortly before the arterial blood was completely shut off, it remained impossible to prevent convulsions and quickly ensuing death.

Finally, instead of closing the arteries to the brain, the abdominal aorta, vena cava and vena porta were tied off and the heart's action utilised to pump the liquid through the brain, the perfused fluid going into the heart by one jugular and from the brain through the other. By this method anæmia could also be induced, convulsions entirely prevented, and life considerably prolonged.

As in the experiments with the cold-blooded animals, there was in these also a fairly regular disappearance of functions, the intervals appearing to vary with the total time of perfusion. With all of the solutions, including serum, both in the rabbits and in the dogs, the order of cessation usually was: (*a*) Respiration; (*b*) Lid reflex; (*c*) Nose reflex; (*d*) Heart beat.

In some of the experiments, it should be noted, the nose and lid reflexes ceased at practically the same instant. In a few, also, it was impossible to determine the sequence of termination of these two and respiration.

In a single special experiment with a small dog (5 kilos), 200 c.c. of blood was taken, and an equal quantity of horse serum immediately afterwards was transfused to take its place. This process was repeated three times at intervals of half an hour. After the fourth withdrawal of fluid, the dog ceased to breathe, and did not recover when the serum was transfused. Aside from variations in heart action and respiration, there were no special functional changes until the end, when respiration suddenly ceased, and the other functions quickly disappeared in the order of the other experiments. Death was neither preceded nor accompanied by convulsions.

The more important conclusions of this preliminary research are:

1. When the brain is subjected to acute anæmia produced by the ligature of its arteries or by the transfusion of indifferent solutions such as physiological saline, Ringer's, Schücking's and also serum, its functions are not maintained (and convulsions ensue, but may be prevented by producing *gradual* instead of *acute* anæmia).

2. In gradual anæmia of the brain, as induced in these experiments, the following functions cease, usually in this order: (*a*) Respiration; (*b*) Lid reflex; (*c*) Nose reflex; (*d*) Heart beat.

MONDAY, SEPTEMBER 18.

The following Papers were read:—

1. *On the Innervation of the Thoracic and Abdominal Parts of the Œsophagus. By* W. MUHLBERG, *of Cincinnati.* [*From the Physiological Institute of the University of Bern.*]

The course and function of the branches of the superior laryngeal nerve which are distributed to the cervical part of the œsophagus are already well known from the researches of Lüscher. The distribution of the vagi in the thoracic part has, so far as we are aware, not been hitherto investigated.

I have previously shown by dissection the mode of branching of the vagi on the œsophagus of the dog and rabbit.

The functions of these nerves have now been investigated by me in conjunction with Professor Kronecker on etherised *curarised* animals. The following is summary of the results obtained regarding the action of the parts concerned under these conditions:—

1. Water placed in the mouth does not give rise to swallowing movements.

2. Stimulation of the superior laryngeal (central end) produces no movements of the pharynx and upper part of the œsophagus, but the larynx is sometimes slightly elevated. During the stimulation the thoracic and œsophageal parts of the gullet are slightly drawn up. About two seconds *after* stimulation contraction of the cardia occurs—often quite a strong one.

3. Similar phenomena attend stimulation of the central end of either vagus.

4. Stimulation of the peripheral end of the vagus also frequently causes contraction of the same parts, but only after eight to ten seconds.

5. Direct stimulation of the cardia causes it to contract. During this observation the artificial respiration was suspended in order the better to observe the movements of the cardia. If this suspension of respiration was long continued the slight automatic movements of the cardia became increased in amount.

6. With vagus stimulation there was contraction of the pylorus without any inhibition.

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2. *Observations, Physiological and Pharmacological, on the Intestinal Movements of a Dog with a Vella Fistula. By* J. E. ESSELMONT. [*From the Physiological Institute of the University of Bern.*]

Physiological Observations.

I. The rhythm of the 'pendulum movements' (Bayliss and Starling) was extremely regular, the frequency of ten to twelve per minute being preserved in the fasting and feeding animal, with or without peristalsis. Occasionally the frequency rose to eighteen and twenty per minute. The movements were then irregular, and suggested the interference of two distinct sets of waves.

The great variation in size of these pendulum movements, which occurred from time to time, did not correspond to variations in the rate of peristalsis. With the most rapid peristalsis the waves were small, probably masked by the tonic intestinal contraction around the balloon sound used for recording purposes.

II. Peristalsis, under different conditions, varied from 0 to 22½ cm. per minute. The normal average rate, twelve to twenty hours after food, was about ½ cm. per minute, but wide variations occurred from hour to hour and day to day.

Antiperistalsis was never observed. Transient increase of peristalsis appeared after deglutition. After a full meal peristalsis remained depressed for three to six hours or more.

After slight exercise a transient well-marked increase of peristalsis occurred. More prolonged exercise had, as a rule, no further effect than that following slight exercise. When pushed to the point of moderate fatigue, some retardation of the movements occurred. After emotion a marked increase constantly occurred, but lasted for only a few minutes. Light sleep seemed to have no decided effect on the movements.

Pharmacological Observations.

When certain purgatives, chiefly derivatives of aloe (kindly furnished to me, and their chemical properties determined by Professor Tschirsch) were given to the dog, by mouth, the doses required to produce purgation were approximately the same as those required for a man of ten times the dog's weight.

A phase of increased peristalsis in the fistulous loop usually preceded the onset of purgation by several hours.

The substances investigated were barbaloin, its three derivatives—aloe-emodin, alochrysin, alonigrin—and also, nataloin and chrysophanic acid.

The experiments went to show that barbaloin, with its derivatives, and chrysophanic acid, which probably all agree chemically in possessing the anthracene nucleus in their molecules, agree also pharmacologically in possessing marked purgative properties. Nataloin, whose molecule does not possess the anthracene nucleus, is inactive for man, and has but very slight action in the dog.

The most active were aloe-emodin and alochrysin, either when given by the fistula or by the mouth, while barbaloin itself, although freely soluble, appeared to be active only when given by the mouth, and not when given through the fistula direct. It apparently requires to be split up under the action of the alkaline intestinal juice.

[A detailed account of the physiological experiments will appear in the 'Zeitschrift für Biologie,' and of the pharmacological, in the 'Archiv für experimentelle Pathologie und Pharmakologie.']

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3. *On Respiration on Mountains.* *By* Dr. EMIL BURGI.

[From the Physiological Institute of the University of Bern.]

At Professor Kronecker's advice, Dr. Burgi has continued the investigations on the above subject, the earlier results of which were communicated to the Physiological Congress in Cambridge, 1898. In these experiments he found that, for equal amounts of work performed at the foot and on the top of the Brienzer Rothhorn, the CO_2 output was greater in the latter case. After seven days' training on the mountain this difference disappeared.

This year Dr. Burgi has repeated this experiment on the Gornergrat railway, since the experiments could here be carried out at a height (3,035 metres) at which 'mountain sickness' is frequently observed.

The CO_2 outputs by rest and work at the foot of the Brienzer Rothhorn (650 m.) were compared with the output under similar conditions on the top of the Gornergrat (about 3,000 m.).

He expired, at rest, during 12 minutes at 650 m. 31 gm. CO_2
,, ,, ,, ,, at 3,000 m. 34 gm. CO_2
After training ,, ,, ,, at 650 m. 29 gm. CO_2
,, ,, ,, ,, at 3,000 m. 30 gm. CO_2

He then repeated the experiments previously carried out on the Brienzer Rothhorn, but with varying steepness, and therefore severity of work.

The work done is shown in the following table:—

Dr. Burgi weighed (with pack) 108 kgm. The distance traversed in each case was 270 metres.

Inclination.	Height traversed.	Work done.
17·29 per cent.	46·0005 m.	4968·0 kgm.
19·0 ,,	50·3984 m.	5443·2 ,,
19·3 ,,	51·1638 m.	5525·3 ,,
25 ,,	65·5 m.	7074·0 ,,

The CO_2 output per 1,000 kgm. work was found to be as follows:—

Inclination.		Output (gm. CO_2).		
17·29 per cent.	(at 650 m.)	6·08.		
19·0 ,,	,,	5·14	The work here was accomplished by traversing 135 metres *twice*.	
19·3 ,,	(at 3,000 m.)	5·78		
19·3 ,,	,,	6·66		
25·0 ,,	,,	5·46	(*after training*).	
19·3 ,,	,,	5·09	,,	Traversing 135 metres twice.
19·0 ,,	(at 650 m.)	5·01	,,	
19·3 ,,	(at 3,000 m.)	5·45	,,	
17·29 ,,	(at 650 m.)	5·30	,,	

These experiments give therefore an average excretion per 1,000 kgm. work of 5·6 gm. CO_2 in the untrained, and 5·0 gm. CO_2 in the trained subject.

4. *On Protamines, the Simplest Proteids.* *By* Professor A. Kossel.

5. *Protamines and their Cleavage Products: their Physiological Effects.* *By* Professor W. H. Thompson.

6. *The Vascular Mechanism of the Testis.*

By Walter E. Dixon, *M.D., B.Sc. London.*

The method adopted was the Plethysmographic, both testes being rapidly shelled out, and, after incising or removing the tunica vaginalis, enclosing them in a gutta-percha oucometer. The animals used were mainly dogs and cats, although rabbits and goats were occasionally employed. By this method it was shown that the testis undergoes changes in volume passively as a result of alterations in blood pressure, and active changes due to vasomotor nerves.

The following were the main conclusions which were drawn:—

1. Operations involving the testis are usually followed by some vascular disturbance, the blood pressure falling and the heart beating more feebly.

2. The sympathetic filaments in the spermatic cord may be divided into three groups according to the effect produced on the testis whilst stimulating their peripheral end, viz.: (*a*) vaso-constrictors; (*b*) vaso-dilators; (*c*) those producing no alteration in volume, these probably being afferent fibres associated with testicular sensation.

3. The vaso-constrictor nerves to the testis were traced and shown to pass mainly through the anterior roots of the thirteenth dorsal and first and second lumbar nerves in the dog. There is still some doubt with regard to the position of the vaso-dilators.

4. Injections of testicular extract produce a different effect in different animals; in the cat there is a fall of blood-pressure with marked inhibition, whilst in the goat there is a considerable rise without the inhibition. The chief active constituent is nucleo-proteid. In every case the ultimate effect on the testis is one of dilatation.

5. The substances having the most marked effect on testicular volume were the following:—

(*a*) *Gold Chloride.*—In small doses there is comparatively little effect on blood pressure. The testis first contracts and then gradually dilates, the dilated condition being considerable and permanent.

(*b*) *Cantharidin.*—In very small doses (·001 gramme to an animal of three or four kilos) there is first a rise in pressure with slowing, followed by a very insignificant fall; the intestinal area is dilated, and the testes and kidneys undergo marked constriction. This active testicular constriction is greater and more prolonged than that which could be produced with any other substance, and is followed by a stage of very considerable dilatation.

(*c*) *Valerian.*—A concentrated infusion in medicinal doses produces ultimately a passive slight testicular dilatation.

(*d*) *Anhalonnine* produces an entirely passive dilatation of testis as a result of rise in blood pressure.

(*e*) *Other substances.*—The following substances all produced some testicular dilatation, generally insignificant: strychnine, cannabis indica, amyl nitrite, ergot, alcohol.

TUESDAY, SEPTEMBER 19.

The following Papers were read :—

1. *The Dependence of the Tonus of the Muscles of the Bladder in Rabbits on the Spinal Cord. By* John P. Arnold, *Philadelphia.* [*From the Physiological Institute of the University of Bern.*]

I. The tonus of the Sphincter is normally greater than that of the Detrusor.

1. The Sphincter may be so strongly contracted as to withstand, at first, a water pressure of 38·2 cm. In other cases it may only withstand a pressure of 17 cm.
2. The Detrusor tonus in a moderately filled bladder, soon after catheterisation, may be as high as 31·4 cm. water pressure. On the other hand the tonus of the Detrusor in a moderately filled bladder may be as low as 3·5 cm.
3. Normally the Sphincter tonus remains tolerably constant between 25 cm. and 30 cm., but may vary between 31 cm. and 38·2 cm., as observed in one rabbit, or between 17 cm. and 24 cm. as observed in another.
4. The tonus of the moderately filled bladder is normally between 4 cm. and 5 cm. water pressure. The tension rises in proportion to the fulness.
5. Under high pressure both the Sphincter and the Detrusor make rhythmic contractions at irregular intervals.

II. After shutting off the blood supply from the lower part of the spinal cord by compression or ligation of the abdominal aorta, the tonus of the Sphincter and of the Detrusor sinks rapidly.

1. The tonus of the Sphincter falls at once very rapidly, quite low, then gradually, until all tonus is lost. In one animal the tonus of the Sphincter did not begin to fall until twelve minutes after ligation of the aorta. In this case the aorta was ligated just above its division.
2. The Sphincter may still retain a small degree of tonus as long as 1½ hour after death.
3. The tonus of the Detrusor falls more slowly than that of the Sphincter.
4. In one experiment we observed, after swallowing movements produced by stimulation of both superior laryngeal nerves, a rapid sinking of the Sphincter tonus.
5. Physical disturbances, such as loud noises, lower the tonus of the Sphincter.

In our experiments normal salt solution, kept at a constant temperature between 39° and 41° C., was used in the bladder. Before passing the catheter the penis was rendered anæsthetic by a 5 per cent. solution of cocain.

Animals which were killed by bleeding or by section between the medulla and cerebellum gave similar results to those observed after ligation or compression of the aorta. After section above the medulla artificial respiration was used. During this period the Sphincter tonus fell more slowly.

2. *Observations on Visual Acuity from Torres Straits. By* Dr. W. H. R. Rivers.—See Reports, p. 586.

3. *Observations on Visual Acuity from New Guinea. By* C. G. Seligmann.

4. *On a New Instrument for measuring the duration of Persistence of Vision on the Human Retina. By* Eric Stuart Bruce, *M.A.Oxon., F.R.Met.Soc.*

The aerial graphoscope devised by the author for measuring the duration of persistence of vision on the retina consists of a lath of wood 76 centimetres long and 5 centimetres broad, painted white in front with a grey centre gradually diminishing in shade to white towards the extremities. This is revolved at its centre by an electric motor provided with a means of counting its revolutions, and worked by means of a five-cell electric storage battery. The lath is placed 1 metre 14 centimetres from the nozzle of a projection lantern, in which there is a lantern slide representing a statue or other definite figure. On the lath at rest a small portion of the lantern image is projected and focussed. When the lath is revolved rapidly at about 318 revolutions per half-minute, the whole picture appears standing out boldly in space and in relief, and at this rate of revolutions is steady. The persistent image, however, is visible, though not steady, at much lower rates of revolution, the lowest rate being a matter of individual capacity. By ascertaining the rate of revolutions of which each person can just see persistence his particular capacity is calculated.

Tables containing the results of a hundred tests with 67 persons were shown. One of these gave a group of 25 tests with persons of both sexes and various ages and classes. The low rate of 27 revolutions per half-minute was taken as the lowest limit for the tests.

Another table of special interest gave tests of 26 schoolboys before and after the bodily fatigue produced by running. The persistence of every subject was altered by running, except one, who registered the same in each case. The record of seven was lowered, but that of nineteen was heightened, showing that bodily fatigue tends to prolong persistence of vision, which seems to be the tendency of illness.

A third table showed tests under the light of different colours; the rays from the lantern passing through red, green, and violet glasses. It also showed tests of three persons before and after retinal rest.

The question of persistence of vision in relation to its duration in different individuals and in the same individual under different circumstances, appears to have an important bearing on modern rapid visual signalling. In reading the signals the signaller has to discriminate between real and incidental images, and his sharp reading of dots and dashes will depend upon the persisting capacity of his retina. A good signaller is likely to be one whose persistence of vision is abnormally low, a bad signaller one whose persistence of vision is abnormally high. The aerial graphoscope affords a means of testing signallers as to their capacities of persistence of vision, and of selecting the fittest. For this purpose it has lately been installed in the school of signalling at Aldershot.

SECTION K.—BOTANY.

PRESIDENT OF THE SECTION—SIR GEORGE KING, K.C.I.E., LL.D., M.B., F.R.S.

THURSDAY, SEPTEMBER 14.

The President delivered the following Address:—

A Sketch of the History of Indian Botany.

THE earliest references in literature to Indian plants are, of course, those which occur in the Sanskrit classics. These are, however, for the most part vague and obscure. The interest which these references have, great as it may be, is not scientific, and they may therefore be omitted from consideration on the present occasion. The Portuguese, who were the first Europeans to appear in India as conquerors and settlers, did practically nothing in the way of describing the plants of their Eastern possessions. And the first contribution to the knowledge of the Botany of what is now British India was made by the Dutch in the shape of the 'Hortus Malabaricus,' which was undertaken at the instance of Van Rheede, governor of the territory of Malabar, which during the latter half of the seventeenth century had become a possession of Holland. This book, which is in twelve folio volumes and is illustrated by 794 plates, was published at Amsterdam between the years 1686 and 1703, under the editorship of the distinguished Botanist Commelyn. Van Rheede was himself only a Botanical amateur, but he had a great love of plants and most enlightened ideas as to the value of a correct and scientific knowledge of them. The 'Hortus Malabaricus' was based on specimens collected by Brahmins, on drawings of many of the species made by Mathæus, a Carmelite missionary at Cochin, and on descriptions originally drawn up in the vernacular language of Malabar, which were afterwards translated into Portuguese by Corneiro, a Portuguese official in Cochin, and from that language finally done into Latin by Van Douet. The whole of these operations were carried on under the general superintendence of Casearius, a missionary at Cochin. Of this most interesting work the plates are the best part; in fact, some of these are so good that there is no difficulty in identifying them with the species which they are intended to represent. The next important contribution to the Botanical literature of Tropical Asia deals rather with the plants of Dutch than of British India. It was the work of George Everhard Rumph (a native of Hanover), a physician and merchant, who for some time was Dutch consul at Amboina. The materials for this book were collected mainly by Rumphius himself, and the Latin descriptions and the drawings (of which there are over one thousand) were his own work. The book was completed in 1690, but it remained unpublished during the author's lifetime. Rumph died at Amboina in 1706, and his manuscript, after lying for thirty years in the hands of the Dutch East India Company, was rescued from oblivion by Professor John Burman, of Amsterdam (commonly known as the elder Burman), and was published under the title of 'Herbarium Amboinense,' in seven folio volumes, between the years 1741 and 1755. The illustrations of this work cover over a thousand species, but they are printed on 696 plates. These illustrations are as much inferior to those of Van Rheede's book as the descriptions are superior to those of the latter. The works of Plukenet, published in London between 1696 and 1705, in quarto, contain figures of a number of Indian plants which, although small in size, are generally good portraits, and therefore deserve mention in an enumeration of botanical books connected with British India. An account of the plants of Ceylon, under the name 'Thesaurus Zeylanicus,' was published in 1737 by John Burman (the elder Burman), and in this work many of the plants which are common to that island and to Peninsular India are described. Burman's book was founded on the collections of Paul Hermann, who spent seven years (from 1670 to 1677) exploring the Flora of Ceylon at the expense of the Dutch East India Company. The nomenclature of the five books already mentioned is all uni-nominal.

Hermann's Cingalese collection fell, however, sixty years after the publication of Burman's account of it, into the hands of Linnæus, and that great systematist published in 1747 an account of such of the species as were adequately represented by specimens, under the title 'Flora Zeylanica.' This Hermann Herbarium, consisting of 600 species, may still be consulted at the British Museum, by the trustees of which institution it was acquired, along with many of the other treasures possessed by Sir Joseph Banks. Linnæus's 'Flora Zeylanica' was followed in 1768 by the 'Flora Indica' of Nicholas Burman (the younger Burman)—an inferior production, in which about 1,500 species are described. The Herbarium on which this 'Flora Indica' was founded now forms part of the great Herbarium Delessert at Geneva.

The active study of Botany on the binominal system of nomenclature invented by Linnæus was initiated in India itself by Koenig, a pupil of that great reformer and systematist. It will be convenient to divide the subsequent history of Botanic science in India into two periods, the first extending from Koenig's arrival in India in 1768 to Sir Joseph Hooker's arrival in 1848; and the second from the latter date to the present day.

The pioneer John Gerard Koenig was a native of the Baltic province of Courland. He was a correspondent of Linnæus, whose pupil he had formerly been. Koenig went out to the Danish Settlement at Tranquebar (150 miles south of Madras) in 1768, and at once began the study of Botany with all the fervour of an enthusiasm which he succeeded in imparting to various correspondents who were then settled near him in Southern India. These friends formed themselves into a society under the name of 'The United Brothers,' the chief object of their union being the promotion of Botanical study. Three of these brothers, viz. Heyne, Klein, and Rottler, were missionaries located near Tranquebar. Gradually the circle widened, and before the century closed, the enthusiasm for Botanic research had spread to the younger Presidency of Bengal, and the number of workers had increased to about twelve, among whom may be mentioned Fleming, Hunter, Anderson, Berry, John, Roxburgh, Buchanan (afterwards Buchanan-Hamilton), and Sir William Jones, so well known as an Oriental scholar. At first it was the custom of this brotherhood merely to exchange specimens, but gradually names began to be given, and specimens, both named and unnamed, began to be sent to Botanists of established reputation in Europe. Many plants of Indian origin came thus to be described by Retz, Roth, Schrader, Willdenow, Vahl, and Smith. Rottler was the only member of the band who himself published in Europe descriptions of any of the new species of his own collecting, and these appeared in the 'Nova Acta Acad. Nat. Curiosorum' of Berlin. A little later Sonnerat and other Botanists of the French Settlement at Pondicherry sent large collections of plants to Paris, and these were followed at a considerably later date by the collections of Leschenhault. These French collections were described chiefly by Lamarck and Poiret. Hitherto Botanical work in India had been more or less desultory, and it was not until the establishment in 1787 of the Botanic Garden at Calcutta that a recognised centre of Botanical activity was established in British India. Robert Kyd, the founder of that Garden, was more of a gardener than a Botanist. He was, however, a man of much energy and shrewdness. The East India Company was still in 1787 a trading company, and a large part of their most profitable business was derived from the nutmegs and other spices exported from their settlements in Penang, Malacca, Amboina, Sumatra, and other islands of the Malayan Archipelago. The Company were also in those days the owners of a fine fleet of sailing vessels, and the teak of which these ships were built had to be obtained from sources outside the Company's possessions. The proposal to found a Botanic Garden near Calcutta was thus recommended to the Governor of the Company's settlements in Bengal on the ground that, by its means, the cultivation of teak and of the Malayan spices might be introduced into a province near one of the Company's chief Indian centres. Kyd, as a Lieutenant-Colonel of the Company's engineers and as Secretary to the Military Board at Calcutta, occupied a position of considerable influence, and his suggestion evidently fell on no unwilling ears; for the Government of Bengal, with the promptitude to accept and to act on good advice in scientific and semi-scientific matters which has characterised them from the day of Kyd until now, lost no time in taking steps to find a site for the proposed garden. Colonel Kyd's official proposal was dated June 1, 1786, and, in a despatch dated August 2, the Calcutta Government recommended Kyd's proposal to the Court of Directors in London. Posts were slow and infrequent in those days, and the Calcutta Government were impatient. They did not wait for a reply from Leadenhall Street, but in the following July they boldly secured the site recommended by Colonel Kyd. This site covered an area of 300 acres, and the whole of it, with the exception of thirty acres which were subsequently given up to Bishop Middleton for an English college, still continues under cultivation as a Botanic Garden. Kyd died in 1793, and in the same year his place as Superintendent of the Garden was taken by Dr. William Roxburgh, a young Botanical enthusiast, and one of Koenig's 'United Brotherhood.' Roxburgh had studied Botany in Edinburgh, where he was a favourite pupil of Dr. Hope. Desirous of seeing something of foreign countries, he made several voyages to Madras in ships belonging to the Honourable East India Company. In 1776 he accepted an appointment in the Company's Medical Establishment, and was posted to the town of Madras, where he very soon made the acquaintance of Koenig. Roxburgh was shortly after transferred to a remote district, a good deal to the north of Madras, then named the Northern Circars. The station of Samulcotta, which formed Roxburgh's headquarters during his sojourn in the Circars, stands on the edge of a hilly region possessing a very interesting Flora, and this Flora he explored with the greatest ardour; and as part of the result of his labours an account of some of the most interesting of its plants was published in London, at the East India Company's expense, in three large folio volumes under the title 'The Plants of the Coast of Coromandel.' This was Roxburgh's earliest publication on a large scale. The first part of this book appeared in 1795, and the last not until 1819, *i.e.* five years after the author's death. The increased facilities afforded to Roxburgh after his transfer to a comparatively well-equipped institution like that at Calcutta induced him at once to begin the preparation of descriptions of all the plants indigenous to British India of which he could procure specimens. And so diligently did he work that, when he was finally driven from India by ill-health in 1813, he left complete and ready for publication the manuscripts of his 'Flora Indica' and of his 'Hortus Bengalensis' (the latter being an enumeration of the plants in cultivation in the Calcutta Garden). He also left admirable coloured drawings (mostly of natural size) of 2,533 species of plants indigenous to India. Seldom have twenty years yielded so rich a Botanical harvest! Dr. Roxburgh was thus the first Botanist who attempted to draw up a systematic account of the plants of India, and his book, which is on the Linnæan system, is the basis of all subsequent works on Indian Botany; and until the publication of Sir Joseph Hooker's monumental 'Flora of British India' it remained the only single book through which a knowledge of Indian plants could be acquired. Roxburgh was immediately succeeded in the Calcutta Garden by Dr. Buchanan-Hamilton, a man of many accomplishments, who had travelled from Nepal in the North to Ava and

Mysore in the South, accumulating materials for a Gazetteer of the Honourable Company's possessions. Dr. Buchanan was a Zoologist as well as a Botanist. He had published a valuable account of Mysore, Canara, and Malabar, and had collected materials for a work on the Fishes of India, besides having accumulated a large Herbarium, part of which may now be consulted at the University of Edinburgh. Prior to his death Buchanan-Hamilton had begun to write a learned commentary on Van Rheede's 'Hortus Malabaricus.' Many of his Nepalese collections were described in 1825 (a few years before his own death) by Don in his 'Prodromus Floræ Nepalensis.' Buchanan-Hamilton remained only one year at Calcutta, and in 1815 he was succeeded by Nathaniel Wallich, a native of Copenhagen, who, prior to his appointment to the Calcutta Garden, had been attached as surgeon to the Danish settlement at Serampore, twenty miles higher up the Hooghly. Wallich remained Superintendent of the Calcutta Garden for thirty years. In 1846 he went to England, and in 1854 he died. During his tenure of office in the Calcutta Garden, Wallich organised collecting expeditions to the then little-known regions of Kamaon and Nepal (in the Himalaya), to Oudh, Rohilcund, Sylhet, Tenasserim, Penang, and Singapore. He personally undertook in fact a botanical survey of a large part of the Company's possessions in India. The vast materials thus collected under his own immediate direction, and the various contributions made by others, were taken to London by him in 1828. With these were subsequently incorporated the collections of Russell, Klein, Heyne, Rottler, Buchanan-Hamilton, and Roxburgh. And by the help of a band of distinguished European Botanists, among whom may be named De Candolle, Kunth, Lindley, Meissner, Nees von Esenbeck, Von Martius, and Bentham (the latter in a very special manner), this vast mass of material was classified and named specifically. A catalogue of the collection was prepared by Wallich himself (largely aided by Bentham), and sets of the named specimens were distributed to the leading Botanical institutions in Europe, every example of each species bearing the same number. No description of the whole collection was ever attempted, but many of the plants belonging to it were subsequently described in various places and at various times. So extensive was the Wallichian distribution that, amongst the names and synonyms of tropical Asiatic plants, no citation is more frequent in Botanical books than that of the contraction 'Wall. Cat.' Besides the naming and distribution of this gigantic collection, Wallich prepared and published, at the expense of the same liberal and enlightened East India Company, his 'Plantæ Asiaticæ Rariores,' in three folio volumes with 300 coloured plates. He also contributed to an edition of Roxburgh's 'Flora Indica,' which was begun by the celebrated Dr. Carey of Serampore, descriptions of many plants of his own collecting. But the task of publishing his discoveries in this way proved beyond his powers, as it would have proved beyond those of any one who had only 365 days to his year, and less than a hundred years as his term of life! Carey and Wallich's edition of Roxburgh's 'Flora Indica' was brought to an untimely conclusion at the end of the *Pentandria Monogynia* of Linnæus. Wallich also began an illustrated account of the Flora of Nepal under the title 'Tentamen Floræ Nepalensis.' But this also came to a premature end with the publication of its second part.

During much of the time that Wallich was labouring in Northern India, Robert Wight, a botanist of remarkable sagacity and of boundless energy, was labouring in Southern India, chiefly in parts of the Peninsula different from those in which Koenig and his band had worked. Wight was never liberally supported by the Government of Madras, and it was mostly by his own efforts and from his own resources that his collections were made, and that his Botanical works were published. The chief of the latter is his 'Icones Plantarum.' This book consists of figures with descriptions of more than two thousand Indian species. A good many of the plates are indeed copies from the suite of drawings already referred to as having been made at Calcutta by Dr. Roxburgh. The rest are from drawings made by native artists under his personal supervision. Ample evidence of the extraordinary energy of Dr. Wight is afforded by the facts that, although he had to teach the native artists whom he employed both to draw and to lithograph, the two thousand *Icones* which he published and described were issued during the short period of thirteen years, and that during the whole of this time he performed his official duties.

Besides this *magnum opus* Wight published his *Spicilegium Nilghirense* in two vols. quarto, with 200 coloured plates. And between 1840 and 1850 he issued in two vols. quarto, with 200 plates, another book named 'Illustrations of Indian Botany,' the object of which was to give figures and fuller descriptions of some of the chief species described in a systematic book of the highest Botanical merit, which he prepared conjointly with Dr. G. A. Walker-Arnot, Professor of Botany in the University of Glasgow, and which was published under the title 'Prodromus Floræ Peninsulæ Indicæ.' The 'Prodromus' was the first attempt at a Flora of any part of India in which the natural system of classification was followed. Owing to various causes, this work was never completed, and this splendid fragment of a Flora of Peninsular India ends with the natural order *Dipsaceæ.*

The next great Indian botanist whose labours demand our attention is William Griffith. Born in 1810, sixteen years after Wight, and twenty-four years later than Wallich, Griffith died before either. But the labours even of such devotees to science as were these two are quite eclipsed by those of this most remarkable man. Griffith's Botanical career in India was begun in Tenasserim. From thence he made Botanical expeditions to the Assam valley, exploring the Mishmi, Khasia, and Naga ranges. From the latter he passed by a route never since traversed by a Botanist, through the Hookung valley down the Irrawadi to Rangoon. Having been appointed, soon after his arrival in Rangoon, surgeon to Pemberton's Embassy to Bhotan, he explored part of that country, and also sent collectors into the neighbouring one of Sikkim. At the conclusion of this exploration he was transferred to the opposite extremity of the Northern frontier, and was posted to the Army of the Indus. After the subjugation of Cabul, he penetrated to Khorassan. Subsequently he visited the portion of the Himalaya of which Simla is now the best-known spot. He then made a run down the Nerbudda valley in Central India, and finally appeared in Malacca as Civil Surgeon of that Settlement. At the latter place he soon died of an abscess of the liver brought on by the hardships he had undergone on his various travels, which were made under conditions most inimical to health, in countries then absolutely unvisited by Europeans. No Botanist ever made such extensive explorations, nor himself collected so many species (9,000), as Griffith did during the brief thirteen years of his Indian career; none ever made so many field notes or wrote so many descriptions of plants from living specimens. His Botanical predecessors and contemporaries were men of ability and of devotion. Griffith was a man of genius. He did not confine himself to the study of flowering plants, nor to the study of them from the point of view of their place in any system of classification. He also studied their morphology. The difficult problems in the latter naturally had most attraction for him, and we find him publishing, in the 'Linnæan Transactions,' the results of his researches on the ovule in *Santalum*, *Loranthus*, *Viscum*, and *Cycas*. Griffith was also a cryptogamist. He collected, studied, and wrote much on Mosses, Liverworts, *Marsiliaceæ*, and Lycopods, and he made hundreds of drawings to illustrate his microscopic observations. Wherever he travelled he made sketches of the most striking features in the scenery. His habit of making notes was inveterate; and his itinerary diaries are full of information not only on the Botany, but also on the zoology, physical geography, geology, meteorology, archæology, and agriculture of the countries through which he passed. His manuscripts and drawings, although left in rather a chaotic state, were published after his death under the editorship of Dr. McClelland, at the expense of the enlightened and ever-liberal East India Company. They occupy six volumes in octavo, four in quarto, and one (a 'Monograph of Palms') in folio.

Another Botanist of much fame, who died prematurely in 1822, after an Indian career of only nine years, was Dr. William Jack. In 1814–15 Jack accompanied Ochterlony's army to the Nepal terai. He was transferred in 1818 to the Company's Settlement in Sumatra under Sir Stamford Raffles, and during the four years of his residence in Sumatra he contributed to Botanical literature descriptions of many new genera and species which were published in his 'Malayan Miscellanies.' His collections, unfortunately, were for the most part lost by an accident, but those which were saved are now in the Herbarium Delessert in Geneva.

Somewhat similar to Griffith in temperament and versatility was the brilliant Victor Jacquemont, a French Botanist who, at the instance of the Paris Natural History Museum, travelled in India for three years from 1829 to 1832. During this period Jacquemont collected largely in the Gangetic plain. He then entered the North-West Himalaya at Mussourie, explored Gharwal and Sirmur, ascended the Sutlej to Kanawer and Piti (at that time unexplored), visited Cashmir, and returning to the plains, crossed Northern Rajputana to Malwa and the Deccan. He finally reached Bombay with the intention of returning to France. But at Bombay he succumbed to disease of the liver, brought on by hard work and exposure. His remains, after having lain in the cemetery there for fifty years, were, with that tender regard for the personality of her famous sons which France has always shown, exhumed in 1881, and conveyed in a French frigate to find a permanent resting-place in the place of Jacquemont's birth. Jacquemont's collections were transmitted to Paris, and his plants were described by Cambessedes and Decaisne, while his non-botanical collections were elaborated by workers in the branches of science to which they respectively appertained, the whole being published in four volumes quarto, at the expense of the French Government.

The roll of eminent Botanists who worked in India during the first half of the century closes with the name of Thomas Thomson, who collected plants extensively between 1842 and 1847 in Rohilkund and the Punjab, and again still more extensively during a Government mission to the North-West Himalaya and Tibet which was continued from 1847 to 1849. During this period Dr. Thomson explored Simla, Kanawar, Piti, Cashmir, Ladak, and part of the Karakoram. His collections, which were large and important, were transmitted to the Botanic Garden at Calcutta, and thence in part to Kew. They formed no insignificant part of the materials on which the 'Flora Indica' and 'Flora of British India' were founded. Dr. Thomson also published an account of his travels—an admirable book, though now jostled out of memory by the quantities of subsequently issued books of Himalayan travel and adventure.

About the year 1820 a second centre of Botanical enterprise was established at Seharunpore, in the North-West Provinces. A large old garden near that important town, which had been originally founded by some Mohammedan nobles of the Delhi Court, was taken over by the Honourable Company, and was gradually put upon a scientific basis by Dr. George Govan, who was appointed its first superintendent. Dr. Govan was in 1823 succeeded by Dr. J. Forbes Royle, and he in 1832 by Dr. Hugh Falconer. Dr. Royle made collections in the Jumno-Gangetic plain, in the Lower Gharwal Himalaya, and in Cashmir. He was distinguished in the field of Economic rather than in that of Systematic Botany, his chief contribution to the latter having been a folio volume entitled 'Illustrations of the Botany of the Himalaya Mountains.' His valuable labours as an Economic Botanist will be noticed later on. Hugh Falconer was an accomplished palæontologist who devoted but little of his splendid talents to Botany. His great contribution to palæontology, the value of which it is almost impossible to over-estimate, consisted of his exploration and classification of the tertiary fossils of the Sewalik range. Falconer was transferred to the Calcutta Garden in 1842. He was succeeded at Seharunpore by Dr. W. Jameson, who explored the Botany of Gharwal, Kamaon, and Cashmir, but who published nothing Botanical, his chief energies having been devoted to the useful work of introducing the cultivation of the China tea plant into British India, and this he did (as will afterwards be mentioned) with triumphant success.

During the first half of the century, a considerable amount of excellent Botanic work was done in Western India by Graham, Law, Nimmo, Gibson, Stocks, and Dalzell, the results of whose labours culminated in the preparation by Graham of a List of the Plants of Bombay, which was not, however, published until 1839 (after his death); in the publication by Stocks of various papers on the Botany of Scinde; and in the publication by Dalzell and Gibson in 1861 of his 'Flora of Bombay.' It is impossible in a brief review like the present to mention the names of all the workers who, in various parts of the gradually extending Indian Empire, added to our knowledge of its Botanical wealth. It must suffice to mention the names of a few of the chief, such as Hardwicke, Madden, Munro, Edgeworth, Lance, and Vicary, who collected and observed in Northern India, and who all, except the two last mentioned, also published Botanical papers and pamphlets of more or less importance; Jenkins, Masters, Mack, Simons, and Oldham, who all collected extensively in Assam; Hofmeister, who accompanied Prince Waldemar of Prussia, and whose collections form the basis of the fine work by Klotzsch and Garcke (*Reis. Pr. Wald.*); Norris, Prince, Lobb, and Cuming, whose labours were in Penang and Malacca; and last, but not least, Strachey and Winterbottom, whose large and valuable collections, amounting to about 2,000 species, were made during 1848 to 1850 in the higher ranges of the Kamaon and Gharwal Himalaya, and in the adjacent parts of Tibet. In referring to the latter classic Herbarium, Sir Joseph Hooker remarks that it is 'the most valuable for its size that has ever been distributed from India.' General Strachey is the only one who survives of the splendid band of collectors whom I have mentioned. I cannot conclude this brief account of the Botanical labours of our first period without mentioning one more book, and that is the 'Hortus Calcuttensis' of Voigt. Under the form of a list, this excellent work, published in 1845, contains a great deal of information about the plants growing near Calcutta, either wild or in fields and gardens. It is strong in vernacular names and vegetable economics.

The second period of our history begins with the arrival in India in 1848 of Sir (then Dr.) Joseph Hooker. This distinguished Botanist came out in the suite of Lord Dalhousie, who had been appointed Governor-General of India. The province to the exploration of which Sir Joseph directed his chief attention was that of Sikkim in the Eastern Himalaya, the higher and inner ranges of which had never previously been visited by a Botanist, for Griffith's explorations had been confined to the lower and outer spurs. The results of Sir Joseph's labours in Sikkim were enormous. Towards the end of his exploration of Sikkim he was joined by Dr. Thomas Thomson, and the two friends subsequently explored the Khasia Hills (one of the richest collecting grounds in the world), and also to some extent the districts of Sylhet, Cachar, and Chittagong. Dr. Thomson subsequently amalgamated the collections made by himself in the Western Himalaya with those made in Sikkim by Sir Joseph individually, and by them both conjointly in Eastern India; and a distribution of the duplicates after the fashion of the Wallichian issue, and second only to it in importance, was subsequently made from Kew. The number of species thus issued amounted to from 6,000 to 7,000, and the individuals were much more numerous than those of the Wallichian collection. The immediate literary results of Sir Joseph Hooker's visit to Sikkim were, (1) his superbly illustrated monograph of the new and magnificent species of *Rhododendron* which he had discovered; (2) a similar splendid volume illustrated by plates founded on drawings of certain other prominent plants of the Eastern Himalaya which had been made for Mr. Cathcart, a member of the Civil Service of India, and (3) his classic 'Himalayan Journals'—a book which remains until this day the richest repertory of information concerning the botany, geography, and anthropology of the Eastern Himalaya. A remoter result was the appearance in 1855 of the first volume of a 'Flora Indica,' projected by himself and his friend Dr. Thomson. The first half of this volume is occupied by a masterly introductory essay on Indian Botany, of which it is hardly possible to overrate the importance. This remarkable essay contains by far the most important contribution to the Physico-Geographical Botany of India that has ever been made, and it abounds in sagacious observations on the limitation of species and on hybridisation, besides containing much information on the history of Indian Botanical collections and collectors. The taxonomic part of the book was cast in a large mould, and the descriptions were written in Latin. Unfortunately the condition of Dr. Thomson's health and the pressure of Sir Joseph's official duties at Kew made it impossible that the book should be continued on the magnificent scale on which it had been conceived. After a period of about twelve years Sir Joseph, however, returned to the task of preparing, with the aid of other Botanists, a Flora of the Indian Empire, conceived on a smaller scale and written in the English language. His proposals for this work were accepted and officially sanctioned by the Duke of Argyll while he was Secretary of State for India. The first part of this great work was published in 1872 and the last in 1897. In the execution of this great undertaking Sir Joseph had the assistance of Mr. C. B. Clarke, who elaborated various natural orders; of Mr. J. G. Baker, who worked out *Leguminosæ* and *Scitamineæ*, and of Sir W. Thiselton Dyer, Messrs. A. W. Bennett, Anderson, Edgeworth, Hiern, Lawson, Maxwell Masters, Stapf, and Gamble. The greater proportion, however, of the book is Sir Joseph's own work, and a noble monument it forms of his devotion and genius.

Since the date of Sir Joseph Hooker's visit to India, by far the most important Botanical work done in India has been that of Mr. C. B. Clarke. Rather than attempt to give any appreciation of my own of Mr. Clarke's labours (which would be more or less of an impertinence), I may be allowed to quote from the preface to the concluding volume of the 'Flora of British India,' Sir Joseph Hooker's estimate of them. Referring to all the collections received at Kew since the preparation of the 'Flora' was begun, Sir Joseph writes: 'The first in importance amongst them are Mr. C. B. Clarke's, whether for their extent, the knowledge and judgment with which the specimens were selected, ticketed, and preserved, and for the valuable observations which accompany them.' Mr. Clarke has published numerous papers on Indian Botanical subjects in the Journals of the Linnæan and other societies. He has issued as independent books monographs of Indian *Compositæ* and *Cyrtandraceæ*, the former in octavo, the latter in folio, and illustrated by many plates; and he is now engaged on his *opus maximum*, viz. a monograph of the *Cyperaceæ*, not only of India, but of the whole world; and to the completion and publication of this every systematic Botanist is looking forward with eager anxiety.

During this second half of the century Dr. Thomas Anderson, who was for ten years superintendent of the Calcutta Garden, collected much; and he had just entered on what promised to be a brilliant career of Botanical authorship when his life was cut short by disease of the liver, contracted during his labours to establish the cultivation in British India of the quinine-yielding species of cinchona. Dr. Anderson was also the earliest Conservator of Forests in Bengal. Sulpiz Kurz, for many years Curator of the Calcutta Herbarium, also collected largely in Burma, and besides many excellent papers which he contributed to the 'Journal of the Asiatic Society of Bengal,' he prepared for Government an excellent manual entitled 'The Forest Flora of Burma.' This was published in two volumes in 1877. Other collectors in Burma were Colonel Eyre (in Pegu), Mr. Burness (at Ava), and the Rev. Mr. Parish, to whom horticulturists are indebted for the introduction to Europe of the beautiful orchids of this rich province. And in this connection must be mentioned Mr. E. H. Man, C.I.E., who, although not himself a Botanist, has given for many years past the greatest possible help in the Botanical exploration of the Andaman and Nicobar groups of islands, our first knowledge of which was, by the way, derived from the collections made by the naturalists of the Austrian and Danish exploring expeditions. A large book on Burma, which contains a good deal of Botany, was published by an American missionary named Mason, who resided for the greater part of his working life in that country. General Sir Henry Collett, who commanded a brigade during the last Burmese war, also made most interesting collections in that country, the novelties of which were described by himself in collaboration with Mr. W. Botting Hemsley, of the Kew Herbarium, in the Linnæan Society's 'Journal' some years ago. Sir Henry Collett also collected much in the Khasia and Naga hills, and in the portion of the North-Western Himalaya of which Simla is the capital, and on these latter collections, together with the materials in Kew Herbarium, Sir Henry is now elaborating a local Flora of Simla. The preparation of a local Flora for an Indian district is an entirely new departure, and the publication of Sir Henry's book, which is to be well illustrated, is looked forward to with much interest. At rather an earlier period, Dr. Aitchieson, C.I.E., was a diligent collector of the plants of the

Punjab and of the North-Western Frontier. Some results of his work are to be found in his 'List of Punjab Plants,' which was published in 1867, and in various papers which he contributed (some of them in conjunction with Mr. Hemsley) to the Linnæan Society and to the Botanical Society of Edinburgh. In Dr. G. Henderson's book on Yarkand there are also descriptions of some plants of the extreme North-Western Himalaya and of Western Tibet. Mr. (now Sir George) Birdwood also made some contributions to the Botany of the Bombay Presidency.

Five officers of the Indian Forest Department, viz. Dr. Lindsay Stewart, Colonel Beddome, Sir D. Brandis, and Messrs. Talbot and Gamble, C.I.E., have within the past thirty years made important contributions to the Systematic Botany of India. Dr. Stewart collected largely, and published in 1869 his 'Punjab Plants,' a book which gives a very imperfect impression of his acquirements as a Botanist. Sir Dietrich Brandis issued in 1874 his admirably accurate 'Forest Flora of the North-West Provinces of India,' illustrated by seventy excellent plates. Between the years 1869 and 1873, Colonel Beddome issued his 'Flora Sylvatica of the Madras Presidency,' illustrated by numerous plates. He also published, between 1869 and 1874, a volume of descriptions and figures of new Indian plants, under the title 'Icones Plantarum Indiæ Orientalis.' Colonel Beddome is the only Indian Botanist of note, except Griffith, Mr. C. B. Clarke, and Mr. C. W. Hope, who has written much on Indian Ferns. His two works, the 'Ferns of Southern India' and the 'Ferns of British India,' published, the former in 1863 and the latter between 1865 and 1870, practically give a systematic account, together with excellent figures, of the whole Fern Flora of India. Of these excellent books a condensation in a popular and abridged form has also been issued. The fourth Forest officer who has published contributions to Systematic Botany is Mr. W. A. Talbot, whose 'List of the Trees, Shrubs, and Woody Climbers of the Bombay Presidency' gives evidence of much careful research. And the fifth is Mr. J. S. Gamble, who, besides amassing at his own expense probably the largest private collection of plants ever owned in India, has published a systematic account of the Indian *Bambuseæ*, a tribe of grasses which, from the peculiarity of many of the species in the matter of flowering, had so long been the bane of the Indian agrostologist. Mr. Gamble, in his monograph, gives a description and a life-sized figure of every one of the Indian species. Of this monograph (which forms a volume of the 'Annals of the Botanic Garden, Calcutta') Sir Joseph Hooker writes (at p. 375, vol. vii. of his 'Flora of British India'): 'It is indispensable to the student of the tribe by reason of its descriptions and admirable plates and analyses.' Mr. Gamble has also published a Manual of Indian Timbers. A Forest officer who was ever ready to help in Botanical work, but who never himself published, was Mr. Gustav Mann, for many years Conservator of Forests in Assam, but now lost to India by his premature retirement. Other Forest officers, who have done, and are still doing, good botanical work in their various spheres, are Messrs. Lace, Heinig, Haines, McDonell, Ellis, Oliver, and Upendra Nath Kanjilal. Mr. Bourdillon, Conservator of Forests in the Travancore State, is also an enthusiastic Botanist and collector.

In the Madras Presidency Botanical work has been carried on during this second half of the century by Noton, Perrottet, Metz, Hohenacher, Schmidt (on the Nilgiris), Bidie, and Lawson. By the efforts of the latter two a second public Herbarium was established in Madras (the first having been broken up many years ago), and in this second Madras Herbarium are to be found many of the collections of Wight, besides those of the other Madras Botanists just named.

In the Bombay Presidency the only public Herbarium is at Poona. This is of recent origin, and owes its existence to the devotion of four men, viz. Dr. Theodore Cooke (late Principal of the College of Science at Poona), Mr. Marshall Woodrow (until recently Superintendent of the Garden at Guneshkind and Lecturer in Botany in the Poona College), the late Mr. Ranade (a native gentleman), and Dr. Lisboa (a medical practitioner in the Deccan)—all four enthusiastic Botanists. The amount of Government support given to the Herbarium at Poona has hitherto been very inadequate. It is to be hoped that greater liberality may be extended to it now that a stranger to the Bombay Presidency has just been appointed to its charge in the person of Mr. George Gammie, hitherto employed in the Cinchona Department of Bengal.

Reference has already been made to the Botanic Gardens at Seharunpore and Calcutta. But to complete this sketch, and especially in order to give a clear idea of the apparatus at present existing in India for carrying on the study and practice of Systematic Botany, it is necessary again to refer to them. On the retirement of Dr. Jameson in 1872, Mr. J. F. Duthie was selected by the Secretary of State for India as Superintendent of the Seharunpore Garden. Mr. Duthie is still at Seharunpore. During his tenure of office he has added to the Herbarium previously existing there (which consisted chiefly of the collections of Royle, Falconer, and Jameson) a magnificent collection of his own. Mr. Duthie has published a valuable book on the 'Field and Garden Crops of the North-Western Provinces,' and another on the Grasses of the same area. He is now engaged on the preparation of local Floras of the North-West Provinces and of the Punjab.

The Calcutta Garden at the date of Sir J. D. Hooker's arrival in India in 1848 was under the temporary charge of Dr. McClelland, who soon made way for Dr. Falconer, who, in 1855, was succeeded by Dr. J. Thomson, and he in turn by Dr. T. Anderson in 1861. Mr. C. B. Clarke acted as Superintendent during the interregnum between Dr. Anderson's lamented death in 1870 and my own appointment in 1871. The Garden and Herbarium at Calcutta have been most liberally supported by the Government of Bengal. By funds thus supplied the Garden has been remodelled and improved; the Herbarium has been housed in an excellent fire-proof building (erected in 1883), and the collections of which it consists have been greatly increased. The chief items of these later acquisitions have been the large contributions of Mr. C. B. Clarke; of Dr. D. Prain, for many years Curator of the Herbarium, and now Superintendent of the Garden and of the cinchona plantation and factory; of Mr. G. A. Gammie, formerly one of the staff of the cinchona plantation, and now Lecturer on Botany in the College of Science at Poona; of Mr. R. Pantling, Deputy-Superintendent of the Cinchona plantation, who, in addition to dried specimens of the orchids of Sikkim, contributed nearly five hundred drawings, most of which have been lithographed as the illustrations to a book published in the 'Annals' of the Garden, as the 'Orchid Flora of Sikkim;' of Mr. Kunstler, a collector in the Malay Peninsula; and last, but by no means least, of a trained band of aborigines of Sikkim named Lepchas who possess keener powers of observation of natural objects, more patience, sweeter tempers, and, I am bound in fairness to add, dirtier clothes than any race I have ever met—black, yellow, or white! In addition to their liberal grants to the Garden and Herbarium, the Bengal Government, twelve years ago, sanctioned the publication, at their expense, as occasion might offer, of monographs of important families or genera of Indian plants. These monographs are printed in quarto, and they are, with one exception, profusely illustrated by plates drawn and lithographed by Bengali draughtsmen. The series is known as 'The Annals of the Royal Botanic Garden, Calcutta,' and it has now reached its eighth volume, the ninth being in active preparation. These 'Annals' have been contributed to by Dr. Prain (my successor at the Calcutta Garden), by Dr. D. Douglas Cunningham, Mr. J. S. Gamble, Mr. R. Pantling, and myself.

About ten years ago, it occurred to the Supreme Government of India that it might be to the interest of Science if the four Botanical establishments at Calcutta, Seharunpore, Madras, and Poona were to be formed into a kind of hierarchy under the designation of The Botanical Survey of India, without removing either the officers or the four institutions to which they were attached from the financial or general control of the local administrations within which they are respectively situated, the Supreme Government making a small contribution of money for the purpose of exploring little-known districts and making itself responsible for the cost of a publication called 'The Records of the Botanical Survey.' The four institutions just mentioned continue, therefore, to be paid for and controlled by the Governments of Bengal, the North-West Provinces, Madras, and Bombay, but their Superintendents are placed on the cadre of the Botanical Survey. The published Records of this Survey now extend to twelve numbers, each of which is devoted to an account of the Botany of some part of the enormous and continually expanding area to be explored.

Such, then, is the machinery by which Systematic and Geographical, as distinguished from Economic and Physiological, Botany is carried on within the Indian Empire. But the work done in India itself by no means represents all that is being carried on in connection with the elucidation of the Flora of the Empire of India. On the contrary the bulk of the work of elaborating the materials sent from India in the shape of dried specimens has always been, and must always be, done in a large Herbarium; and until lately no Herbarium in Asia has been sufficiently extensive. The last word on every difficult taxonomic question must still lie in Europe. A very large number of the Herbarium specimens collected in India have found their way to the various centres of Botanical activity in Europe, and have been described by Botanists of many nationalities. The lion's share of these specimens has naturally come to the two great national Herbaria in the British Museum and at Kew, but especially to the latter. It was in the Kew Herbarium that Sir Joseph Hooker and his collaborateurs prepared the Flora of British India. And it is in the Kew Herbarium that are to be found the types of an overwhelming proportion of the new species described for the first time in that monumental work. The Kew Herbarium is therefore to the Indian Botanist the most important that exists. I must apologise for diverging for a moment to remind you what a type specimen is. It is the very one on which an author has founded any species to which he has given a name. And in order to determine absolutely what is the specific form to which the author meant his name to apply, it is often necessary to examine his type. This necessity increases in urgency with the extension of our knowledge of the Flora of the world.

The preservation in good condition of a type specimen is therefore, from the point of view of a Systematic Botanist, as important as is the preservation to the British merchant of the standard pound weight and the standard yard measure on which the operations of British commerce depend. 'Types' also stand to the Systematic Botanist much in the same relation as the national records do to the national historian. The latter are guarded in the Record Office, I understand, with all the skill which the makers of fire-proof, damp-proof, and burglar-proof depositories can suggest. If, however, the type of a species happens to be deposited at Kew, what are the probabilities of its preservation? Such a type at Kew is incorporated in what is admitted to be in every sense the largest and, for its size, the most accurately named, the most easily consulted, and therefore the most valuable Herbarium in the world, the destruction of which would be a calamity commensurate in extent with that of the burning of the Library at Alexandria. One might therefore reasonably expect that a people who rather resent being called a 'nation of shopkeepers' would feel pride in providing for this priceless national collection a home which, although perhaps somewhat inferior to that provided for the National Historical Records, might at least be safe from fire. This expectation is not fulfilled. The infinitely valuable Kew Herbarium and library have no safer home than an old dwelling-house on Kew Green, to which a cheap additional wing has been built. The floor, galleries, and open inner roof of this additional wing are constructed of pine coated with an inflammable varnish, and on the floor and galleries are arranged cabinets (also made of pine-wood), in which the specimens (which are mounted on paper) are lodged. The provision of a fireproof building, capable of expansion as the collections extend, is surely not beyond the means of an exchequer which last year netted over one hundred and six millions sterling of revenue. On behalf of the Flora of India, I venture to express the hope that the provision of a proper home for its types may receive early and favourable consideration by the holders of the national purse-strings. But India is by no means the only portion of the Empire interested in this matter, for the types of the Australasian Floras, those of a large part of the North American Flora, and those of many species inhabiting countries outside British rule or influence, find their resting-place at Kew. The safe custody of the Kew Herbarium is, therefore, not merely a national, but a cosmopolitan responsibility.

In this Address I have hitherto made little reference to Cryptogamic and Economic Botany. As regards Cryptogamic Botany there is little to relate. Except Griffith, no Indian Botanist of the earlier of the two periods into which

I have divided my sketch ever did any serious work amongst non-vascular Cryptogams. During the second period two men have done gallant work under difficulties which no one who has not lived in a tropical country can thoroughly appreciate. I refer to Drs. Arthur Barclay and D. D. Cunningham. The former made some progress in the study of Uredinous fungi, which was cut short by his untimely death, while the latter, in addition to his bacterial and other researches connected with the causation of human disease, conducted protracted investigations into some diseases of plants of fungal or algal origin. Some of the results of Dr. Cunningham's labours were published in the 'Transactions' of the Linnean Society, and in a series entitled the 'Scientific Memoirs, by Medical Officers of the Indian Army.' To the 'Annals of the Botanic Garden, Calcutta,' Dr. Cunningham also contributed elaborate memoirs on the phenomena of Nyctitropism, and on the mode of fertilisation in an Indian species of *Ficus* (*F. Roxburghii*). There is no doubt that in the past Cryptogamic Botany has not been studied in India as it ought to have been and might have been. This discredit will, I hope, be soon removed; and I trust that, by the time the twentieth century opens, a Cryptogamist may have been appointed to the staff of the Calcutta Botanic Garden. The collecting of Cryptogams was not, however, altogether neglected in India in times past. For, from materials sent to England, Mitten was able to elaborate a Moss Flora of India, while Berkeley and Browne were enabled to prepare their account of the *Fungi* of Ceylon. Dr. George Wallich, in whom the Botanical genius of his father burnt with a clear though flickering flame, did some excellent work amongst Desmids, and was among the earliest of deep-sea dredgers.

Economic Botany has, on the other hand, by no means been neglected. It was chiefly on economic grounds that the establishment of a Botanic Garden at Calcutta was pressed upon the Court of Directors of the East India Company. And almost every one of the workers whose labours I have alluded to has incidentally devoted some attention to the economic aspect of Botany. Roxburgh's 'Flora Indica' contains all that was known up to his day of the uses of the plants described in it. Much of Wight's time was spent in improving the races of cotton grown in India. The Botanists of the Seharunpore Garden during the middle of the century were especially prominent in this branch of Botanical activity. Royle wrote largely on cotton and on other fibres, on drugs, and on various vegetable products used, or likely to be of use, in the arts. These Botanists introduced into the Himalayas more than fifty years ago the best European fruits. From gardens which owe their origin to Royle, Falconer, and Jameson, excellent apples grown in Gharwal and Kamaon are to-day purchasable in Calcutta. Peaches, nectarines, grapes, strawberries, of European origin, are plentiful and cheap all over the North-West Himalaya, and are obtainable also in the submontane districts. Potatoes, and all the best European vegetables, were introduced long ago; and at Seharunpore there is still kept up a large vegetable garden from which seeds of most European vegetables are issued for cultivation during the cold season in the gardens of the various regiments of the Queen's troops quartered in Upper India. More or less attention has been given in the past by Government Botanists in India generally to the improvement of the cultivation of flax, hemp, rheea, tobacco, henbane, dandelion, vanilla, sarsaparilla, coffee (Arabian and Liberian), cocoa, ipecacuanha, aloes, jalap, indiarubber, Japanese paper-mulberry, cardamoms, tapioca, coca, tea, and cinchona. Only to three economic enterprises, however, have I time to allude in any detail. These are (1) the cultivation of tea, (2) the introduction of cinchona, and (3) the formation of the Forest Department. But before proceeding to the consideration of these I wish to give a short account of the inauguration of the office of Reporter on Economic Products. Up to the year 1883 there had been no special Government department in India for dealing with questions connected with the natural products of the Empire. Whatever had been done prior to that date (and the amount was by no means unimportant) was the result of isolated and uncoördinated effort. In 1883 the Government of India founded a department for dealing with the Economic Products of the Indian Empire, and under the title of Reporter on these products they were fortunate enough to secure Dr. George Watt, a member of the Bengal Educational Service.

Dr. Watt is an accomplished and able Botanist. He has collected Indian plants largely, and has made numerous notes both in the field and in the bazaar. The great work which, on the initiative of Sir Edward Buck, Secretary to the Department of Revenue and Agriculture, and of Sir W. Thiselton Dyer, of Kew, Dr. Watt began and carried to a successful termination was the compilation of his 'Dictionary of Economic Products,' in which valuable book is collected all that is known of almost every Indian product, whether vegetable, animal, or mineral. The study of Economic Botany is now pursued in India as part of a highly specialised system of inquiry and experiment. Dr. Watt has a competent staff under him in Calcutta, one of whom is Mr. D. Hooper, well known for his original researches into the properties of various Indian drugs. Dr. Watt has arranged in Calcutta a magnificent museum of economic products, and there is no doubt the economic resources of the Empire are now being studied with as much energy as intelligence.

Tea cultivation is one of the enterprises in the introduction and development of which Botanists took a very leading part. The advisability of introducing the industry was first pressed on the attention of the East India Company by Dr. Govan (of Seharunpore), and in this he was seconded by Sir Joseph Banks as President of the Royal Society. Royle in 1827, and Falconer slightly later, again urged it as regards the North-West Himalaya. In 1826 David Scott demonstrated to rather unwilling eyes in Calcutta the fact that real tea grows wild in Assam. In 1835 Wallich, Griffith, and McClelland were deputed by Government to visit Assam, to report on the indigenous tea. In the year 1838 the first consignment of Indian-grown tea was offered for sale in London. The consignment consisted of twelve chests containing 20 lbs. each. This first sample of 240 lbs. was favourably reported upon. Last year the exports of tea from India to all countries reached 157 millions of pounds, besides 120 millions of pounds exported from Ceylon!

The introduction of cinchona into India originated purely with the Government Botanists. As everybody knows, quinine, and to a less extent the other alkaloids present in cinchona bark, are practically the only remedies for the commonest, and in some of its forms one of the most fatal, of all Indian diseases, viz. *malarious fever*. The sources of supply of the cinchona barks in their native countries in South America were known to be gradually failing, and the price of quinine had for long been increasing. The advisability of growing cinchona in the mountains of British India was therefore pressed upon Government by Dr. Royle in 1835, and he repeated his suggestions in 1847, 1853, and 1856. Dr. Falconer, in his capacity of Superintendent of the Botanic Garden, Calcutta, made a similar suggestion in 1852; and his successors at Calcutta, Dr. T. Thomson and Dr. T. Anderson, in turn advocated the proposal. In 1858 Government at last took action, and, as the result of the labours of Sir Clements Markham and Sir W. J. Hooker, of Kew, the medicinal cinchonas were finally, in the period between 1861 and 1865, successfully introduced into British India—on the Nilgiris under Mr. McIvor, and on the Sikkim-Himalaya under Dr. T. Anderson. Various experiments on the best mode of utilising the alkaloids contained in red cinchona bark resulted in the production in 1870 by Mr. Broughton, Quinologist on the Nilgiri plantation, of an amorphous preparation containing all the alkaloids of that bark. This preparation was named *Amorphous Quinine*. Somewhat later (1875) a similar preparation, under the name of *Cinchona Febrifuge*, was produced at the Sikkim plantation by Mr. C. H. Wood, the Quinologist there; and of these drugs about fifty-one tons had been distributed from the Sikkim plantation up to the end of last year. The preparation of pure quinine from the yellow cinchona barks, so successfully grown in the Sikkim plantation, long remained a serious problem. The manufacture of quinine had hitherto been practically a trade secret. And when the Indian Government had succeeded in providing the raw material from which a cheap quinine might be made for distribution amongst its fever-stricken subjects, the knowledge of the means of extracting this quinine was wanting. Philanthropic platitudes were freely bandied about as to the immensity of the boon which cheap quinine would be to a fever-stricken population numbering so many millions. But there was a singular absence of any practical help in the shape of proposals, or even hints, as to how quinine was to be extracted from the rapidly increasing stock of crown and yellow bark. The officers in charge of the cinchona plantations in India had therefore to do their best to solve the problem for themselves. And it was ultimately solved by Mr. C. H. Wood, at one time Government Quinologist in Sikkim, who suggested, and Mr. J. A. Gammie, Deputy-Superintendent of the plantation there, who carried into practice a method of extraction by the use, as solvents of the cinchona alkaloids, of a mixture of fusel-oil and petroleum. The details of this process were published in the 'Calcutta Official Gazette,' for the benefit of all whom it might concern. Very soon after the introduction of this method of manufacture, the Government factories in Sikkim and the Nilgiris were able to supply the whole of the Government hospitals and dispensaries in India with all the quinine required in them (some 5,000 or 6,000 pounds annually), besides providing an almost equal quantity for the supply of Government officers for charitable purposes. The latest development of the quinine enterprise in India has been the organisation of a scheme for the sale at all the post-offices in the province of Bengal, and in some of those of Madras, of packets each containing five grains of pure quinine, that being a sufficient dose for an ordinary case of fever in a native of India. These packets (of which some are on the table for distribution) are sold at one pice each, the pice being a coin which is equal, at the current rate of exchange, to one farthing sterling!

In conclusion, I wish to make a few remarks on the third great economic enterprise connected with Botany in India, viz. the Forest Department. The necessity for taking some steps to preserve a continuity of supply of timber, bamboos, and other products from the jungles which had for generations been exploited in the most reckless fashion, was first recognised by the Government of Bombay, who in 1807 appointed commissioners to fix the boundaries of and to guard the forests in that Presidency. This scheme was abandoned in 1822, but was resumed in a modified form during 1839-40. Seven years later a regular forest service was established in Bombay, and Dr. Gibson was its first head. Dr. Gibson in turn was succeeded by Mr. Dalzell—and both were Botanists. In the Madras Presidency the first man to recognise the necessity of perpetuating the supply of teak for ship-building was Mr. Connolly, collector of Malabar, who in 1843 established a teak plantation at Nelumbur, which has been carried on, and annually added to, down to the present time. In 1847 Dr. Cleghorn (a Botanist) was appointed to report on the conservation of the forests of Mysore (which contain the well-known sandal-wood), and the following year Lieutenant Michael (still with us as General Michael, a hale and hearty veteran) was appointed to organise and conserve the public forests in Coimbatore and Cochin. The crowning merit of General Michael's administration was the establishment, for the first time in India, of a system of protection against the fires which annually used to work such deadly havoc. In 1850 the British Association, at their Edinburgh Meeting, appointed a Committee to consider and report upon the probable effects, from an economic and physical point of view, of the destruction of tropical forests. This Committee's Report was submitted to the Association at the Meeting at Ipswich in 1851. The weighty evidence collected in this Report so impressed the Court of Directors of the East India Company that, within a few years, regular forest establishments were sanctioned for Madras and British Burma, the two main sources of the supply of teak.

In 1856 Mr. (now Sir Dietrich) Brandis was appointed to the care of the forests of the latter province. These forests had been the object of spasmodic efforts in conservancy for many years previously. In 1827 Dr. Wallich reported on the teak forests, and five years later a small conservancy establishment was organised, officered by natives. This, however, was kept up for only three or four years. In 1837 and 1838 Dr. Helfer reported on these forests, and an English conservator was appointed. In 1842 and 1847 Codes of Forest Laws were drawn up, but do not appear to have been enforced to any extent. In 1853 Dr. McClelland was appointed superintendent, but he continued to hold the office for only a short time. A few years after Sir Dietrich Brandis's assumption of the charge of the

Burmese Forests, he was appointed Inspector-General of all the Government Forests in British India; and it is to him that we owe for the most part the organisation of the Indian Forest Department as it now exists. That organisation includes two Schools of Forestry (in both of which Botany is taught), one in connection with Cooper's Hill and the other at Dehra Dun in Upper India. The latter has for many years been under the direction of a gentleman who is distinguished both as a Forester and as a Botanist. In the Cooper's Hill School, the higher grades of Forest officers receive their training; at Dehra Dun those of the lower grades receive theirs. The officers of the department on the Imperial list, according to the latest official returns, now number 208, divided into the grades of conservator, deputy- and assistant-conservator, with a single inspector-general as chief. In addition to these, there are 566 provincial officers, ranking from rangers upwards to extra deputy-conservators.

Botanists took a leading part in moulding the department in its earlier years; for, as already stated, its pioneers—Gibson, Dalzell, Cleghorn, Anderson, Stewart, and Brandis—were all Botanists. And to most people, who give even casual attention to the matter, it appears fitting that the possession of a knowledge and liking for Botany should form a strong characteristic of officers whose main duties are to be in the forest. And this belief did for some time exercise considerable influence in the selection of recruits for the department. But, except in the Dehra Dun School, it does not appear to guide the department any longer. For example, at the Entrance Examination to the Forest School at Cooper's Hill, only three subjects are obligatory for a candidate, viz. mathematics, to which 3,000 marks are allowed; German, to which 2,000 are allowed; and English, for which 1,000 are given. Botany is one of the nine optional subjects of which a candidate may take up two, and in each of which 2,000 marks may be made.

Botany is taught at Cooper's Hill, and (according to the Calendar of the College) it forms one of the 'special auxiliary subjects' for the Forest student. I do not wish to say a single word in depreciation of the Botanical teaching at this College, which is probably excellent of its sort. I do not know what value, as part of their professional equipment, students are accustomed or encouraged to attach to the possession of the means of acquiring a knowledge of the trees and shrubs in the midst of which they are to pass their lives in India. But this I do know, that the ordinary Forest officer educated in England now arrives in India without sufficient knowledge to enable him to recognise from their Botanical characters the most well-marked Indian trees. To tell such an officer the name of the natural family to which a plant belongs conveys no information to him whatever, for he knows nothing of Botanical affinities. Moreover, the Forest officer after he has arrived in India is not encouraged to familiarise himself with the contents of the forests under his charge. This will be better appreciated by giving an example than by any number of remarks. Some three years ago, Mr. J. S. Gamble (a Forest officer) published a monograph of the Bamboos of British India. From bamboos, as you may possibly be aware, a very large amount of Forest revenue is annually derived. The sales of bamboos for the year 1896–97 amounted to no less than 110 millions of stems. A great number of the species of bamboos have the curious habit of flowering gregariously at remote intervals of thirty or forty years, and the flowering is followed by death. The absence from the forests for years in succession of flowers of a number of the species, and the similarity of many of them in leaves, had hitherto made members of the group most difficult of identification. Mr. Gamble had devoted himself to their study for many years. He had carefully examined all the previously collected materials stored in the Herbaria at Kew, the British Museum, Calcutta, and elsewhere; and large special collections had been made for him by Mr. Gustav Mann and other officers of Government. Moreover, he had General Munro's great paper in the 'Linnean Transactions' as a basis. Mr. Gamble's work was undertaken with the full approval of Sir Joseph Hooker, who indeed accepted Mr. Gamble's account of the bamboos for his 'Flora of British India.' Mr. Gamble's monograph is illustrated by a life-sized drawing of each species, with analyses of the flowers on a larger scale. When completed, the book was published as one of the volumes of the

'Annals of the Calcutta Botanic Garden.' In consideration of the supposed great importance of the book to the forester, and in the belief that the copies would be eagerly taken by the Forest Department, an extra hundred copies were printed, and these hundred copies were put into stout canvas binding suitable for camp use. These copies, or as many of them as he cared to take, were offered to the Head of the Forest Department in India at the reduced price of fifteen rupees per copy. The result was an official refusal to buy a single one, although the purchase of the whole hundred (which was not asked for) would have cost only fifteen hundred rupees—a sum which would have reduced the revenue of the year by about one twelve-thousandth part! An appeal against this ruling having been made to a still higher authority, a modified order was subsequently issued permitting such Forest officers as desired to possess the book to buy copies and charge the cost in their office expenditure. I may state that the book was not a private venture. It was produced at the expense of the Government of Bengal.

It is not because I like to play the censor that I have made these remarks about the Forest Department. Having myself served in it from 1869 to 1871, I can speak from my own experience as to the value, from the utilitarian point of view, of a knowledge of the names, affinities, and properties of the trees, shrubs, and herbs which compose an Indian jungle, and of a knowledge of these as individual members of the vegetable kingdom rather than as masses of tissue to be studied through a microscope. The appointment which I held in India for twenty-six years after leaving the Forest Department gave me full opportunity of getting into touch with all who interest themselves in a knowledge of plants, and of discovering how few of these at the present day are Forest officers. The majority of the latter, if they love their trees, are content to do so without knowing their names or relationships! There are, of course, splendid exceptions who know as well as love. The general decadence of the teaching of Systematic Botany in England during the past twenty years is, perhaps, to some extent the cause of the low estimation in which the science is held by the authorities of the Indian Forest Department. Twenty-five years ago Systematic and Morphological Botany, no doubt, had too great prominence given to them in the teaching at universities and colleges of this country, and the other branches of Botanical science were too much neglected, although I do not think they were despised. Now it appears to me that Systematic Botany is too much neglected. I hope it is not also despised! Few of the systematists who survive in England are now to be found attached to the universities. They are mostly clustered round the two great Herbaria in London; and such of them as have to look to Systematic Botany for the means of livelihood are not in the receipt of salaries such as one might reasonably expect in one of the richest countries in the world!

The following Papers and Reports were read:—

1. *Some Methods for Use in the Culture of Algæ.*
By Professor Marshall Ward, *F.R.S.*

The following notes are of the nature of suggestions, since the experiments are not yet completed, and much has still to be done, no doubt, before the efficacy of the treatment and the faults and difficulties of the methods in detail are fully demonstrated; but since the author has found they can be used with some measure of success, the various workers interested in the culture of algæ may care to take the methods up and try to improve them.

1. If agar is swollen in dilute acetic acid, and then washed very thoroughly so that every trace of soluble salt is removed, it can be used, mixed with the necessary culture fluids, as a convenient medium for the growth of some algæ, as Beyjerinck had already observed. But, so far as the author knows, the use of such a medium for separating algæ in plate culture and for observing their growth in hanging drops has not been attempted. It can be done, however, though the

high melting-point of the agar and the sliminess of some algæ occasionally cause difficulties.

The author has also succeeded in separating algæ by the following methods:—

2. Shake them up in sterilised nutritive mineral solutions, mix rapidly with silica jelly, also sterilised, and pour into glass dishes. With species of *Oscillaria* and of *Palmella* the author has observed growth in hanging drops of this silica jelly medium under high powers, and has seen sufficient to make it hopeful that even Diatoms may be cultivated this way; and it is not impossible that some modification of the process could be utilised for the culture of marine algæ.

Another device is as follows:—

3. Shake the algæ up in the nutritive solution and rapidly mix with sterilised plaster of paris and pour into dishes. The fixed algæ grow *in situ* in some cases, but others appear to be too sensitive for such treatment.

Experiments have also been made as follows, with some promise of success:—

4. The algæ are shaken up in the culture medium, and a large quantity of lime-water quickly added. Then carbon dioxide gas is passed rapidly through, and the algæ are thrown down with the precipitate of calcium carbonate; this is poured into dishes as if it were plaster of paris. Perhaps this method could be utilised in the study of calcareous algæ, but with some forms it appears too drastic. It is possible baryta may succeed with some algæ, but the trials have not yet been completed, and it seems to act as a poison to some. One drawback here is the difficulty of obviating the use of unsterilised materials.

It is clear that if once we obtain a pure colony on a glass dish, a trace fished out with a needle may be used to start other cultures. Season, temperature, intensity of light, and other factors, are of importance in these matters.

2. *On the Growth of* Oscillaria *in Hanging Drops of Silica Jelly.*
By Professor MARSHALL WARD, *F.R.S.*

In illustration of the applications of the methods for use in the culture of algæ Professor Ward described the results of observations of the growth of *Oscillaria tenerrima* in hanging drops of silica jelly. The growth of a single filament was followed for more than a week, and the curve showed that growth ceased during the hours of darkness, and was coincident with assimilation during the day.

The author has also obtained light-figures by exposing plates of green algæ, covered with stencil letters, to various intensities of daylight, reflected from mirrors. When the incident light was not too strong a green letter on a colourless ground was found, but with intense illumination the algæ exposed on the letter was killed, while those in the covered area, illuminated only by the diffuse light, were able to grow; the result was a *colourless* letter on a green ground.

The division of the contents of certain green Protococcoideæ into zoospores has also been seen in hanging drops of algar, &c.

3. *On the Life-history and Cytology of* Halidrys siliquosa.
By J. LLOYD-WILLIAMS.

The chief points dealt with in the paper are the formation and liberation of the sexual cells, the striking phenomena accompanying the act of fertilisation, the segmentation of the spore together with the cytology of the various processes.

4. *The Sand Dunes between Deal and Sandwich, with Remarks on the Flora of the Districts.* *By* G. Dowker, *F.G.S.*

The author in this paper gave an account of the formation of the dunes and mud banks, claiming for them the reclamation of the large tract of sand from the sea, mostly since the Roman occupation of Britain. He referred to the Acts of Parliament passed prohibiting the destruction of the mat grass, which contributed so largely to the preservation of the hills, and lamented that nothing was done to prevent the wholesale gathering of sea holly by men who ruthlessly destroyed it by taking it away to sell. He recounted his long experience and knowledge of the district, dating back to his schoolboy days with the Rev. J. Layton, a distinguished botanist of Sandwich. He particularised the following rare plants as denizens of the hills: *Allium vineale* and *compactum, Poa bulbosa, Hippophae rhamnoides, Silene conica, Orobanche caryophyllacea, Lepidium latifolium,* and on the salt marshes, *Atriplex pedunculata, Frankenia levis, Aster Tripolium,* and *Polypogon monspeliensis.* The author added a list of over 300 species of flowering plants to be met with in the district.

5. *The Research Laboratory in the Royal Botanic Garden, Peradeniya, Ceylon.* *By* J. C. Willis.

6. *Report on Fertilisation in the Phæophyceæ.* See Reports, p. 610.

7. *Report on Experimental Investigation of Assimilation in Plants.* See Reports, p. 611.

FRIDAY, SEPTEMBER 15.

The following Papers were read:—

1. *On White-Rot—a Bacterial Disease—of the Turnip.* *By* Professor M. C. Potter.

The author has found in the early autumn numerous turnips, whose roots, when fully grown, have become completely rotten. The rotten portion presents a white glazy appearance, and the tissues are reduced to a soft pulpy condition; the cell-walls are much swollen, faintly stratified, and separate from each other along the middle lamella. The decaying mass is infested with bacteria, but the most careful microscopic search has failed to detect any fungoid hyphæ, and no fungi have appeared in the experimental cultures.

The rottenness can be readily introduced into a sound root by inoculation at a wounded surface; from this point the decay spreads rapidly through the root, the leaves gradually turn yellow, and in about fourteen days the entire plant has succumbed.

Among the bacteria found in the rotten mass one has been isolated, which, when sown from a pure culture on to turnips, under sterile conditions, induces all the characteristic effects of the 'white-rot.' The liquid expressed from the pulp of one of these cultivations, when passed through a Pasteur-Chamberland filter, yields a clear light yellow filtrate, which was found to have the same powerful action upon the living cells of the turnip, causing the swelling of the wall and the separation of the cells by the dissolution of the middle lamella. This action was destroyed by boiling. When diluted with four to five volumes of alcohol, the extract yields a copious flocculent precipitate; the precipitate was dried and digested with a little water, and the solution, after filtration through the Pasteur-Chamberland filter, was also found to have the same effect upon the cell-walls, the action again being destroyed by boiling. The whole appearance of the sections corresponded exactly with those taken from turnips affected by the rot. The bacterium, therefore, secretes a cytase enzyme, which, in healthy living tissues, dissolves the middle lamella and causes the swelling of the cell-wall. The same enzyme is produced when the bacterium is grown in Koch's bouillon.

The bacterium has a single polar flagellum, and, adopting Migula's classification, the author has ventured to describe it under the name *Pseudomonas destructans*.

General Characteristics.

Short rods about 3μ long by $\cdot 8\mu$ broad, with one polar flagellum.
Rapidly liquefies gelatine, forming circular whitish colonies.
Agar-agar, whitish glazy growth.
Stab cultures grow along the track of the wire, rapidly forming a funnel.
Aerobic.
Parasitic on turnips, potatoes, carrots, but not beetroot, forming a cytase.
Copious evolution of carbonic acid during the fermentation.

Infection by *P. destructans* appears always to be introduced at a wound, and it is powerless to set up decay unless placed in contact with the parenchymatous cells of the cortex. Having gained an entrance, the organism penetrates the living tissues by means of the intercellular spaces, and by the action of the enzyme it breaks through the intercellular substance and traverses the middle lamella. Many of the intercellular spaces are crowded with bacteria, and in some sections they are found lying in the track of the middle lamella.

2. *On the Phosphorus-containing Elements in Yeast.*
By HAROLD WAGER.

3. *On the Influence of the Temperature of Liquid Hydrogen on the Germinative Power of Seeds.* *By* Sir WILLIAM THISELTON-DYER, *K.C.M.G., F.R.S.*

Sir William Thiselton-Dyer described some experiments made by Professor Dewar on the influence of the temperature of liquid hydrogen on the germinative power of seeds. The most important was one in which five kinds of seeds, varying in size and conformation, were immersed for six hours in liquid hydrogen. The temperature to which they were cooled was $-453°$ F. below melting ice. They were subsequently sown at Kew, and germinated readily without exception.

The bearing of the experiments on the accepted conception of protoplasm gave rise to some discussion. Protoplasm is conceived to consist of physiological molecules, the properties of which cannot be explained with our present knowledge of either physics or chemistry. They are in a state of constant kinetic energy, based upon equally continued metabolic change. But if it is admitted that the latter is impossible at very low temperatures the former must cease and the evidence of life disappears. The physiological molecule becomes purely static; its energy is wholly potential, and, in fact, it becomes, as Professor Casimir de Candolle has pointed out, analogous to an explosive.

4. *On a Horn-destroying Fungus.* *By* Professor MARSHALL WARD, *F.R.S.*

5. Bulgaria polymorpha (*Wettstein*) *as a Wood-destroying Fungus.*
By R. H. Biffen, *Cambridge.*

Bulgaria polymorpha (Wettstein), *B. inquinans* (Fr.), is stated by Ludwig to be parasitic on oak. The author has examined its anatomy, and studied it in pure cultures on wood and in food-material. The white early growth soon becomes bright orange; small rounded elevations are afterwards formed, which are incipient reproductive bodies.

The action on wood is examined in some detail. The fungus grows better on oak than on pine. The lignified wood-elements are de-lignified. Details as to the reactions in various stages of its destructive action are dealt with in the paper. The author does not regard this fungus as of great importance as a wood-destroying fungus in this country.

6. *On a Disease of* Tradescantia fluminensis *and* T. sebrina.
By Albert Howard, *B.A., Scholar of St. John's College, Cambridge.*

During the summer it was found that two species of *Tradescantia*, viz. *T. fluminensis* and *T. sebrina*, growing in greenhouses, were being attacked by a fungus. Diseased leaves and stems were in many cases found to be covered with long white conidiophores. Pure cultures were made of this form, and the complete development was followed out by the hanging-drop method. The fungus proved to be a species of *Botryosporium*. Some difficulty was experienced in obtaining this form free from another fungus, a species of *Cladosporium*. Infection experiments, made with the spores and mycelium of the *Botryosporium* under the most diverse conditions, failed, nor would the mycelium infect the healthy leaves if previously invigorated by cultivation.

It was found in the case of the naturally growing host plants that infection started either on the upper side of the leaf as a small semitransparent dot, or from the margin. Tangential sections of the upper epidermis of the leaf containing one of these transparent areas, and also portions of the infected margin, when grown in hanging drops, showed in all cases hyphæ on the epidermis, which gave rise to the same species of *Cladosporium* as that mentioned above, occurring as a weed in the Botryosporium cultures. The development of this *Cladosporium* was then followed out from a single spore by the hanging-drop method, and infection experiments were made which proved successful.

7. *Demonstration of Vermiform Nuclei in the Fertilised Embryo-Sac of* Lilium Martagon. *By* Miss Ethel Sargant.

8. *On the Sexuality of the Fungi.* *By* Harold Wager.

SATURDAY, SEPTEMBER 16.

Joint Discussion with Section B on Symbiosis.—See p. 692.

MONDAY, SEPTEMBER 18.

The following Papers were read:—

1. *On the Localisation of the Irritability in Geotropic Organs.*
By FRANCIS DARWIN, *F.R.S.*

The seedlings of *Setaria*, *Sorghum*, and some other grasses are remarkable for possessing a hypocotyl or stalk-like part intercalated between the grain and the cotyledon. Rothert has shown that while the hypocotyl is the motor apparatus, the sensitiveness to light resides in the cotyledon, which transmits a stimulus to the hypocotyl, and this results in curvature. The author showed that the cotyledon is also a sense organ for gravitation, the stimulus which leads to geotropic curvature being in like manner transmitted to the hypocotyl. If a seedling of *Sorghum* or *Setaria* is fixed by its grain to a support, so that the hypocotyl is horizontal, it bends apogeotropically till the cotyledon is vertical; it then ceases to be geotropically stimulated, and no longer transmits an influence to the region of curvature. But if the conditions are reversed, if the seedling is supported by its cotyledon (which is fixed in a horizontal position), while the hypocotyl projects freely, the result is otherwise. The hypocotyl begins to curve upwards, just as in the first experiment, but it does not cease to curve when the free end points vertically upwards; the curvature continues indefinitely, so that the hypocotyl curls into a spiral of three or four rings. This can only be explained by the assumption that the geotropic sensitiveness resides in the cotyledon, and that since the cotyledon remains horizontal it continues to be stimulated, and transmits a continuous influence to the motor part of the seedling.

2. *Studies in Araceæ.* *By* Prof. DOUGLAS CAMPBELL.

1. The Araceæ have been much neglected in studies of the development of the flower and embryo, and our knowledge of these is very incomplete.

2. The materials for the present studies were collected mostly in Jamaica, and include species of *Dieffenbachia*, *Aglaonema*, *Philodendron*, and *Anthurium*. A study was also made of *Lysichiton*, of Pacific North America.

3. A study of the development of the ovule indicates that the primitive form is axial, as in other low monocotyledons.

4. The early development of the embryo-sac follows the ordinary type. Later, there is a multiplication of the antipodal cells, and the sac becomes very early filled with endosperm.

5. The ovule is often massive, and there is a marked development of mucilage-secreting hair upon the funiculus and the base of the nucellus.

6. In all forms so far examined the embryo is destitute of a suspensor, and the cotyledon is very large, sometimes suggesting the scutellum of the grass-embryo.

7. The forms with a single carpel are probably most primitive and most nearly related to the other low monocotyledons.

3. *On the Morphology and Life History of the Indo-Ceylonese Podostemaceæ. By* J. C. WILLIS, *Director of the Royal Botanic Garden, Peradeniya, Ceylon.*

The paper read was an abstract of a forthcoming monograph of the Indian and Ceylon species of this very remarkable order of water plants, in which the various species will be described in detail, both morphologically and ecologically. A few typical species were described, their life history explained, showing the extraordinary modifications which the vegetative system has undergone to suit the needs of life in rising and falling water and in rapid currents. The vegetative organs consist largely of modified roots forming thallus-like bodies, and bearing leafy or floral endogenous shoots, and branching themselves in an exo- or endogenous manner. The conclusion was drawn that the endo- or exogenous origin of an organ or a branch is a phenomenon of an adaptive nature in these plants, and to a large extent in others also. The adaptive modifications of the structure, such as the gradual reduction through a series of forms of the shoots and leaves, the increased multiplication of the shoots by vegetative budding, the reduction of the number of flowers per shoot and the change to anemophily, the increased dorsiventrality, and other characters were shown to be rather correlated with the rise and fall of the water than with the velocity of the stream. In conclusion some of the more general questions of morphology were discussed in the light of the observations made on these plants.

4. *Note on the Anabæna-containing Roots of some Cycads.*
By W. G. Freeman.

Attention was drawn to the manner in which the anabæna-containing roots were borne on various members of this group, growing in very poor soil, in an open garden border in the Royal Botanic Garden at Peradeniya, in Ceylon.

In the majority a dense coralloid mass of specialised fleshy roots was found immediately encircling the main stem.

In others—e.g. *Nacrozamia Peroffskiana*—normal-looking lateral roots ran horizontally beneath the ground, giving off the special algal-containing roots at intervals. These primary lateral roots were themselves sometimes apogeotropic for a period, resuming a normal habit of growing downwards again after having borne the anabæna-containing masses.

5. *A Mixed Infection in* Abutilon *Roots.* *By* E. J. Butler, *M.B.*

The roots of seedlings of *Abutilon* hybrids (*Darwinii* × —— ?) in the plant-houses of Queen's College, Cork, presented tuberoid enlargements, due to at least two parasites, a Nematode and an Ascomycete.

(1) The Nematode is a *Heterodera*, apparently identical with *H. radicicola*. It is found also in abundance on the roots of *Solanum Capsicastrum*. All stages of the life-history were worked out. If the female penetrates the central connective tissue of the stele, it does not emerge. The worm will hatch and go through a part of its development in water containing decomposing roots of *Abutilon*. Experiments as to whether it can complete its cycle in liquid are in progress.

(2) The Ascomycete is a new *Thielavia*, which I propose to name *T. Hartogii*, differing from *T. basicola*, Zopf, with more abundant gonidia (up to a hundred) in each pseudo-sporange, and dark green chlamydospores. Only young perithecia were observed. This is a dangerous parasite under favourable conditions of moisture and temperature.

(3) A fungus coexisting with (1) and (2), whose unseptate hyphæ and 'cellulose wall and reproductive bodies recall Peronosporeæ, has been partially studied; it appears to be relatively harmless.

The research was commenced, at Professor Hartog's suggestion, in the Biological Institute of Queen's College, Cork, and continued under Professor Van Tieghem's direction at the Muséum d'Histoire Naturelle, Paris.

6. *Remarks on Fern Sporangia and Spores.*
By Professor F. O. Bower, *F.R.S.*

7. *The Jurassic Flora of Britain.* *By* A. C. Seward, *F.R.S.*

The Lower Oolite rocks exposed in the cliff-section between Whitby and a few miles south of Scarborough have long been famous as affording rich collections of fossil plants, which enable us to form a fairly accurate idea of the chief characteristics of the Jurassic Flora. Plants from the Yorkshire coast are abundantly represented in most of the English museums as well as in Continental collections. The Ferns and Cycadean genera constituted a large proportion of the vegetation, with an abundance of one or two species of *Equisetites* and a few conifers; no trace of undoubted Angiosperms has so far been discovered.

The account of the flora includes a description of the more important types, a general comparison of the English species with recent plants, and remarks on the characteristics and distribution of the Lower Oolite floras.

TUESDAY, SEPTEMBER 19.

The following Papers were read:—

1. *A new Genus of Palæozoic Plants.* *By* A. C. Seward, *F.R.S.*

The description of this genus, which represents a new type of Cycadofilices, is founded on a single specimen in the Binney Collection of Coal-measure Plants (presented in 1892 to the Woodwardian Museum, Cambridge). The specimen consists of a small piece of stem, unfortunately without the cortical tissues, with the structure of the primary and secondary wood very clearly preserved. A strand of primary xylem, 1·9 cm. in diameter, occupies the axial region; this consists of large isodiametric or slightly elongated tracheids with multiseriate bordered pits on their walls, associated with parenchymatous tissue; the narrow and spirally thickened protoxylem elements occur at the margin of the primary stele, which is, therefore, of exarch structure. Surrounding the primary stele there is a broad cylinder of secondary wood exhibiting anatomical features characteristic of Cycadean stems. Leaf-traces are given off from the periphery of the primary strand; these consist of long tracheids intermixed with parenchyma.

The features of most interest in the anatomy of this stem are (1) the manner of origin and behaviour of the leaf-traces; (2) the exarch structure of the primary system; and (3) the structure of the large primary tracheids.

The genus is placed among the Cycadofilices, and compared with *Heterangium* and other Palæozoic genera, also with *Lygodium* and other recent plants.

2. *On the Structure of a Stem of a Ribbed Sigillaria.*
By Professor C. Eg. Bertrand (*Lille*).

The specimen described was obtained by M. Breton from a colliery in the Hardinghem district, Pas de Calais; it presents external features similar to those of *Sigillaria elongata,* and the structure of the wood is well preserved. The fragment of stem measures 100 × 60 mm. and the surface is traversed by 72 ribs. The primary system (corona) is in places perfectly preserved; it agrees with that of a *Diploxylon* stem and forms a continuous centripetally developed ring. Exteriorly the primary wood is succeeded by a continuous zone of centrifugal secondary wood, but the cambial and phloeum regions have not been preserved. The continuou corona consists of 10–13 rows of large scalariform tracheids; its external surface is characterised by the very prominent teeth which form ridges separated by sinuses. The narrowest xylem elements are situated in the projecting teeth. The leaf-traces arise as separate strands from the external face of the primary wood, and each is detached from the middle of a sinus; the arrangement of the leaf-traces suggests an almost regularly verticillate disposition of the appendices. Each leaf-trace consists of 6 tracheæ in the form of a tangentially elongated group, and 6–8 rows of radially disposed centripetal scalariform vessels. The traces consist only of primary elements, and pass outwards through a medullary ray of the secondary wood.

Professor Bertrand compared the Hardinghem specimen with *Diploxylon* stems from Oldham, Halifax, and Burntisland, and with a Sigillaria of the *Leiodermaria* (smooth-barked) section, *S. spinulosa.* In *S. spinulosa* the leaf-traces are given off from the same position on the corona as in the ribbed stem, but in the former species the corona consists of separate groups of tracheids as distinct from the continuous band in the Hardinghem stem. In the Leiodermarian species, as Renault has shown, the leaf-traces consist in part of secondary xylem.

In the *Diploxylon* stem from Halifax and Oldham the leaf-traces are given off from the middle of a sinus of the corona, as in the new *Sigillaria,* but in the Burntisland *Diploxylon* they have a lateral origin, as in *Lepidodendron selaginoides.*

3. *On a biserial* Halonia *belonging to the genus* Lepidophloios.
By Professor F. E. Weiss.

At the Bristol meeting of the British Association, Dr. D. H. Scott exhibited photographs of this *Halonia* from the Hough Hill Colliery, Stalybridge, and pointed out the agreement of its well-preserved internal structure with that of *Lepidodendron fuliginosum* of Williamson. Dr. Scott had most kindly and generously allowed the author to undertake the further examination of this specimen, and this completely confirmed the identity of the internal structure of this *Halonia* with that of Williamson's *Lepidodendron fuliginosum.* Williamson retained this name in his 'Memoir,' pt. xix., published in 1893, though Cash and Lomax had shown conclusively, at the meeting of the British Association at Leeds in 1890, that this type of structure was revealed by a specimen showing undoubtedly *Lepidophloios* leaf-scars, and though Williamson's *Lepidophloios,* figured in pt. xix., also shows the stem structure of the *fuliginosum* type. The same structure is shown also by stems of the ordinary multiseriate Halonias, which, as Kidston and Potonié have shown, belong undoubtedly to the genus *Lepidophloios.* Stems, therefore, showing the structure of *Lepidodendron fuliginosum* (Williamson) should be referred to the genus *Lepidophloios.*

The fruiting branches of this genus, however, termed *Halonia,* or halonial branches, have usually a number of rows of spirally arranged tubercles. The Hough Hill *Halonia* has only two rows of fructigerous tubercles. Hence it would by some palæobotanists be classed as Ulodendroid, but it seems better to call it a 'biserial *Halonia,*' since the name of Halonia has been reserved by Kidston and others for the fruiting branches of *Lepidophloios,* and also because its elevated tubercles distinguish it from the usually depressed Ulodendroid scars. As the Hough Hill *Halonia* shows no leaf-scars, the author has sought for confirmatory evidence for his conclusion that *Lepidophloios* may possess fruiting branches with two rows of fruit-bearing tubercles. The *Lepidophloios* figured by Williamson in his nineteenth 'Memoir' (figs. 30 to 38), and coming from the same locality, is described as possessing two rows of halonial tubercles, and this is confirmed by two pieces of this specimen preserved, one in the Williamson collection in the British Museum, and another in the Wilde collection in the Manchester Museum. The author also submitted photographs of two other biserial Halonias showing distinct *Lepidophloios* leaf-scars, one from the Williamson collection (No. 1946B) at the British Museum, and one presented by Mr. Dawes to the Manchester Museum, Owens College. These, he considered, confirmed his conclusion that the biserial *Halonia* from the Hough Hill Colliery was also a fruiting branch of *Lepidophloios.*

4. *The Maiden-hair Tree* (Ginkgo biloba, *L.*).

By A. C. SEWARD, *F.R.S., and* Miss J. GOWAN.

The chief points dealt with in this paper may be summarised as follows:—

1. *Ginkgo biloba.*—The history of our knowledge of *Ginkgo*; its external features and peculiarities; the variability in form and structure of the leaves; the structure and morphology of the male and female flowers; pollination and fertilisation of the ovule; the development and structure of the embryo; the anatomy of the seedling and adult plant; comparison of *Ginkgo* with other genera, and its place in the plant-kingdom.

2. *Fossil Ginkgoaceæ.*—A general consideration of the evidence available towards an account of the past history of *Ginkgo* and closely allied plants; a comparison of *Ginkgo* with various fossil types from Palæozoic, Mesozoic, and Tertiary horizons; the geographical distribution of *Ginkgo* during the Mesozoic and Tertiary epochs.

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5. *Stem-structure in* Schizæaceæ, Gleicheniaceæ, *and* Hymenophyllaceæ.

By L. A. BOODLE.

There is a wide difference between the types of stem-structure shown by the different members of the *Schizæaceæ.* Thus *Lygodium* has a stele in which the xylem forms a solid mass in the centre of the stem, and is surrounded by a continuous ring of phloem pericycle and endodermis.

Aneimia Phyllitidis, on the other hand, has a ring of separate bundles (or steles), which may be compared with those of *Aspidium* or other *Polypodiaceæ*; each of them consisting of a band of xylem surrounded by a phloem, pericycle, and endodermis of its own.

Mohria resembles *Aneimia Phyllitidis* in type. Certain species of *Aneimia, e.g. A. mexicana,* have in the internodes a complete ring of xylem bounded on the inner and outer side by a ring of phloem, pericycle, and endodermis, with a central pith, and thus resemble *Marsilia. Schizæa* has a ring of xylem surrounding a central pith, but no internal phloem or endodermis.

The above four genera, which make up the *Schizæaceæ,* agree in having a stem-protoxylem, which is not well marked, as it consists of elements which are not annular or spiral, and are usually not specially small. *Lygodium, Aneimia,* and *Mohria* are exarch; in *Schizæa,* however, the relative position of the protoxylem has not been made out with certainty.

In their main points the types of stem-structure found in the *Schizæaceæ* agree with the structures shown at successive levels in the stem of a 'seedling' plant of *Polypodium, i.e.* at successive stages in the ontogeny of such a fern. Hence the *Aneimia* type (which corresponds with that of a mature *Polypodium*) may be regarded as the more specialised type among the *Schizæaceæ,* and *Lygodium* (which corresponds in structure with the base of the stem of *Polypodium*) as the more primitive type.

The *Gleicheniaceæ* and *Hymenophyllaceæ* also include forms with a solid central mass of xylem, but differing in some details from *Lygodium.* The protoxylem is well marked and composed of annular and spiral elements in both orders. *Gleichenia* is mesarch and closely resembles the fossil genus *Heterangium.*

In the *Gleicheniaceæ* the only advance on the *Lygodium* type is found in *Platyzoma* (a subgenus of *Gleichenia*) in which there is a ring of xylem surrounding a central pith, as in *Schizæa,* but differing from the latter plant in having an inner endodermis.

In the larger species of *Trichomanes* there is a solid xylem-mass, but with a group of parenchyma in connection with the one or two protoxylems, which are more or less centrally placed. In *Hymenophyllum* the corresponding parenchymatous mass is large in proportion to the amount of xylem. In the smallest species of *Trichomanes* the stele of the rhizome takes the form of a collateral bundle. The protoxylem of *Trichomanes spicatum*, unlike the other species examined, resembles that of the *Schizæaceæ*.

The solid stele may be regarded as primitive, the *Aneimia* type being derived from it by the following steps:—

1. Solid central xylem-mass surrounded by phloem, &c.
2. Ring of xylem surrounding a central pith.
3. Ring of xylem with internal phloem, endodermis, and pith.
4. Ring of separate bundles formed by the breaking up of the above vascular ring, owing to large leaf-gaps.

The *Aneimia* type thus explained would not be polystelic, in the morphological sense of the word, but the separate bundles would represent peripheral parts of an originally solid stele, in which the central part has been replaced by parenchyma, additional pieces of phloem and endodermis having been differentiated to complete the concentric bundles.

6. *Notes on Indiarubber.* *By* R. H. Biffen, *Cambridge.*

Starch and caoutchouc appear not to occur together. Caoutchouc occurs as small particles in latex, and coagulation begins with their running together. Certain reagents will bring this about; but it is better to avoid all chemical processes, any of which do harm. Two physical processes are now being used. (1) The latex, mixed with water, is strained and churned; the thick cream which rises to the surface is pressed through rollers and converted into rubber. (2) The author's process consists in separating the rubber with a centrifugal apparatus. Details are given in the paper regarding the chemical properties of the different kinds of rubber obtained from *Hevea, Castilloa, Manihot, Ficus, Hancornia, Kicksia, Artocarpus,* and *Clusia.* The author also raises some questions of theoretical interest with regard to possible relations between caoutchouc, starch, and resin-bodies, and indicates lines for further inquiry.

7. *Some Isolated Observations bearing on the Function of Latex.*
By J. Parkin, *M.A.*

The author has lately returned from a year's sojourn in Ceylon, where he has been acting as scientific assistant to Mr. Willis, the Director of the Royal Botanic Gardens. During his time there he has been principally engaged in investigations on caoutchouc-yielding trees, chiefly *Hevea brasiliensis* (Para Rubber), and *Castilloa elastica var.* (a Central American Rubber-tree). The results of this research are contained in a recently-published circular of the Royal Botanic Gardens, Ceylon, entitled 'Caoutchouc or Indiarubber,' intended primarily for those interested in rubber cultivation.

The purpose of this paper is to draw attention to some of the observations and experiments recorded in the Circular, which, besides their practical value, have a general botanical interest, and also to make public other observations which may throw light on the functions of laticiferous tissue. It is arranged in six sections. The main features of these are here briefly given.

Section I. is occupied chiefly with the coagulation of the latex of *Hevea*. Coagulation is now known to be brought about by the proteid contained in the latex passing from a soluble to an insoluble state. The latex of *Hevea* is not coagulable by heat or slight additions of alkalies, but is coagulable in the cold, by small quantities of acids. The approximate weight of acid required to clot completely 100 c.c. of latex has been worked out for sulphuric, hydrochloric, nitric, acetic, oxalic, tartaric, and citric acids. Experimental evidence points to the proteid in question being alkali-albumen rather than ordinary albumen. It has previously been called albumen.

The behaviour of this latex towards certain saline solutions has also been investigated. Mercuric chloride is shown to be a powerful coagulator.

Section II. contains observations and remarks relating to the carbohydrates of latex.

Sugar in variable proportions is of frequent occurrence in latex. The little contained in the trunk-latex of *Hevea* seems to be cane-sugar.

It is suggested that the sugar may arise, in part at least, from the surrounding injured tissues, and may not be always originally present in the latex.

The starch-rods so characteristic of the laticiferous tubes of *Euphorbia* and allied genera have been found still present in the turned and fallen leaves of the following species examined: *Euphorbia pulcherrima, E. Bojeri, E. rothiana, Pedilanthus tithymaloides, Hura crepitans, Excæcaria bicolor,* and *Sapium biglandulosum.* This fact is somewhat opposed to the view of these tubes functioning as conductors of starch from the leaf.

In Section III. reasons are given for thinking that in some caoutchouc trees the latex of the young stems and leaves differs in the composition of its globules in suspension from that of the trunk and main branches. While the latter yield rubber free of stickiness, the former give a somewhat viscous substance with feeble elasticity. Such is the case with *Hevea, Castilloa, Landolphia Kirkii, Ficus elastica,* and *Urceola esculenta.*

Section IV. treats of an important fact connected with the tapping of *Hevea* trees, *viz.*, that wounding the bark causes a greater flow of latex from subsequent injuries. A point first indicated in the experiments of Mr. Willis, who found that the weight of rubber obtained from the second tapping was about double that from the first. The author has followed this up with some instructive results.

In Section V. a peculiarity in the exudation of latex from the severed base of the petiole of *Hevea brasiliensis* and *Plumiera acutifolia* is described and discussed.

In Section VI. a special laticiferous system developed in the immature seed of *Hevea brasiliensis* is brought to notice.

The paper concludes with general remarks and suggestions on the origin and functions of laticiferous tissue.

8. *Intumescences of* Hibiscus vitifolius (*L.*). *By* Miss E. Dale, *Cambridge.*

I. *Anatomical Part.*

The plants on which the following observations were made were grown, directly or indirectly, from seed from Somaliland. The intumescences, which vary in size and shape, occur on the leaves, stems, green parts of the flower, and on the young fruit. Some are entirely colourless; others are green at the base. Those on (1) the leaf differ from those on (2) the stem.

1. *On the leaf* the intumescences are of two types.

(*a*) Purely epidermal.
(*β*) Partly sub-epidermal.

a. The purely epidermal and smaller type consists of one or two tiers, of much elongated, thin-walled cells, usually twisted spirally round one another. At the apex is a stoma, which may or may not lead into an intercellular space.

β. The larger outgrowths contain basal prolongations of parenchyma.

2. *On the stem* the outgrowths are more complex, and usually larger. The basal part consists of elongated sub-epidermal cells divided by periclinal walls. The upper part is made up of much enlarged, thin-walled epidermal cells, similarly divided. The outgrowths later become cut off by cork, which arises in the lowest row of daughter cells derived from the original epidermis, *i.e.* in the lowest colourless cells; after suberisation of these cells the outgrowth shrivels.

II. *Experimental Part.*

Seedlings were raised in the Tropical Pit, and eight of them were planted, each in a separate pot, and allowed to grow on under identical conditions. They all developed intumescences, and were all very much alike. When each had about nine or ten leaves, and was beginning to flower, the plants were placed under different conditions, and examined at the end of six weeks:—

The plant grown in the open was entirely free from intumescences; it was particularly vigorous, and had strong lateral branches.

The plant in the temperate house had outgrowths only on the *under* sides of the leaves, and on the flowers and fruits.

The plant in the filmy fern-house was very unhealthy, but had no outgrowths.

All the other plants had outgrowths on one or both sides of most of the leaves, on the stems, the green parts of the flowers, and on the young fruits.

Conclusions.

As far as the evidence goes at present, it seems to point to the conclusion that the intumescences are pathological, and are due neither to insects nor to fungi, but to the direct effects of environment. The formation of outgrowths appear to be caused by excessive moisture combined with a high temperature. If the temperature is low the plants do not appear to have strength to form them. The production of outgrowths seems to be a response on the part of the plant to insufficient transpiration.

Note.—Similar, but less well-marked, outgrowths were observed on the leaves of plants of *Ceratotheca triloba.* As in the case of *Hibiscus vitifolius*, they were not formed in a plant placed in the open ground.

Outgrowths which may prove to be of the nature of those in *Hibiscus vitifolius* have been described by Sorauer in *Dracæna* (*angustifolia*, &c.), *Cassia tomentosa*, *Acacia* (*semperflorens*, &c.).

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References to reports and papers printed in extenso *are given in Italics.*
*An Asterisk * indicates that the title only of the communication is given.*
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Lord Armstrong, C.B., LL.D.
Sir J. D. Hooker, K.C.S.I., F.R.S.
Sir G. G. Stokes, Bart., F.R.S.
Lord Kelvin, G.C.V.O., F.R.S.
Prof. A. W. Williamson, F.R.S.
Sir John Lubbock, Bart., F.R.S.
Lord Rayleigh, D.C.L., F.R.S.
Sir H. E. Roscoe, D.C.L., F.R.S.
Sir F. J. Bramwell, Bart., F.R.S.
Sir F. A. Abel, Bart., K.C.B., F.R.S.
Sir Wm. Huggins, K.C.B., F.R.S.
Sir Archibald Geikie, LL.D., F.R.S.
Sir J. S. Burdon Sanderson, Bart. F.R.S.
The Marquis of Salisbury, K.G., F.R.S.
Lord Lister, D.C.L., Pres. R.S.
Sir John Evans, K.C.B., F.R.S.
Sir William Crookes, F.R.S.

GENERAL OFFICERS OF FORMER YEARS.

F. Galton, Esq., D.C.L., F.R.S.
Prof. Sir Michael Foster, K.C.B., Sec. R.S.
G. Griffith, Esq., M.A.
P. L. Sclater, Esq., Ph.D., F.R.S.
Prof. T. G. Bonney, D.Sc., F.R.S.
Prof. A. W. Williamson, F.R.S.
A. Vernon Harcourt, Esq., F.R.S.
Prof. A. W. Rücker, D.Sc., Sec.R.S.

AUDITORS.

Dr. D. H. Scott, F.R.S.
Sir H. Trueman Wood, M.A.
Dr. Horace Brown, F.R.S.

LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1899.

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* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
§§ indicates Annual Subscribers who will be entitled to the Annual Report if their Subscriptions are paid by December 31, 1899.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members, elected before 1845, not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Assistant General Secretary, G. Griffith, Esq., Burlington House, W.

Year of Election.

1887. *Abbe, Professor Cleveland. Weather Bureau, Department of Agriculture, Washington, U.S.A.
1897. ‡Abbott, A. H. Brockville, Ontario, Canada.
1898. §Abbott, George, M.R.C.S. 33 Upper Grosvenor-road, Tunbridge Wells.
1881. *Abbott, R. T. G. Whitley House, Malton.
1887. ‡Abbott, T. C. Eastleigh, Queen's-road, Bowdon, Cheshire.
1863. *ABEL, Sir FREDERICK AUGUSTUS, Bart., K.C.B., D.C.L., D.Sc., F.R.S., V.P.C.S., President of the Government Committee on Explosives. The Imperial Institute, Imperial Institute-road, and 2 Whitehall-court, S.W.
1885. *ABERDEEN, The Right Hon. the Earl of, G.C.M.G., LL.D., Haddo House, Aberdeen.
1885. ‡Aberdeen, The Countess of. Haddo House, Aberdeen.
1885. ‡*Abernethy, David W. Ferryhill Cottage, Aberdeen.*
1885. ‡Abernethy, James W. 2 Rubislaw-place, Aberdeen.
1873. *ABNEY, Captain Sir W. DE W., K.C.B., D.C.L., F.R.S., F.R.A.S. Rathmore Lodge, Bolton-gardens South, Earl's Court, S.W.

Year of Election.

1886. ‡Abraham, Harry. 147 High-street, Southampton.
1884. ‡Acheson, George. Collegiate Institute, Toronto, Canada.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1882. *Acland, Alfred Dyke. 38 Pont-street, Chelsea, S.W.
1869. ‡Acland, Sir C. T. Dyke, Bart., M.A. Killerton, Exeter.
1877. *Acland, Captain Francis E. Dyke, R.A. Woodmansterne Rectory, Banstead, Surrey.
1873. *Acland, Rev. H. D., M.A. Luccombe Rectory, Taunton.
1894. *Acland, Henry Dyke, F.G.S. The Old Bank, Great Malvern.
1832. *ACLAND, Sir HENRY W. DYKE, Bart., K.C.B., M.D., LL.D., F.R.S. Broad-street, Oxford.
1877. *Acland, Theodore Dyke, M.A. 74 Brook-street, W.
1898. §§Acworth, W. M. 47 St. George's-square, S.W.
1887. ‡ADAMI, J. G., M.A., M.D., Professor of Pathology in the University, Montreal, Canada.
1892. ‡Adams, David. Rockville, North Queensferry.
1884. ‡Adams, Frank Donovan. Geological Survey, Ottawa, Canada.
1871. §Adams, John R. 2 Nutley-terrace, Hampstead, N.W.
1879. *ADAMS, Rev. THOMAS, M.A., D.C.L., Canon of Quebec, Principal of Bishop's College, Lennoxville, Canada.
1869. *ADAMS, WILLIAM GRYLLS, M.A., D.Sc., F.R.S., F.G.S., F.C.P.S., Professor of Natural Philosophy and Astronomy in King's College, London. 43 Campden Hill-square, W.
1879. ‡Adamson, Robert, M.A., LL.D., Professor of Logic in the University of Glasgow.
1896. ‡Adamson, W. Sunnyside House, Prince's Park, Liverpool.
1898. §Addison, William L. T. Byng Inlet, Ontario, Canada.
1890. ‡Addyman, James Wilson, B.A. Belmont, Starbeck, Harrogate.
1890. ‡ADENEY, W. E., F.C.S. Royal University of Ireland, Earlsfort-terrace, Dublin.
1899. §Adie, R. H., M.A., B.Sc. 8 Richmond-road, Cambridge.
1883. ‡Adshead, Samuel. School of Science, Macclesfield.
1896. ‡Affleck, W. H. 28 Onslow-road, Fairfield, Liverpool.
1884. ‡Agnew, Cornelius R. 266 Maddison-avenue, New York, U.S.A.
1887. ‡Agnew, William. Summer Hill, Pendleton, Manchester.
1864. *Ainsworth, David. The Flosh, Cleator, Carnforth.
1871. *Ainsworth, John Stirling. Harecroft, Gosforth, Cumberland.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.
1895. *Airy, Hubert, M.D. Stoke House, Woodbridge, Suffolk.
1891. *Aisbitt, M. W. Mountstuart-square, Cardiff.
1871. §AITKEN, JOHN, F.R.S., F.R.S.E. Ardenlea, Falkirk, N.B.
1898. ‡AKERS-DOUGLAS, Right Hon. A., M.P. 106 Mount-street, W.
1884. *Alabaster, H. Lytton, Mulgrave-road, Sutton, Surrey.
1886. *Albright, G. S. The Elms, Edgbaston, Birmingham.
1896. §Aldridge, J. G. W., Assoc.M.Inst.C.E. 9 Victoria-street, Westminster, S.W.
1894. ‡Alexander, A. W. Blackwall Lodge, Halifax.
1891. ‡Alexander, D. T. Dynas Powis, Cardiff.
1883. ‡Alexander, George. Kildare-street Club, Dublin.
1888. *Alexander, Patrick Y. Experimental Works, Bath.
1896. ‡Alexander, William. 45 Highfield South, Rockferry, Cheshire.
1891. *Alford, Charles J., F.G.S. 15 Great St. Helens, E.C.
1883. ‡Alger, Miss Ethel. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, W. H. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.

Year of Election.
1867. ‡Alison, George L. C. Dundee.
1885. ‡Allan, David. West Cults, near Aberdeen.
1871. ‡Allan, G., M.Inst.C.E. 10 Austin Friars, E.C.
1871. ‡ALLEN, ALFRED H., F.C.S. 67 Surrey-street, Sheffield.
1879. *Allen, Rev. A. J. C. The Librarian, Peterhouse, Cambridge.
1898. §Allen, E. J. The Laboratory, Citadel Hill, Plymouth.
1888.§§ALLEN, F. J., M.A., M.D., Professor of Physiology, Mason College, Birmingham.
1884. ‡Allen, Rev. George. Shaw Vicarage, Oldham.
1891. ‡Allen, Henry A., F.G.S. Geological Museum, Jermyn-street, S.W.
1887. ‡Allen, John. Kilgrimol School, St. Anne's-on-the-Sea, viâ Preston.
1878. ‡Allen, John Romilly. 28 Great Ormond-street, W.C.
1891. ‡Allen, W. H. 24 Glenroy-street, Roath, Cardiff.
1889. ‡Allhusen, Alfred. Low Fell, Gateshead.
1889. ‡Allhusen, Frank E. The School, Harrow.
1886. ‡Allport, Samuel, F.G.S. Mason College, 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, M.A., F.G.S. Geological Survey, Ottawa, Canada.
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.
1899. *Anderson, Miss Mary K. 13 Napier-road, Edinburgh.
1888. *Anderson, R. Bruce. 35A Great George-street, 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.
1880. ‡Andrew, Mrs. 126 Jamaica-street, Stepney, E.
1883. ‡Andrew, Thomas, F.G.S. 18 Southernhay, Exeter.
1895. ‡Andrews, Charles W. British Museum (Natural History), 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., F.I.C. 6 Beacons-field, Derby-road, Withington, Manchester.
1886. ‡Annan, John, J.P. Whitmore Reans, Wolverhampton.
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.
1898.§§Archer, G. W. 11 All Saints'-road, Clifton, Bristol.
1894. §Archibald, A. The Bank House, Ventnor.
1884. *Archibald, E. Douglas. Constitutional Club, Northumberland Avenue, W.C.
1851. ‡ARGYLL, His Grace the Duke of, K.G., K.T., D.C.L., F.R.S., F.R.S.E., F.G.S. Inveraray.
1883. §Armistead, Richard. Chambres House, Southport.
1883. *Armistead, William. Oakfield, 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.

Year of Election.
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, 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.*
1889. ‡Armstrong, Thomas John. 14 Hawthorn-terrace, Newcastle-upon-Tyne.
1893. ‡Arnold-Bemrose, H., M.A., F.G.S. 56 Friar-gate, Derby.
1870. *Ash, Dr. T. Linnington. Penroses, Holsworthy, North Devon.
1874. ‡Ashe, Isaac, M.B. Dundrum, Co. Dublin.
1889. ‡Ashley, Howard M. Airedale, Ferrybridge, Yorkshire.
1887. ‡Ashton, Thomas Gair, M.A. 36 Charlotte-street, Manchester.
*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.
Ashworth, Henry. Turton, near Bolton.
1888. *Ashworth, J. Jackson. Haslen House, Handforth, Cheshire.
1890. ‡Ashworth, J. Reginald, B.Sc. 105 Freehold-street, Rochdale.
1887. ‡Ashworth, John Wallwork, F.G.S. Thorne Bank, Heaton Moor, Stockport.
1887. ‡Ashworth, Mrs. J. W. Thorne Bank, Heaton Moor, Stockport.
1887. ‡Aspland, Arthur P. Werneth Lodge, Gee Cross, near Manchester.
1875. *Aspland, W. Gaskell. Tuplins, Newton Abbot.
1861. ‡Asquith, J. R. Infirmary-street, Leeds.
1896. *Assheton, Richard. Birnam, Cambridge.
1861. ‡*Aston, Theodore. 11 New-square, Lincoln's Inn, W.C.*
1896.§§Atkin, George, J.P. Egerton Park, Rockferry.
1887. §Atkinson, Rev. C. Chetwynd, D.D. 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.
1898. *Atkinson, E. Cuthbert. Temple Observatory, Rugby.
1894. ‡Atkinson, George M. 28 St. Oswald's-road, S.W.
1894. *Atkinson, Harold W. Rossall School, Fleetwood, Lancashire.
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, E.C.
1884. ‡Auchincloss, W. S. 209 Church-street, Philadelphia, U.S.A.
1877. *AYRTON, W. E., F.R.S., Professor of Applied Physics in the City and Guilds of London Institute, Central Institution, Exhibition-road, S.W. 41 Kensington Park-gardens, W.

1884. ‡Baby, The Hon. G. Montreal, Canada.
1900. §BACCHUS, RAMSDEN (LOCAL SECRETARY). 15 Welbury Drive, Bradford.
1883. *Bach, Madame Henri. 12 Rue Fénélon, Lyons.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's, Wolsingham, R.S.O., Durham.
1887. *Bacon, Thomas Walter. Ramsden Hall, Billericay, Essex.

Year of Election.

1887. ‡Baddeley, John. 1 Charlotte-street, Manchester.
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. 7 Drummond-place, Edinburgh.
1870. ‡Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1887. *Bailey, G. H., D.Sc., Ph.D. Marple Cottage, Marple, Cheshire.
1865. †Bailey, Samuel, F.G.S. Ashley House, Calthorpe-road, Edgbaston, Birmingham.
1899. §Bailey, T. Lewis. 35 Hawarden-avenue, Liverpool.
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. 11 Ramsay-garden, Edinburgh.
1878. ‡BAILY, WALTER. 4 Roslyn-hill, Hampstead, N.W.
1885. ‡BAIN, ALEXANDER, M.A., LL.D. Ferryhill Lodge, Aberdeen.
1897. §BAIN, JAMES, jun. 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.
1898.§§Baker, Herbert M. Wallcroft, Durdham Park, Clifton, Bristol.
1898.§§Baker, Hiatt C. Mary-le-Port-street, Bristol.
1891. ‡Baker, J. W. 50 Stacey-road, Cardiff.
1881. ‡Baker, Robert, M.D. The Retreat, York.
1875. ‡BAKER, W. PROCTOR. 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. 24 Addison-road, Kensington, W.
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., Regius Professor of Surgery in the University of Dublin. 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.
1899. §Bampton, Mrs. 42 Marine-parade, Dover.
1882. ‡Bance, Colonel Edward, J.P. Oak Mount, Highfield, Southampton.
1898. §Bannerman, W. Bruce, F.R.G.S., F.G.S. The Lindens, Sydenham-road, Croydon.
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.

Year of Election.

1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
1894. §Barclay, Arthur. 29 Gloucester-road, South Kensington, S.W.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1887. *Barclay, Robert. Sedgley New Hall, Prestwich, 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, S.E.
1899 §Barker, John H. 26 Park-parade, Cambridge.
1882. *Barker, Miss J. M. Hexham House, Hexham.
1879. *Barker, Rev. Philip C., M.A., LL.B. Priddy Vicarage, Wells, Somerset.
1898. §Barker, W. R. 106 Redland-road, Bristol.
1886. ‡Barling, Gilbert. 85 Edmund-street, Edgbaston, Birmingham.
1873. ‡Barlow, Crawford, B.A., M.Inst.C.E. Deene, Tooting Bec-road, Streatham, S.W.
1889. §Barlow, H. W. L., M.A., M.B., F.C.S. 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.
1885. *BARLOW, WILLIAM, F.G.S. The Red House, Great Stanmore.
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.
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.
1899. §Barnes, Robert. 29 Thorngate-road, St. Peter's Park, W.
1884. ‡Barnett, J. D. Port Hope, Ontario, Canada.
1899. §Barnett, W. D. 41 Threadneedle-street, E.C.
1881. ‡BARR, ARCHIBALD, D.Sc., M.Inst.C.E. The University, Glasgow.
1890. ‡Barr, Frederick H. 4 South-parade, Leeds.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
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.
1872. *BARRETT, W. F., F.R.S., 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.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1893. *BARROW, GEORGE, F.G.S. Geological Survey Office, 28 Jermyn-street, S.W.
1886. ‡Barrow, George William. Baldraud, Lancaster.
1886. ‡Barrow, Richard Bradbury. Lawn House, 13 Ampton-road, Edgbaston, Birmingham.

Year of Election.
1896. §Barrowman, James. Staneacre, 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, S.W.
1883. ‡Barry, Charles E. 1 Victoria-street, S.W.
1881. ‡Barry, J. W. Duncombe-place, York.
1884. *Barstow, Miss Frances A. 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, M.Inst.C.E. 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.
1899. *Barton, Miss Ethel S. Cornwall House, Reading-road, Pangbourne.
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.
1898.§§Bason, Vernon Millward. 7 Princess-buildings, Clifton, Bristol.
1876. ‡Bassano, Alexander. 12 Montagu-place, W.
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, 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, W.
1889. ‡Batalha-Reis, J. Portuguese Consulate, Newcastle-upon-Tyne.
1883. ‡BATEMAN, A. E., C.M.G., Controller General, Statistical Department. Board of Trade, 7 Whitehall Gardens, S.W.
1868. ‡Bateman, Sir F., M.D., LL.D. Upper St. Giles's-street, Norwich.
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.
1863. §BAUERMAN, H., F.G.S. 14 Cavendish-road, Balham, S.W.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1892. §Bayly, F. W. 8 Royal Mint, E.
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. Winterdyne, Chine Crescent-road, Bournemouth.
1886. ‡Beale, C. Calle Progress No. 83, Rosario de Santa Fé, Argentine Republic.

Year of Election.

1886. ‡Beale, Charles G. Maple Bank, Edgbaston, Birmingham.
1860. *BEALE, LIONEL S., M.B., F.R.S. 61 Grosvenor-street, 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, B.Sc., F.R.S.E., M.Inst.C.E. University College, W.C.
1842. *Beatson, William. 2 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, W.
1886. ‡Beaugrand, M. H. Montreal.
1861. *Beaumont, Rev. Thomas George. Oakley Lodge, Leamington.
1887. *Beaumont, W. J. The Laboratory, Citadel Hill, Plymouth.
1885. *BEAUMONT, W. W., M.Inst.C.E., F.G.S. Outer Temple, 222 Strand, W.C.
1896. ‡Beazer, C. Hindley, near Wigan.
1871. *Beazley, Lieut.-Colonel George G. 74 Redcliffe-square, S.W.
1887. *BECKETT, JOHN HAMPDEN. Corbar Hall, Buxton, Derbyshire.
1885. ‡BEDDARD, FRANK E., M.A., F.R.S., F.Z.S., Prosector to the Zoological Society of London, Regent's Park, N.W.
1870. §BEDDOE, JOHN, M.D., F.R.S. The Chantry, Bradford-on-Avon.
1896. §Bedford, F. P. 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., M.Sc., Assist.-Sec. G.S. Burlington House, W.
1892. ‡Bell, A. Beatson. 143 Princes-street, Edinburgh.
1871. ‡Bell, Charles B. 6 Spring-bank, Hull.
1884. ‡Bell, Charles Napier. Winnipeg, Canada.
1894. ‡BELL, F. JEFFREY, M.A., F.Z.S. 35 Cambridge-street, Hyde Park, 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. Howell Hill Lodge, Ewell, Surrey.
1896.§§Bell, James. Care of the Liverpool Steam Tug Co., Limited, Chapel-chambers, 28 Chapel-street, 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. 100 Leyland-road, Southport.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
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.

Year of Election.

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., Professor of Biology in the University of Otago, New Zealand.
1891. ‡Bennett, Alfred Rosling. 44 Manor Park-road, Harlesden, N.W.
1870. ‡Bennett, Alfred W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, N.W.
1896. §Bennett, George W. West Ridge, Oxton, Cheshire.
1881. §Bennett, John Ryan. 3 Upper Belgrave-road, Clifton, Bristol.
1883. *Bennett, Laurence Henry. The Hall, East Ilsley, Berkshire.
1896. ‡Bennett, Richard. 19 Brunswick-street, Liverpool.
1881. ‡Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishopshill Junior, York.
1889. ‡Benson, John G. 12 Grey-street, Newcastle-upon-Tyne.
1887. *Benson, Mrs. W. J. Care of Standard Bank of South Africa, Stellenbosch, South Africa.
1863. ‡Benson, William. Fourstones Court, Newcastle-upon-Tyne.
1898. *Bent, Mrs. Theodore. 13 Great Cumberland-place, W.
1884. ‡Bentham, William. 724 Sherbrooke-street, Montreal, Canada.
1897. ‡Bently, R. R. 97 Dowling-avenue, Toronto, Canada.
1896. *Bergin, William, M.A., Professor of Natural Philosophy in Queen's College, Cork.
1894. §Berkeley, The Right Hon. the Earl of. Foxcombe, Boarshill, near Abingdon.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1886. ‡Bernard, W. Leigh. Calgary, Canada.
1898. §Berridge, Miss C. E. 17 Rotunda-terrace, Cheltenham.
1894. §Berridge, Douglas, M.A., F.C.S. The College, Malvern.
1862. ‡Besant, William Henry, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1882. *Bessemer, Henry. 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, W.
1885. ‡Beveridge, R. Beath Villa, Ferryhill, Aberdeen.
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1870. ‡Bickerton, A.W. Christchurch, Canterbury, New Zealand.
1888. *Bidder, George Parker. Savile Club, Piccadilly, W.
1885. *Bidwell, Shelford, Sc.D., 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.
1898. §Billington, Charles. Studleigh, Longport, Staffordshire.
1891. ‡Billups, J. E. 29 The Parade, Cardiff.
1886. ‡Bindloss, G. F. Carnforth, Brondesbury Park, N.W.
1887. *Bindloss, James B. Elm Bank, Eccles, Manchester.
1884. *Bingham, Lieut.-Colonel John E., J.P. West Lea, Ranmoor, Sheffield.
1881. ‡Binnie, Sir Alexander R., M.Inst.C.E., F.G.S. London County Council, Spring-gardens, S.W.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
1899. §Bird, F. J. Norton House, Midsomer Norton, Bath.
1880. ‡Bird, Henry, F.C.S. South Down House, Millbrook, near Devonport.
1888. *Birley, Miss Caroline. 14 Brunswick-gardens, Kensington, W.
1887. *Birley, H. K. Hospital, Chorley, Lancashire.
1871. *Bischof, Gustav. 19 Ladbroke-gardens, W.
1894. ‡Bisset, James. 5 East India-avenue, E.C.
1885. ‡Bissett, J. P. Wyndem, Banchory, N.B.

Year of Election.

1886. *Bixby, Major W. H. Engineer's Office, Cincinnati, Ohio, 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.*
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.
1883. ‡Blacklock, Mrs. Sea View, Lord-street, Southport.
1896. ‡Blackwood, J. M. 16 Oil-street, Liverpool.
1886. ‡Blaikie, John, F.L.S. The Bridge House, Newcastle, Staffordshire.
1895. ‡Blaikie, W. B. 6 Belgrave-crescent, Edinburgh.
1883. ‡Blair, Mrs. Oakshaw, Paisley.
1892. ‡Blair, Alexander. 35 Moray-place, Edinburgh.
1892. ‡Blair, John. 9 Ettrick-road, Edinburgh.
1883. *BLAKE, Rev. J. F., M.A., F.G.S. 69 Comeragh-road, W.
1846. *Blake, William. Bridge, South Petherton, Somerset.
1891. ‡BLAKESLEY, THOMAS H., M.A., M.Inst.C.E. Royal Naval College, Greenwich, S.E.
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, W.
1887. *Bles, A. J. S. Palm House, Park-lane, Higher Broughton, Manchester.
1887. *Bles, Edward J., B.Sc. Newnham Lea, Grange-road, 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, 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.
1859. ‡*Blunt, Captain Richard. Bretlands, Chertsey, Surrey.*
Blyth, B. Hall. 135 George-street, Edinburgh.
1885. ‡BLYTH, JAMES, M.A., F.R.S.E., Professor of Natural Philosophy in Anderson's College, Glasgow.
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, E.C.
1884. ‡Body, Rev. C. W. E., M.A. Trinity College, Toronto, Canada.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1898. §Bolton, H. The Museum, Queen's-road, Bristol.
1876. ‡Bolton, J. C. Carbrook, Stirling.
1898. §§Bolton, J. W. Baldwin-street, Bristol.
1894. §Bolton, John. 15 Clifton-road, Crouch End, N.
1898. §BONAR, J., M.A., LL.D. 1 Redington-road, Hampstead, N.W.

Year of Election.

1883.§§Bonney, Frederic, F.R.G.S. Colton House, Rugeley, Staffordshire.
1883. §Bonney, Miss S. 23 Denning-road, Hampstead, 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, N.W.
1898.§§Booby, Edward P. 2 Clifton-terrace, Torquay.
1888. ‡Boon, William. Coventry.
1893. ‡Boot, Jesse. Carlyle House, 18 Burns-street, Nottingham.
1890. *BOOTH, CHARLES, D.Sc., F.R.S., F.S.S. 2 Talbot-court, Gracechurch-street, E.C.
1883.§§Booth, James. Hazelhurst, Turton.
1883. ‡Booth, Richard. 4 Stone-buildings, Lincoln's Inn, W.C.
1876. ‡Booth, Rev. William H. Mount Nod-road, Streatham, 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. Castillo Zamora, Realejo-Alto, Tenerife.
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. Otterwood, Beaconsfield-road, Weston-super-Mare.
1887. ‡Bott, Dr. Owens College, Manchester.
1872. ‡Bottle, Alexander. 4 Godwyne-road, 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. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
1892. ‡Bottomley, W. B., B.A., Professor of Botany, King's College, W.C.
1876. ‡Bottomley, William, jun. 15 University-gardens, Glasgow.
1890. ‡Boulnois, Henry Percy, M.Inst.C.E. 44 Campden House Court, Kensington, W.
1883. ‡Bourdas, Isaiah. Dunoon House, Clapham Common, 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. Savile House, Mansfield-road, Oxford.
1889. ‡*Bourne, R. H. Fox.* 41 *Priory-road, Bedford Park, Chiswick.*
1866. §BOURNE, STEPHEN. 5 Lansdown-road, Lee, S.E.
1890. ‡Bousfield, C. E. 55 Clarendon-road, Leeds.
1884. ‡BOVEY, HENRY T., M.A., M.Inst.C.E., 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.R.S.E., F.L.S., Regius Professor of Botany in the University of Glasgow.
1898. *Bowker, Arthur Frank, F.R.G.S., F.G.S. Royal Societies Club, St. James's-street, S.W.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1898. §Bowley, A. L., M.A. St. John's School, Leatherhead.
1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1865. §Bowman, F. H., D.Sc., F.R.S.E. Mayfield, Knutsford, Cheshire.
1899. *Bowman, Herbert Lister, M.A. 13 Sheffield-gardens, Kensington, W

Year of Election.
1899. *Bowman, John Herbert. 13 Sheffield Gardens, Kensington, W.
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, S.W.
1892. §BOYS, CHARLES VERNON, F.R.S. 27 The Grove, Boltons, S.W.
1872. *BRABROOK, E. W., C.B., F.S.A. 178 Bedford-hill, Balham, 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.
1899. *Bradley, J. W., Assoc.M.Inst.C.E. Town Hall, Wolverhampton.
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., 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, S.E.*
1888. §Braikenridge, W. J., J.P. 16 Royal-crescent, Bath.
1898.§§Bramble, James R. Seafield, Weston-super-Mare.
1865. §BRAMWELL, Sir FREDERICK J., Bart., D.C.L., LL.D., F.R.S., M.Inst.C.E. 5 Great George-street, 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. Alton Lodge, Hale, Bowdon, Cheshire.
1890. *Bray, George. Belmont, Headingley, Leeds.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, W.C.
1877. ‡*Brent, Francis. 19 Clarendon-place, Plymouth.*
1898. §Brereton, Cuthbert A., M.Inst.C.E. 21 Delahay-street, S.W.
1882. *Bretherton, C. E. Goldsmith-buildings, Temple, E.C.
1866. ‡Brettell, Thomas. Dudley.
1891. ‡Brice, Arthur Montefiore, F.G.S., F.R.G.S. 159 Strand, W.C.
1886. §BRIDGE, T. W., M.A., D.Sc., Professor of Zoology in the Mason University 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, S.W.
1893.§§Briscoe, Albert E., B.Sc., A.R.C.Sc. Municipal Technical Institute, Romford-road, West Ham, E.
1884. ‡Brisette, M. H. 424 St. Paul-street, Montreal, Canada.
1898.§§BRISTOL, the Right Rev. G. F. BROWNE, Lord Bishop of, D.D. 17 The Avenue, Clifton, Bristol.
1879. *BRITTAIN, W. H., J.P., F.R.G.S. Alma Works, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, S.W.

Year of Election.

1884. *Brittle, John R., M.Inst.C.E., F.R.S.E. 9 Vanbrugh-hill, Blackheath, S.E.
1899. §Broadwood, Miss Bertha M. Pleystowe, Capel, Surrey.
1899. §Broadwood, James H. E. Pleystowe, Capel, Surrey.
1897. ‡Brock, W. R. Toronto.
1896. *Brocklehurst, S. Olinda, Sefton Park, Liverpool.
1859. ***Brodhurst, Bernard Edward**, F.R.C.S. 21 Portland-place, W.
1883. *Brodie, David, M.D. Care of Mrs. Johnson, Ventnor House, Canterbury.
1884. ‡Brodie, William, M.D. 64 Lafayette-avenue, Detroit, Michigan, U.S.A.
1883. *Brodie-Hall, Miss W. L. 5 Devonshire-place, Eastbourne.
1881. ‡Brook, Robert G. Wolverhampton House, St. Helens, Lancashire.
1864. *Brooke, Ven. Archdeacon J. Ingham. The Vicarage, Halifax.
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. Camera Club, Charing-cross-road, W.C.
1883. *Brotherton, E. A. Arthington Hall, Wharfedale, viâ Leeds.
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, Sir Charles Gage, M.D., K.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.
1883. *Brown, Mrs. H. Bienz. Fochabers, Morayshire.
1883. ‡Brown, Mrs. Helen. Canaan-grove, Newbattle-terrace, Edinburgh.
1870. §**Brown, Horace T.**, LL.D., F.R.S., F.G.S. 52 Nevern-square, 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, 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. Stockbridge House, Padisham, Lancashire.
1882. *Brown, John. 7 Second-avenue, Nottingham.
1895. *Brown, John Charles. 2 Baker-street, Nottingham.
1894. ‡Brown, J. H. 6 Cambridge-road, Brighton.
1882. *Brown, Mrs. Mary. Stockbridge House, Padisham, Lancashire.
1898. §Brown, Nicol, F.G.S. 4 The Grove, Highgate, N.

Year of Election.
1897. ‡Brown, Price, M.B. 37 Carlton-street, Toronto, Canada.
1886. §Brown, R., R.N. Laurel Bank, Barnhill, Perth.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-upon-Tyne.
1897. ‡Brown, Richard. Jarvis-street, Toronto, Canada.
1896. ‡Brown, Stewart H. Quarry Bank, Allerton, Liverpool.
1891. §BROWN, T. FORSTER, M.Inst.C.E., F.G.S. Guild Hall 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.
1863. ‡Browne, Sir Benjamin Chapman, M.Inst.C.E. Westacres, Newcastle-upon-Tyne.
1892. ‡Browne, Harold Crichton. Crindon, Dumfries.
1895. *Browne, H. T. Doughty. 10 Hyde Park-terrace, W.
1879. ‡BROWNE, Sir J. CRICHTON, M.D., LL.D., F.R.S., F.R.S.E. 61 Carlisle-place-mansions, Victoria-street, S.W.
1891. ‡BROWNE, MONTAGU, F.G.S. Town Museum, Leicester.
1862. *Browne, Robert Clayton, M.A. Browne's Hill, 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, 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. 11 Mount Pleasant, Joppa, Edinburgh.
1863. *Brunel, H. M., M.Inst.C.E. 21 Delahay-street, Westminster, S.W.
1863. ‡Brunel, I. 15 Devonshire-terrace, W.
1875. ‡Brunlees, John, M.Inst.C.E. 12 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, W.
1897. *Brush, Charles F. Cleveland, Ohio, U.S.A.
1878. §Brutton, Joseph Yeovil.
1886. *BRYAN, G. H D.Sc., F.R.S., Professor of Mathematics in University College, Bangor.
1894. ‡Bryan, Mrs. R. P. Plas Gwyn, Bangor.
1884. ‡BRYCE, Rev. Professor GEORGE. Winnipeg, Canada.
1897. ‡BRYCE, Right Hon. JAMES, D.C.L., M.P., F.R.S. 54 Portland-place, W.
1894. ‡Brydone, R. M. Petworth, Sussex.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1871. §BUCHAN, ALEXANDER, M.A., LL.D., F.R.S., 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, W.
1886. *Buckle, Edmund W. 23 Bedford-row, W.C.
1865. **Buckley, Henry. 18 Princes-street, Cavendish-square, W.*
1886. §Buckley, Samuel. Merlewood, Beaver Park, Didsbury.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, W.
1880. ‡Buckney, Thomas, F.R.A.S. 53 Gower-street, W.C.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.

Year of Election.
1887. ‡Budenberg, C. F., B.Sc. Buckau Villa, Demesne-road, Whalley Range, Manchester.
1875. ‡Budgett, Samuel. Penryn, Beckenham, Kent.
1883. ‡Buick, Rev. George R., M.A. Cullybackey, Co. Antrim, Ireland.
1893. §BULLEID, ARTHUR, F.S.A. Glastonbury.
1871. ‡Bulloch, Matthew. 48 Prince's-gate, S.W.
1883. ‡Bulpit, Rev. F. W. Crossens Rectory, Southport.
1895. ‡Bunte, Dr. Hans. Karlsruhe, Baden.
1886. §BURBURY, S. H., M.A., F.R.S. 1 New-square, Lincoln's Inn, W.C.
1842. *Burd, John. Glen Lodge, Knocknerea, Sligo.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, W.
1881. ‡Burdett-Coutts, W. L. A. B., M.P. 1 Stratton-street, Piccadilly, W.
1891. ‡Burge, Very Rev. T. A. Ampleforth Cottage, near York.
1894. ‡Burke, John. Trinity College, Cambridge.
1884. *Burland, Lieut.-Col. Jeffrey H. 824 Sherbrook-street, Montreal, Canada.
1899. §Burls, Herbert T. 206 Lewisham High-road, S.E.
1888. ‡Burne, H. Holland. 28 Marlborough-buildings, Bath.
1883. *Burne, Major-General Sir Owen Tudor, G.C.I.E., K.C.S.I., F.R.G.S. 132 Sutherland-gardens, Maida Vale, 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.
1899. §Burr, Malcolm. Dorman's Park, East Grinstead.
1887. ‡Burroughs, Eggleston, M.D. Snow Hill-buildings, 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, N.W.
1891. ‡Burt, J. J. 103 Roath-road, Cardiff.
1888. ‡Burt, John Mowlem. 3 St. John's-gardens, Kensington, W.
1888. ‡Burt, Mrs. 3 St. John's-gardens, Kensington, W.
1894. ‡Burton, Charles V. 24 Wimpole-street, W.
1866. *BURTON, FREDERICK M., F.L.S., F.G.S. Highfield, Gainsborough.
1889. ‡Burton, Rev. R. Lingen. Little Aston, Sutton Coldfield.
1897. ‡Burton, S. H., M.B. 50 St. Giles's-street, Norwich.
1892. ‡Burton-Brown, Colonel Alexander, R.A., F.R.A.S., F.G.S. St. George's Club, Hanover-square, W.
1897. ‡Burwash, Rev. N., LL.D., Principal of Victoria University, Toronto, Canada.
1887. *Bury, Henry. Trinity College, Cambridge.
1899. §Bush, Anthony. 43 Portland-road, Nottingham.
1895. §Bushe, Colonel C. K., F.G.S. 19 Cromwell-road, S.W.
1878. ‡BUTCHER, J. G., M.A. 22 Collingham-place, S.W.
1884. *Butcher, William Deane, M.R.C.S.Eng. Holyrood, 5 Cleveland-road, Ealing, W.
1884. ‡Butler, Matthew I. Napanee, Ontario, Canada.
1888. ‡Buttanshaw, Rev. John. 22 St. James's-square, Bath.
1884. *Butterworth, W. 3 Doop-street, Thomas-street, Shudehill, 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, S.W.
1872. ‡Buxton, Sir Thomas Fowell, Bart., G.C.M.G., F.R.G.S. Warlies, Waltham Abbey, Essex.

Year of Election.
1854. ‡BYERLEY, ISAAC, F.L.S. 22 Dingle-lane, Toxteth Park, Liverpool.
1899. §Byles, Arthur R. 'Bradford Observer,' Bradford, Yorkshire.
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.
1861. *Caird, James Key. 8 Roseangle, Dundee.
1886. **Caldwell, William Hay. Cambridge.*
1868. ‡Caley, A. J. Norwich.
1887. ‡CALLAWAY, CHARLES, M.A., D.Sc., F.G.S. 35 Huskisson-street, Liverpool.
1897. §CALLENDAR, Professor HUGH L., M.A., F.R.S. University College, Gower-street, W.C.
1892. ‡Calvert, A. F., F.R.G.S. Royston, Eton-avenue, N.W.
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., C.B., M.D. 15 Pembroke-road, Dublin
1896. §Cameron, Irving H. 307 Sherbourne-street, Toronto, Canada.
1884. ‡Cameron, James C., M.D. 41 Belmont-park, Montreal, Canada.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1884. ‡Campbell, Archibald H. Toronto, Canada.
1876. ‡Campbell, Right Hon. James A., LL.D., M.P. Stracathro House, Brechin.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1897. ‡Campbell, Major J. C. L. New Club, Edinburgh.
1898. §Campbell, Mrs. Napier. 81 Ashley-gardens, S.W.
1897. ‡Campion, B. W. Queen's College, Cambridge.
1882. ‡Candy, F. H. 71 High-street, Southampton.
1890. ‡CANNAN, EDWIN, M.A., F.S.S. 24 St. Giles's, Oxford.
1897. §Cannon, Herbert. Woodbank, Erith, Kent.
1898. ‡CANTERBURY, Right Hon. and Most Rev. F. TEMPLE, Lord Archbishop of. Lambeth Palace, S.E.
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, W.C.
1880. ‡Capper, Robert. 9 Bridge-street, Westminster, S.W.
1883. ‡Capper, Mrs. R. 9 Bridge-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, W.
1896. *Carden, H. V. Balinveney, Bookham, Surrey.
1877. ‡Carkeet, John. 3 St. Andrew's-place, Plymouth.
1898. §§Carlile, George M. 7 Upper Belgrave-road, Bristol.
1867. ‡Carmichael, David (Engineer). Dundee.
1897. §§Carmichael, Norman R. Queen's University, Kingston, Ontario, Canada.
1884. ‡Carnegie, John. Peterborough, Ontario, Canada.

Year of Election.

1884. ‡Carpenter, Louis G. Agricultural College, Fort Collins, Colorado, U.S.A.
1897. ‡Carpenter, R. C. Cornell University, Ithaca, New York, U.S.A.
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. 14 Vermont-road, Norwood, S.E.
1886. ‡CARSLAKE, J. BARHAM. 30 Westfield-road, Birmingham.
1899. §Carslaw, H. S. Emmanuel College, Cambridge.
1883. ‡Carson, John. 51 Royal-avenue, Belfast.
1868. *Carteighe, Michael, F.C.S., F.I.C. 180 New Bond-street, W.
1897. §Carter, E. Tremlett. Broadclyst, 53 Cloudesdale-road, S.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. 7 Fairfax-road, N.W.
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.
1862. ‡Carulla, F. J. R. 84 Argyll-terrace, Derby.
1894. ‡Carus, Paul. La Salle, Illinois, U.S.A.
1884. *Carver, Rev. Canon Alfred J., D.D., F.R.G.S. Lynnhurst, Streatham Common, 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.
1899. *Case, John Monckton. Dymchurch, Kent.
1897. *Case, Willard E. Auburn, New York, U.S.A.
1896. *Casey, James. 10 Philpot-lane, E.C.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 35 Commercial-street, Halifax.
1897. ‡Caston, Harry Edmonds Featherston. 340 Brunswick-avenue, Toronto, Canada.
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. Lancaster House, Palace-road, Tulse-hill, S.W.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1883. ‡Chadwick, James Percy. 51 Alexandra-road, 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, Assoc.M.Inst.C.E. Colába Observatory, Bombay.
*Champney, Henry Nelson. 4 New-street, York.
1881. *Champney, John E. Abchurch-chambers, E.C.
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.

Year of Election.

1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Hill End, Mottram, Manchester.
1897. ‡Chapman, Edward Henry. 17 St. Hilda's-terrace, Whitby.
1889. ‡Chapman, L. H. 147 Park-road, Newcastle-upon-Tyne.
1884. ‡Chapman, Professor. University College, Toronto, Canada.
1899. §Chapman, Sydney John. University College, Cardiff.
1877. ‡Chapman, T. Algernon, M.D. 17 Wesley-avenue, Liscard, Cheshire.
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, W.C.*
1886. ‡Chate, Robert W. Southfield, Edgbaston, Birmingham.
1884. *Chatterton, George, M.A., M.Inst.C.E. 6 The Sanctuary, Westminster, S.W.
1886. *Chattock, A. P., M.A., Professor of Experimental Physics in 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. 19 Portman-street, Portman-square, W.
1887. ‡Cheetham, F. W. Limefield House, Hyde.
1887. ‡Cheetham, John. Limefield House, Hyde.
1896. ‡Chenie, John. Charlotte-street, Edinburgh.
1874. *Chermside, Major-General Sir H. C., R.E., G.C.M.G., C.B. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, S.W.
1884. ‡Cherriman, Professor J. B. Ottawa, Canada.
1896. ‡Cherry, R. B. 92 Stephen's Green, Dublin.
1879. *Chesterman, W. Belmayne, Sheffield.
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, S.W.
1899. §Chitty, Edward. Suffolk House, London-road, Dover.
1899. §Chitty, Mrs. Edward. Suffolk House, London-road, Dover.
1899. §Chitty, G. W. Mildura, Park-avenue, Dover.
1882. ‡Chorley, George. Midhurst, Sussex.
1887. ‡Chorlton, J. Clayton. New Holme, Withington, Manchester.
1893. *CHREE, CHARLES, D.Sc., F.R.S., Superintendent of the Kew Observatory, Richmond, Surrey.
1884. *Christie, William. 29 Queen's Park, Toronto, Canada.
1875. *Christopher, George, F.C.S. May Villa, Lucien-road, Tooting Graveney, 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.S.A., Professor of Chemistry in the Royal Academy of Arts. Shelsley, Ennerdale-road, Kew.
1898. §CHURCH, Colonel G. EARL, F.R.G.S. 216 Cromwell-road, S.W.
1860. ‡CHURCH, WILLIAM SELBY, M.A. St. Bartholomew's Hospital, E.C.
1896. §Clague, Daniel, F.G.S. 5 Sandstone-road, Stoneycroft, Liverpool.
1890. ‡Clark, E. K. 13 Wellclose-place, Leeds.
1877. *Clark, F. J., J.P., F.L.S. Netherleigh, Street, Somerset.
Clark, George T. 44 Berkeley-square, W.

Year of Election.

1876. ‡Clark, George W. 31 Waterloo-street, Glasgow.
1892. ‡*Clark, James, M.A., Ph.D., Professor of Agriculture in the 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. 112 Wool Exchange, E.C.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1887. §Clarke, C. Goddard, J.P. Fairlawn, 157 Peckham-rye, 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.
1897. §Clarke, Colonel S. C., R.E. Parklands, Caversham, near Reading.
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, W.C.
1890. *Clayton, William Wikely. Gipton Lodge, Leeds.
1859. ‡Cleghorn, John. Wick.
1875. ‡*Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.*
1861.§§CLELAND, JOHN, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 The University, Glasgow.
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.
1898.§§Clissold, H. 30 College-road, Clifton, Bristol.
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. London County Council, Spring-gardens, S.W., and 17 Bedford Court-mansions, W.C.
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.
1897. ‡Coates, J., M.Inst.C.E. 99 Queen-street, Melbourne, Australia.
1884. §Cobb, John. Westfield, Ilkley, Yorkshire.
1895. *COBBOLD, FELIX T., M.A. The Lodge, Felixstowe, Suffolk.
1889. ‡Cochrane, Cecil A. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1864. *Cochrane, James Henry. Burston House, Pittville, Cheltenham.
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.
1898. §Coffey, George. 5 Harcourt-terrace, Dublin.
1881. *COFFIN, WALTER HARRIS, F.C.S. 94 Cornwall-gardens, South Kensington, S.W.
1896. *Coghill, Percy de G. Camster, Cressington.
1884. *Cohen, B. L., M.P. 30 Hyde Park-gardens, W.
1887. ‡Cohen, Julius B. Yorkshire College, Leeds.
1894. *Colby, Miss E. L., B.A. Carregwen, Aberystwyth.
1895. *Colby, James George Ernest, M.A., F.R.C.S. Malton, Yorkshire.
1895. *Colby, William Henry. Carregwen, Aberystwyth.

Year of Election.

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, S.W.
1897. §COLEMAN, Dr. A. P. 476 Huron-street, Toronto, Canada.
1893. ‡Coleman, J. B., F.C.S., A.R.C.S. University College, Nottingham.
1899. §Coleman, William. The Shrubbery, Buckland, Dover.
1878. ‡Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, W.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1899. §Collard, George. The Gables, Canterbury.
1892. ‡Collet, Miss Clara E. 7 Coleridge-road, N.
1892. ‡Collie, Alexander. Harlaw House, Inverurie.
1887. ‡COLLIE, J. NORMAN, Ph.D., F.R.S., Professor of Chemistry to the Pharmaceutical Society of Great Britain. 16 Campden-grove, W.
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, W.C.
1861. *Collingwood, J. Frederick, F.G.S. 5 Irene-road, Parson's Green, S.W.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876. ‡COLLINS, J. H., F.G.S. 162 Barry-road, S.E.
1892. ‡Colman, H. G. Mason College, Birmingham.
1882. ‡Colmer, Joseph G., C.M.G. Office of the High Commissioner for Canada, 17 Victoria-street, S.W.
1884. ‡Colomb, Sir J. C. R., M.P., F.R.G.S. Dromquinna, Kenmare, Kerry, Ireland; and Junior United Service Club, S.W.
1897. ‡Colquhoun, A. H. U., B.A. 39 Borden-street, Toronto, Canada.
1896. *Comber, Thomas, F.L.S. 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. 4 Queen's Elms, 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, W.
1899. §COODE, J. CHARLES, M.Inst.C.E. Westminster-chambers, 9 Victoria-street, S.W.
1898. §Cook, Ernest H. 27 Berkeley-square, Clifton, Bristol.
1882. ‡COOKE, Major-General A. C., R.E., C.B., F.R.G.S. Palace-chambers, Ryder-street, S.W.
1876. *COOKE, CONRAD W. 28 Victoria-street, S.W.
1881. ‡Cooke, F. Bishopshill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
1895. ‡*Cooke, Miss Janette E. Holmwood, Thorpe, 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.*

Year of Election.
1899. *Coomara Swamy, A. K. Walden Worplesdon, Guildford.
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, W.C._
1868. ‡Cooper, W. J. New Malden, Surrey.
1889. ‡Coote, Arthur. The Minories, Jesmond, Newcastle-upon-Tyne.
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.
1891. ‡Corbett, E. W. M. Y Fron, Pwllypant, Cardiff.
1887. *Corcoran, Bryan. 9 Alwyne-square, N.
1894. §Corcoran, Miss Jessie R. The Chestnuts, Mulgrave-road, Sutton, Surrey.
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, London. 19 Savile-row, W.
1893. *Corner, Samuel, B.A., B.Sc. 95 Forest-road West, Nottingham.
1889. ‡Cornish, Vaughan, M.Sc., F.R.G.S. Branksome Cliff, Branksome Park, Bournemouth.
1884. *Cornwallis, F. S. W., M.P., F.L.S. Linton Park, Maidstone.
1885. ‡Corry, John. Rosenheim, Parkhill-road, Croydon.
1888. ‡Corser, Rev. Richard K. 57 Park Hill-road, Croydon.
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, W.C.
1891. *_Cotsworth, Haldane Gwilt. G.W.R. Laboratory, Swindon, Wilts._
1874. *COTTERILL, J. H., M.A., F.R.S. 15 St. Alban's-mansions, Kensington Court-gardens, W.
1864. ‡COTTON, General FREDERICK C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, S.W.
1869. ‡_COTTON, WILLIAM. Pennsylvania, Exeter._
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1889. ‡_Courtney, F. S. 77 Redcliffe-square, South Kensington, 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. 17 King William-street, Strand, W.C.
1895. *COWELL, PHILIP H. Royal Observatory, Greenwich, S.E.
Cowie, The Very Rev. Benjamin Morgan, M.A., D.D., Dean of Exeter. The Deanery, Exeter.
1871. ‡_Cowper, C. E. 6 Great George-street, Westminster, S.W._
1899. §Cowper-Coles, Sherard. Grosvenor-mansions, Victoria-street, S.W.
1867. *Cox, Edward. Cardean, Meigle, N.B.
1867. *Cox, George Addison. Beechwood, Dundee.
1892. ‡Cox, Robert. 34 Drumsheugh-gardens, Edinburgh.

Year of Election.
1882. ‡Cox, Thomas A., District Engineer of the S., P., and D. Railway. Lahore, Punjab. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1888. ‡Cox, Thomas W. B. The Chestnuts, Lansdowne, Bath.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1883. ‡Crabtree, William. 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, N.W.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
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 AND BALCARRES, The Right Hon. the Earl of, K.T., LL.D., F.R.S., F.R.A.S. Dun Echt, Aberdeen.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Craiglockhart, Edinburgh.
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, N.
1870. *Crawshay, Mrs. Robert. Caversham Park, Reading.
1885. §CREAK, Captain E. W., R.N., F.R.S. 9 Hervey-road, Blackheath, S.E.
1896. ‡Cregeen, A. C. 21 Prince's-avenue, Liverpool.
1879. ‡Creswick, Nathaniel. Chantry Grange, near Sheffield.
1876. *Crewdson, Rev. Canon George. St. Mary's Vicarage, Windermere.
1887. *Crewdson, Theodore. Norcliffe Hall, Handforth, Manchester.
1896. §Crewe, W. Outram. Central Buildings, North John-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, W.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. ‡Croke, John O'Byrne, M.A. Clouneagh, Ballingarry-Lacy, co. Limerick.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1885. ‡*Crombie, Charles W. 41 Carden-place, Aberdeen.*
1885. ‡CROMBIE, J. W., M.A., M.P. Balgownie Lodge, Aberdeen.
1885. ‡Crombie, Theodore. 18 Albyn-place, Aberdeen.
1887. §CROOK, HENRY T. 9 Albert-square, Manchester.
1898. §Crooke, William. West Leigh, Arterberry-road, Wimbledon.
1865. §CROOKES, Sir WILLIAM, F.R.S., V.P.C.S. 7 Kensington Park-gardens, W.
1879. ‡Crookes, Lady. 7 Kensington Park-gardens, W.
1897. *CROOKSHANK, E. M., M.B., Professor of Bacteriology in King's College, London, W.C.
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.
1853. ‡Crosskill, William. Beverley, Yorkshire.
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1894. *Crosweller, William Thomas, F.Z.S., F.I.Inst. Kent Lodge, Sidcup, Kent.

Year of Election.
1897. *Crosweller, Mrs. W. T. 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.
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.
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.
1897. ‡Cumberland, Barlow. Toronto, Canada.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1898. §Cundall, J. Tudor. 1 Dean Park-crescent, Edinburgh.
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, W.
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.
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-Craig, E. H., B.A., F.G.S. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1892. *Currie, James, jun., M.A., F.R.S.E. Larkfield, Golden Acre, Edinburgh.
1884. ‡Currier, John McNab. Newport, Vermont, U.S.A.
1898.§§Curtis, John. 1 Christchurch-road, Clifton, Bristol.
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, S.W.

1889. ‡Dagger, John H., F.I.C. Victoria Villa, Lorne-street, Fairfield, Liverpool.
1854. ‡Daglish, Robert. Orrell Cottage, near Wigan.
1883. ‡Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1898. §Dalby, W. E. 6 Coleridge-road, Crouch End, N.
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., D.D., LL.D., F.R.S., F.L.S. Ingleside, Newstead-road, Lee, S.E.
Dalton, Edward, LL.D. Dunkirk House, Nailsworth.
1862. ‡DANBY, T. W., M.A., F.G.S. The Crouch, Seaford, Sussex.

Year of Election.

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, W.
1897. §§Darbishire, C. W. Elm Lodge, Elm-row, Hampstead, N.W.
1897. §Darbishire, F. V. Dorotheenstrasse 121, Dresden Strehlen, Germany.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A. 26 George-street, Manchester.
1896. ‡Darbishire, W. A. Penybryn, Carnarvon, North Wales.
1899. *Darwin, Erasmus. The Orchard, Huntingdon-road, Cambridge.
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. 12 Egerton-place, South Kensington, S.W.
1882. ‡Darwin, W. E., M.A., F.G.S. Bassett, Southampton.
1888. ‡Daubeny, William M. 11 St. James's-square, Bath.
1872. ‡Davenport, John T. 64 Marine-parade, Brighton.
1880. *DAVEY, HENRY, M.Inst.C.E., F.G.S. 3 Prince's-street, Westminster, S.W.
1898. §Davey, William John. 6 Water-street, Liverpool.
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.
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.
1896. *Davies, Thomas Wilberforce, F.G.S. 41 Park-place, Cardiff.
1893. *Davies, Rev. T. Witton, B.A., Ph.D. Midland Baptist College, Nottingham.
1898. §Davies, Wm. Howell, J.P. Down House, Stoke Bishop, Bristol.
1887. ‡Davies-Colley, T. C. Hopedene, Kersal, Manchester.
1873. *Davis, Alfred. 26 Victoria-street, S.W.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
1882. ‡Davis, Henry C. Berry Pomeroy, Springfield-road, Brighton.
1896. *Davis, John Henry Grant. Ingleside, Savile Park, Halifax, Yorkshire.
1885. *Davis, Rev. Rudolf. 1 Victoria-avenue, Evesham.
1891. ‡*Davis, W. 48 Richmond-road, Cardiff.*
1886. ‡Davis, W. H. Hazeldean, Pershore-road, Birmingham.
1886. ‡DAVISON, CHARLES, M.A. 16 Manor-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. The Lilacs, Prestatyn, 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.

Year of Election.

1897. §DAWSON, G. M., C.M.G., LL.D., F.R.S., Director of the Geological Survey of Canada. Ottawa, Canada.
1885. *Dawson, Lieut.-Colonel H. P., R.A. Hartlington, Burnsall, Skipton.
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, T. C, F.C.S. 36 Hillside-crescent, Edinburgh.
1870. *DEACON, G. F., M.Inst.C.E. 19 Warwick-square, 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, 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. 38 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. 2 Dr. Johnson's Buildings, Temple, E.C.
1896. §Dempster, John. Tynron, Noctorum, Birkenhead.
1889. ‡Dendy, Frederick Walter. 3 Mardale-parade, Gateshead.
1897. §Denison, F. Napier. Meteorological Office, Victoria, B.C., Canada.
1896. ‡Denison, Miss Louisa E. 16 Chesham-place, S.W.
1889. §DENNY, ALFRED, F.L.S., Professor of Biology in University College, Sheffield.
Dent, William Yerbury. 5 Caithness-road, Brook Green, 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. 76 Lancaster-gate, W.
1894. *Deverell, F. H. 7 Grote's-place, Blackheath, S.E.
1899. §Dewar, A. Redcote. Redcote, Leven, Fife.
1868. ‡DEWAR, JAMES, M.A., LL.D., F.R.S., F.R.S.E., V.P.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, 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'Henry, P. 136 Prince's-road, Liverpool.
1897. ‡Dick, D. B. Toronto, Canada.
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. 2 Starkie-street, Preston.
1887. §DICKSON, H. N., F.R.S.E., F.R.G.S. 2 St. Margaret's-road, Oxford.

Year of Election.

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, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1898. *Dix, John William S. Hampton Lodge, Durdham Park, Clifton, Bristol.
1899 *Dixon, A. C., D.Sc., Professor of Mathematics in Queen's College, Galway.
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, S.W.
1879. *DIXON, HAROLD B., M.A., F.R.S., F.C.S., Professor of Chemistry in the Owens College, 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, Ph.D. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. Hartley Manor, Longfield, Kent.
1897. ‡Doberck, William. The Observatory, Hong Kong.
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, N.W.*
1875. *Docwra, George. Liberal Offices, Cinderford, Glos.
1870. *Dodd, John. Nunthorpe-avenue, York.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.
1897.§§Dodge, Richard E. Teachers' College, Columbia University, New York, U.S.A.
1889. ‡Dodson, George, B.A. Downing College, Cambridge.
1898.§§Dole, James. Redland House, Bristol.
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.
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. 59 Onslow-gardens, S.W.
1881. ‡Dorrington, John Edward. Lypiatt Park, Stroud.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1863. *Doughty, Charles Montagu. Illawara House, Tunbridge Wells.
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.*

Year of
Election.
1884. *Dowling, D. J. Bromley, Kent.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, J. Emerson, M.Inst.C.E. 91 Cheyne-walk, 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, 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.
1893. §DRUCE, G. CLARIDGE, M.A., F.L.S. 118 High-street, Oxford.
1889. ‡Drummond, Dr. 6 Saville-place, Newcastle-upon-Tyne.
1897 §§Drynan, Miss. Northwold, Queen's Park, Toronto, Canada.
1892. ‡Du Bois, Dr. H. Mittelstrasse, 39, Berlin.
1889. ‡Du Chaillu, Paul B. Care of John Murray, Esq., 50A Albemarle-street, W.
1856. *DUCIE, The Right. Hon. HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, W.; and Tortworth Court, Falfield, Gloucestershire.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Christchurch Vicarage, Chester.
1895. *Duddell, William. 47 Hans-place, S.W.
1867. *DUFF, The Right Hon. Sir MOUNTSTUART ELPHINSTONE GRANT-, G.C.S.I., F.R.S., F.R.G.S. 11 Chelsea-embankment, S.W.
1852. ‡DUFFERIN AND AVA, The Most Hon. the Marquis of, K.P., G.C.B., G.C.M.G., G.C.S.I., D.C.L., LL.D., F.R.S., F.R.G.S. Clandeboye, near Belfast, Ireland.
1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange. Waterford.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1884. ‡Dugdale, James H. 9 Hyde Park-gardens, W.
1883. ‡Duke, Frederic. Conservative Club, Hastings.
1892. ‡Dulier, Colonel E., C.B. 27 Sloane-gardens, S.W.
1866. *Duncan, James. 9 Mincing-lane, E.C.
1891. *Duncan, John, J.P. 'South Wales Daily News' Office, Cardiff.
1880. ‡*Duncan, William S. 143 Queen's-road, Bayswater, W.*
1896. ‡Duncanson, Thomas. 16 Deane-road, Liverpool.
1881. ‡Duncombe, The Hon. Cecil, F.G.S. Nawton Grange, York.
1893. *Dunell, George Robert. 7 Spencer-road, Grove Park, Chiswick, Middlesex.
1892. ‡Dunham, Miss Helen Bliss. Messrs. Morton, Rose, & Co., Bartholomew House, E.C.
1881. ‡Dunhill, Charles H. Gray's-court, York.
1896. *DUNKERLEY, S., M.Sc., Professor of Applied Mechanics in the Royal Naval College, Greenwich, S.E.
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.

Year of
Election.
1885. *DUNSTAN, WYNDHAM R., M.A., F.R.S., Sec.C.S., Director of the Scientific Department of the Imperial Institute, S.W.
1869. ‡D'Urban, W. S. M., F.L.S. Newport House, near Exeter.
1898. §Durrant, R. G. Marlborough College, Wilts.
1895. *Dwerryhouse, Arthur R. 5 Oakfield-terrace, Headingley, Leeds.
1887. ‡Dyason, John Sanford. Cuthbert-street, 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, Thos. S., F.C.S. County Technical Laboratory, Chelmsford.

1868. ‡Eade, Sir Peter, M.D. Upper St. Giles's-street, Norwich.
1895. ‡Earle, Hardman A. 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.
1899. §East, W. H. Municipal School of Art, Science, and Technology, Dover.
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.
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. The Lodge, Adel, Leeds.
1899. §Eddowes, Alfred, M.D. 28 Wimpole-Street, W.
*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.
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 Clement's Inn, W.C.
1883. ‡Edmonds, William. Wiscombe Park, Colyton, Devon.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, S.W.
1884. *Edmunds, James, M.D. 26 Manchester-square, W.
1883. ‡Edmunds, Lewis, D.Sc., LL.B., F.G.S. 1 Garden-court, Temple, E.C.
1867. *Edward, Allan. Farington Hall, Dundee.
1899. §Edwards, E. J. 139 Leander-road, Brixton Hill, S.W.
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, E.C.
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.
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.

Year of Election.

Elliott, John Fogg. Elvet Hill, Durham.
1886. ‡ELLIOT, THOMAS HENRY, C.B., F.S.S. Board of Agriculture, 4 Whitehall-place, S.W.
1898. §Elliott, W. J. 14 Buckingham-place, Clifton, Bristol.
1877. ‡*Ellis, Arthur Devonshire. Thurnscoe Hall, Rotherham, Yorkshire.*
1875. *Ellis, H. D. 12 Gloucester-terrace, Hyde Park, W.
1880. *ELLIS, JOHN HENRY. Woodhaye, Ivy Bridge, Devon.
1891. §Ellis, Miss M. A. 11 Canterbury-road, Oxford.
1884. ‡Ellis, Professor W. Hodgson, M.A., M.B. 74 St. Alban's-street, 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, W.C.
1899. *Elvery, Miss Amelia. The Cedars, Maison Dieu-road, Dover.
1897. §Elvery, Mrs. Elizabeth. The Cedars, Maison Dieu-road, Dover.
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.
1897. §Ely, Robert E. 744 Massachusetts-avenue, Cambridge, Massachusetts, U.S.A.
1863. ‡Embleton, Dennis, M.D. 19 Claremont-place, Newcastle-upon-Tyne.
1891. ‡Emerton, Wolseley, D.C.L. Banwell Castle, Somerset.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1890. ‡*Emsley, Alderman W. Richmond House, Richmond-road, Headingley, Leeds.*
1894. ‡Emtage, W. T. A. University College, Nottingham.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
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. 46 Great King-street, Edinburgh.*
1864. *Eskrigge, R. A., F.G.S. 18 Hackins Hey, Liverpool.
1862. *ESSON, WILLIAM, M.A., F.R.S., F.R.A.S., Savilian Professor of Geometry in the University of Oxford. 13 Bradmore-road, Oxford.
1878. ‡Estcourt, Charles. 8 St. James's-square, John Dalton-street, Manchester.
1887. *Estcourt, Charles. Hayesleigh, Montague-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.
1889. *Evans, A. H. 9 Harvey-road, Cambridge.
1881. ‡Evans, Alfred, M.A., M.B. Pontypridd.
1887. *Evans, Mrs. Alfred W. A. Lyndhurst, Upper Chorlton-road, Whalley Range, Manchester.
1870. *EVANS, ARTHUR JOHN, M.A., F.S.A. Youlbury, Abingdon.
1865. *EVANS, Rev. CHARLES, M.A. 41 Lancaster-gate, W.
1896. §Evans, Edward, jun. Spital Old Hall, Bromborough, Cheshire.
1891. ‡Evans, Franklen. Llwynarthen, Castleton, Cardiff.
1889. ‡Evans, Henry Jones. Greenhill, Whitchurch, Cardiff.

Year of
Election.
1883. *Evans, James C. 175 Lord-street, Southport.
1883. *Evans, Mrs. James C. 175 Lord-street, Southport.
1861. *EVANS, Sir JOHN, K.C.B., D.C.L., LL.D., D.Sc., F.R.S., F.S.A., F.L.S., F.G.S. Nash Mills, Hemel Hempstead.
1897. *Evans, Lady. Nash Mills, Hemel Hempstead.
1898. §§Evans, Jonathan L. 4 Litfield-place, Clifton, Bristol.
1881. ‡Evans, Lewis. Llanfyrnach, R.S.O., Pembrokeshire.
1885. *Evans, Percy Bagnall. The Spring, Kenilworth.
1865. ‡EVANS, SEBASTIAN, M.A., LL.D. 15 Waterloo-crescent, Dover.
1899. §Evans, Mrs. 15 Waterloo-crescent, Dover.
1875. ‡*Evans, Sparke. 3 Apsley-road, Clifton, Bristol.*
1865. *Evans, William. The Spring, Kenilworth.
1891. ‡*Evans, William Llewellin. Guildhall-chambers, Cardiff.*
1891. ‡Evan-Thomas, C., J.P. The Gnoll, Neath, Glamorganshire.
1886. ‡Eve, A. S. Marlborough College, Wilts.
1871. ‡Eve, H. Weston, M.A. University College, W.C.
1868. *EVERETT, J. D., M.A., D.C.L., F.R.S., F.R.S.E. 22 Earl's Court-square, S.W.
1895. §§Everett, W. H., B.A. University College, Nottingham.
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 Mechanics in the University of Cambridge. Langdale Lodge, 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.

1890. ‡FABER, EDMUND BECKETT. Straylea, Harrogate.
1896. §Fairbrother, Thomas. 46 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.*
1898. §Faraday, Miss Ethel R., M.A. Ramsay Lodge, Levenshulme, near Manchester.
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, Exhibition-road, S.W.
1886. ‡Farncombe, Joseph, J.P. Saltwood, Spencer-road, Eastbourne.
1897. *Farnworth, Ernest. Rosslyn, Goldthorn Hill, Wolverhampton.
1897. *Farnworth, Mrs. 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 Sir J., K.C.B., R.E. Corrachee, Tarland, Aberdeen.
1859. ‡Farquharson, Robert F. O. Haughton, Aberdeen.

Year of Election.

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.
1897. ‡Farthing, Rev. J. C., M.A. The Rectory, Woodstock, Ontario, Canada.
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.
1900. §FAWCETT, J. E. (LOCAL SECRETARY). Bradford.
1886. §Felkin, Robert W., M.D., F.R.G.S. 6 Crouch Hall-road, N.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.
1883. ‡Fenwick, E. H. 29 Harley-street, 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. Clarence House, Promenade, 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, W.
1892. ‡Ferrier, Robert M., B.Sc. College of Science, Newcastle-upon-Tyne.
1897. ‡Ferrier, W. F. Geological Survey, Ottawa, Canada.
1897.§§Fessenden, Reginald A. Professor of Electrical Engineering, University, Alleghany, Pennsylvania, U.S.A.
1882. §Fewings, James, B.A., B.Sc. King Edward VI. 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.
1897.§§Field, George Wilton, Ph.D. Experimental Station, Kingston, Rhode Island, U.S.A.
1886. ‡Field, H. C. 4 Carpenter-road, Edgbaston, Birmingham.
1869. *FIELD, ROGERS, B.A., M.Inst.C.E. 7 Victoria-street, Westminster, S.W.
1882. ‡Filliter, Freeland. St. Martin's House, Wareham, Dorset.
1883. *Finch, Gerard B., M.A. 1 St. Peter's-terrace, Cambridge.
1878. *Findlater, Sir William. 22 Fitzwilliam-square, Dublin.
1884. ‡Finlay, Samuel. Montreal, Canada.
1887. ‡Finnemore, Rev. J., M.A., Ph.D., F.G.S. 88 Upper Hanover-street, Sheffield.
1881. ‡Firth, Colonel Sir Charles. Heckmondwike.
Firth, Thomas. Northwich.
1895. §Fish, Frederick J. Spursholt, 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.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.

Year o
Election.

1887. *Fison, Alfred H., D.Sc. 25 Blenheim-gardens, Willesden Green, 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, 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. Nile Reservoir, Assuan, Egypt.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Bagot-street, Dublin.
1888. *Fitzpatrick, Rev. Thomas C. Christ's College, Cambridge.
1897. ‡Flavelle, J. W. 565 Jarvis-street, Toronto, Canada.
1881. ‡Fleming, Rev. Canon J., B.D. St. Michael's Vicarage, Ebury-square, S.W.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, Glasgow.
1876. ‡Fleming, Sir Sandford, K.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, S.W.
1892. ‡Fletcher, George, F.G.S. 60 Connaught-avenue, Plymouth.
1888. *Fletcher, Lazarus, M.A., F.R.S., F.G.S., F.C.S., Keeper of Minerals, British Museum (Natural History), Cromwell-road, S.W. 36 Woodville-road, Ealing, W.
1889. ‡Flower, Lady. 26 Stanhope-gardens, S.W.
1877. *Floyer, Ernest A. Downton, Salisbury.
1890. *Flux, A. W., M.A., Professor of Political Economy in the 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, E.C.
1873. *Forbes, George, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 34 Great George-street, S.W.
1883. ‡Forbes, Henry O., LL.D., F.Z.S., Director of Museums for the Corporation of Liverpool. The Museum, Liverpool.
1897. ‡Forbes, J., Q.C. Hazeldean, Putney-hill, S.W.
1885. ‡Forbes, The Right Hon. Lord. Castle Forbes, Aberdeenshire.
1890. ‡Ford, J. Rawlinson. Quarry Dene, Weetwood-lane, Leeds.
1875. *Fordham, H. George. Odsey, Ashwell, Baldock, Herts.
1894. ‡Forrest, Frederick. Beechwood, Castle Hill, Hastings.
1887. ‡Forrest, The Right Hon. Sir John, K.C.M.G., F.R.G.S., F.G.S. Perth, Western Australia.
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, 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.

Year of Election.

1883. ‡Foster, Mrs. C. Le Neve. Llandudno.

1857. *FOSTER, GEORGE CAREY, B.A., F.R.S., F.C.S. (GENERAL TREASURER.) Ladywalk, Rickmansworth.

1896. ‡Foster, Miss Harriet. Cambridge Training College, Wollaston-road, Cambridge.

1877. §Foster, Joseph B. 4 Cambridge-street, Plymouth.

1859. *FOSTER, Sir MICHAEL, K.C.B., M.A., M.D., LL.D., D.C.L., Sec.R.S., F.L.S., Professor of Physiology in the University of Cambridge. (PRESIDENT.) 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.

1892. ‡Fowler, Miss Jessie A. 4 & 5 Imperial-buildings, Ludgate-circus, E.C.

1883. *Fox, Charles. The Chestnuts, Warlingham, Surrey.

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. Rosehill, Falmouth.

1847. *Fox, Joseph Hoyland. The Clive, Wellington, Somerset.

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.

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.

1887. *FRANKLAND, PERCY F., Ph.D., B.Sc., F.R.S., Professor of Chemistry in the Mason College, Birmingham.

1894. §Franklin, Mrs. E. L. 50 Porchester-terrace, W.

1895. *Fraser, Alexander. 63 Church-street, Inverness.

1882. *Fraser, Alexander, M.B. Professor of Anatomy in the 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.

1897. ‡Fraser, Sir Malcolm, K.C.M.G. 15 Victoria-street, S.W.

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. 4 Lower Sloane-street, 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, W.

1887. ‡Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.

1887. ‡Froehlich, The Cavaliere. Grosvenor-terrace, Withington, Manchester.

1892. *Frost, Edmund, M.B. Chesterfield, Meads, Eastbourne.

1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.

Year of
Election.

1887. *Frost, Robert, B.Sc. 53 Victoria-road, W.
1899. §Fry, Edward W. Cannon-street, Dover.
1898. ‡FRY, The Right Hon. Sir EDWARD, D.C.L., LL.D., F.R.S., F.S.A. Failand House, Failand, near Bristol.
1898. §§Fry, Francis J. Leigh Woods, Clifton, Bristol.
1875. *Fry, Joseph Storrs. 17 Upper Belgrave-road, Clifton, Bristol.
1898. §§Fryer, Alfred C., Ph.D. 13 Eaton-crescent, 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, 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.
1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1896. ‡Gair, H. W. 21 Water-street, Liverpool.
1850. ‡GAIRDNER, Sir W. T., K.C.B., 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.
1885. *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
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, FRANCIS, M.A., D.C.L., D.Sc., F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. New University Club, St. James's-street, S.W.
1899. §Galton, Lady Douglas. Himbleton Manor, Droitwich.
1870. §Gamble, Lieut.-Colonel Sir D., Bart., C.B. St. Helens, Lancashire.
1889. ‡Gamble, David. Ratonagh, Colwyn Bay.
1870. ‡Gamble, J. C. St. Helens, Lancashire.
1888. *Gamble, J. Sykes, C.I.E., F.R.S., M.A., F.L.S. Highfield, East Liss, Hants.
1877. ‡Gamble, William. St. Helens, Lancashire.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S. 8 Avenue du Kursaal, Montreux, Switzerland.
1899. *Garcke, E. Sunnyside, Bedford Park, W.
1889. ‡Gamgee, John. 6 Lingfield-road, Wimbledon, Surrey.
1898. §Garde, Rev. C. L. Skenfrith Vicarage, near Monmouth.
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 Groves, Grassendale, Liverpool.
1882. ‡GARDNER, JOHN STARKIE. 29 Albert Embankment, S.E.
1884. ‡Garman, Samuel. Cambridge, Massachusetts, U.S.A.
1887. *Garnett, Jeremiah. The Grange, Bromley Cross, near Bolton, Lancashire.

Year of Election.
1882. ‡Garnett, William, D.C.L. London County Council, Spring-gardens, S.W.
1873. ‡Garnham, John. Hazelwood, Crescent-road, St. John's, Brockley, Kent, S.E.
1883. ‡GARSON, J. G., M.D. 64 Harley-street, W.
1894. *GARSTANG, WALTER, M.A., F.Z.S. Marine Biological Laboratory, Plymouth.
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, N.W.
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. Kilmorie, Colinton-road, Edinburgh.
1898. §Gemmill, James F., M.A., M.B. 16 Dargavel-avenue, Dumbreck, Glasgow.
1882. *GENESE, R. W., M.A., Professor of Mathematics in University College, Aberystwyth.
1875. *George, Rev. Hereford B., M.A., F.R.G.S. Holywell Lodge, 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, S.W.
1887. ‡GIFFEN, Sir ROBERT, K.C.B., LL.D., F.R.S., V.P.S.S. Athenæum Club, S.W.
1888. **Gifford, H. J. Lyston Court, Tram Inn, Hereford.*
1898. *Gifford, J. William. Chard.
1884. ‡Gilbert, E. E. 245 St. Antoine-street, Montreal, Canada.

Year of Election.

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., F.R.S., M.Inst.C.E. Frognal Bank, Finchley-road, Hampstead, N.W.

1878. ‡Giles, Oliver. Brynteg, The Crescent, Bromsgrove.

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.

1884. ‡Gillman, Henry. 130 Lafayette-avenue, Detroit, Michigan, U.S.A.

1896. ‡Gilmour, H. B. Underlea, Aigburth, Liverpool.

1892. *Gilmour, Matthew A. B., F.Z.S. Saffronhall House, Windmill-road, Hamilton, N.B.

1867. ‡Gilroy, Robert. Craigie, by Dundee.

1893. *Gimingham, Edward. Stamford House, Northumberland Park, Tottenham.

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, M.Can.S.C.E. Winnipeg, Manitoba, Canada.

1850. *Gladstone, George, F.R.G.S. 34 Denmark-villas, Hove, Brighton.

1849. *Gladstone, John Hall, Ph.D., D.Sc., F.R.S., F.C.S. 17 Pembridge-square, W.

1883. *Gladstone, Miss. 17 Pembridge-square, 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.

1897. ‡Glashan, J. C., LL.D. Ottawa, Canada.

1883. ‡Glasson, L. T. 2 Roper-street, Penrith.

1881. *Glazebrook, R. T., M.A., F.R.S., Director of the National Physical Laboratory, Kew Observatory, Richmond.

1881. *Gleadow, Frederic. 38 Ladbroke-grove, 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. Corby, Hoylake.

Glover, Thomas. 124 Manchester-road, Southport.

1870. ‡Glynn, Thomas R., M.D. 62 Rodney-street, Liverpool.

1872. ‡Goddard, Richard. 16 Booth-street, Bradford, Yorkshire.

1899. §Godfrey, Ingram F. Brook House, Ash, Dover.

1886. ‡Godlee, Arthur. The Lea, Harborne, Birmingham.

1887. ‡Godlee, Francis. 8 Minshall-street, Manchester.

1878. *Godlee, J. Lister. 3 Clarence-terrace, Regent's Park, N.W.

1880. ‡Godman, F. Du Cane, D.C.L., F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, 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.

1898. §Goldney, F. B. Goodnestone-park, Dover.

1881. ‡Goldschmidt, Edward, J.P. Nottingham.

1886. ‡Goldsmid, Major-General Sir F. J., K.C.S.I., C.B., F.R.G.S. Godfrey House, Hollingbourne.

Year of Election.

1899. §Gomme, G. L. 24 Dorset-square, N.W.
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.
1885. ‡GOODMAN, J. D., J.P. Peachfield, Edgbaston, Birmingham.
1884. *Goodridge, Richard E. W. 54 South Canal Street, Chicago, Illinois, U.S.A.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
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.
1893. ‡Gordon, Mrs. M. M., D.Sc. 1 Rubislaw-terrace, Aberdeen.
1884. *Gordon, Robert, M.Inst.C.E., F.R.G.S. 70 South-street, St. Andrews, N.B.
1885. ‡Gordon, Rev. William. Braemar, N.B.
1899. §Gordon, T. Kirkman. 15 Hampden-road, Nottingham.
1887. ‡*Gordon, William John. 3 Lavender-gardens, S.W.*
1865. ‡GORE, GEORGE, LL.D., F.R.S. 20 Easy-row, Birmingham.
1875. *GOTCH, FRANCIS, M.A., B.Sc., F.R.S., Professor of Physiology in the University of Oxford, The Lawn, Banbury-road, Oxford.
1873. ‡Gott, Charles, M.Inst.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1881. ‡Gough, Rev. Thomas, B.Sc. King Edward's School, Retford.
1894. ‡Gould, G. M., M.D. 119 South 17th-street, Philadelphia, U.S.A.
1888. ‡Gouraud, Colonel. Little Menlo, Norwood, S.E.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. ‡Gow, Robert. Cairndowan, Dowanhill Gardens, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill Gardens, 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, Professor F. S., M.A., D.Litt. 2 Cranmer-street, Nottingham.
1896. ‡Grant, Sir James, K.C.M.G. Ottawa, Canada.
1892. ‡Grant, W. B. 10 Ann-street, Edinburgh.
1864. ‡Grantham, Richard F., M.Inst.C.E., F.G.S. Northumberland-chambers, Northumberland-avenue, W.C.
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1899. §Gray, Albert Alexander. 16 Berkeley-terrace, Glasgow.
1890. ‡GRAY, ANDREW, M.A., LL.D., F.R.S., F.R.S.E., Professor of Natural Philosophy in the University of Glasgow.
1899. §Gray, Charles. 11 Portland-place, W.
1864. *Gray, Rev. Canon Charles. West Retford Rectory, Retford.
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 Hunter, M.A., B.Sc. 3 Crown Office-row, Temple, E.C.

Year of Election.
1892. §Gray, John, B.Sc. 351 Coldharbour-lane, Brixton, S.W.
1887. ‡Gray, Joseph W., F.G.S. St. Elmo, Leckhampton-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. Glenburn Park, Belfast.
*GRAY, Colonel WILLIAM. Farley Hall, near Reading.
1883. ‡Gray, William Lewis. Westmoor Hall, Brimsdown, Middlesex.
1883. ‡Gray, Mrs. W. L. Westmoor Hall, Brimsdown, Middlesex.
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, N.W.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1888. §GREEN, J. REYNOLDS, M.A., D.Sc., F.R.S., F.L.S., Professor of Botany to the Pharmaceutical Society of Great Britain. Arncliffe, Grange-road, Cambridge.
1887. ‡*Greene, Friese. 162 Sloane-street, S.W.*
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, N.W.
1898. *Greenly, Edward. Achnashean, near Bangor, North Wales.
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.
1894. *GREGORY, J. WALTER, D.Sc., F.G.S. 3 Aubrey-road, Kensington, W.
1896. §Gregory, R. A. The Homestead, Westover-road, Wandsworth Common, S.W.
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.
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
1836. Griffin, S. F. Albion Tin Works, York-road, N.
1894. *Griffith, C. L. T. College-road, Harrow, Middlesex.
1859. *GRIFFITH, G. (ASSISTANT GENERAL SECRETARY.) College-road, Harrow, 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, M.Inst.C.E. Australian Club, Sydney, New South Wales.
1884. ‡Grinnell, Frederick. Providence, Rhode Island, U.S.A.

Year of Election.

1894. ‡Groom, P., M.A., F.L.S. 38 Regent-street, Oxford.
1894. ‡Groom, T. T., D.Sc. 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. Broadley, Westerhall-road, Weymouth.
1869. ‡GRUBB, Sir HOWARD, F.R.S., F.R.A.S. 51 Kenilworth-square, Rathgar, Dublin.
1897. ‡Grünbaum, A. S., M.A., M.D. 45 Ladbroke-grove, W.
1897. §Grünbaum, O. F. F., B.A., D.Sc. Trinity College, Cambridge.
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.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1891. ‡Gunn, Sir 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. 22 Lichfield-road, Kew, Surrey.
1894. ‡Günther, R. T. Magdalen College, Oxford.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
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.
1884. ‡Hadden, Captain C. F., R.A. Woolwich.
1881. *HADDON, ALFRED CORT, M.A., F.R.S., F.Z.S. Inisfail, Hills-road, Cambridge.
1842. Hadfield, George. Victoria Park, Manchester.
1888. *Hadfield, R. A., M.Inst.C.E. The Grove, Endcliffe Vale-road, Sheffield.
1892. ‡Haigh, E., M.A. Longton, Staffordshire.
1870. ‡Haigh, George. 27 Highfield South, Rockferry, Cheshire.
1879. ‡HAKE, H. WILSON, Ph.D., F.C.S. Queenwood College, Hants.
1883. ‡HALIBURTON, R. G., Q.C. 13 Pall Mall, S.W.
1899. §Hall, A. D. South-Eastern Agricultural College, Wye, Kent.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1881. ‡Hall, Frederick Thomas, F.R.A.S. 15 Gray's Inn-square, W.C.
1854. *HALL, HUGH FERGIE, F.G.S. Cowley House, Headington Hill, Oxford.
1898. §Hall, J. P. The 'Tribune,' New York, U.S.A.
1887. ‡*Hall, John. Springbank, Leftwich, Northwich.*
1899. §Hall, John, M.D. National Bank of Scotland, 37 Nicholas-lane, E.C.
1885. §Hall, Samuel, F.I.C., F.C.S. 19 Aberdeen-park, Highbury, N.
1896. §Hall, Thomas B. Larch Wood, Rockferry, Cheshire.
1884. ‡Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1896. ‡Hall-Dare, Mrs. Caroline. 13 Great Cumberland-place, 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. Church Cottage, 17 Marylebone-road, W.

Year of Election.

Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. Fairley, Weston, Bath.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1885. ‡Hamilton, David James. 41 Queen's-road, Aberdeen.
1899. §Hamilton, G. E. H. Barrett. Kilmarnock, Arthurstown, Ireland.
1881. *Hammond, Robert. 64 Victoria-street, Westminster, S.W.
1899. *Hanbury, Daniel. La Mortola, Ventimiglia, Italy.
1892. ‡Hanbury, Thomas, F.L.S. La Mortola, Ventimiglia, Italy.
1878. §Hance, Edward M., LL.B. Municipal Offices, Liverpool.
1875. ‡Hancock, C. F., M.A. 125 Queen's-gate, S.W.
1897.§§HANCOCK, HARRIS. University of Chicago, U.S.A.
1861. ‡Hancock, Walter. 10 Upper Chadwell-street, Pentonville, E.C.
1890. ‡Hankin, Ernest Hanbury. St. John's College, Cambridge.
1882. ‡Hankinson, R. C. Bassett, Southampton.
1884. ‡Hannaford, E. P., M.Inst.C.E. 2573 St. Catherine-street, Montreal, Canada.
1894. §Hannah, Robert, F.G.S. 82 Addison-road, W.
1886. §Hansford, Charles, J.P. Englefield House, Dorchester.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., F.R.S., F.C.S. Cowley Grange, Oxford.
1890. *HARCOURT, L. F. VERNON, M.A., M.Inst.C.E. 6 Queen Anne's-gate, S.W.
1886. *Hardcastle, Basil W., F.S.S. 12 Gainsborough-gardens, Hampstead, N.W.
1892. *Harden, Arthur, Ph.D., M.Sc. 20 Kensington-crescent, W.
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.
1897. ‡HARDY, Hon. ARTHUR S., Premier of the Province of Ontario. Toronto, Canada.
1894. ‡Hare, A. T., M.A. Neston Lodge, East Twickenham, Middlesex.
1894. ‡Hare, Mrs. Neston Lodge, East Twickenham, Middlesex.
1898.§§Harford, W. H. Oldown House, Almondsbury.
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. 1 St. Mary's-road, Canonbury, N.
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.
1883. *Harley, Miss Clara. Rosslyn, Westbourne-road, Forest Hill, S.E.
1883. *Harley, Harold. 14 Chapel-street, Bedford-row, W.C.
1862. *HARLEY, Rev. ROBERT, M.A., F.R.S., F.R.A.S. Rosslyn, Westbourne-road, Forest Hill, S.E.
1899. §Harman, Dr. N. Bishop. St. John's College, Cambridge.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *HARMER, SIDNEY F., M.A., B.Sc., F.R.S. King's College, Cambridge.

Year of Election.
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. University-street, Montreal, Canada.
1872. *Harris, Alfred. Lunefield, Kirkby Lonsdale, Westmoreland.
1888. ‡Harris, C. T. 4 Kilburn Priory, N.W.
1842. *Harris, G. W., M.Inst.C.E. Millicent, South Australia.
1889. §HARRIS, H. GRAHAM, M.Inst.C.E. 5 Great George-street, Westminster, S.W.
1898.§§Harrison, A. J., M.D. Failand Lodge, Guthrie-road, Clifton, Bristol.
1888. ‡Harrison, Charles. 20 Lennox-gardens, S.W.
1860. ‡Harrison, Rev. Francis, M.A. North Wraxall, Chippenham.
1864. ‡*Harrison, George. Barnsley, Yorkshire.*
1858. *HARRISON, J. PARK, M.A. 22 Connaught-street, Hyde Park, 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, W.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1892. ‡Harrison, Rev. S. N. Ramsey, 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.
1897. ‡Hartley, E. G. S. Wheaton Astley Hall, Stafford.
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.
1886. *HARTOG, Professor M. M., D.Sc. Queen's College, Cork.
1887. ‡Hartog, P. J., D.Sc. Owens College, Manchester.
1897.§§Harvey, Arthur. Rosedale, Toronto, Canada.
1898.§§Harvey, Eddie. 10 The Paragon, Clifton, Bristol.
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.
1893. §Haslam, Lewis. 44 Evelyn-gardens, S.W.
1875. *HASTINGS, G. W. Elm Lodge, Dartford Heath, Bexley, Kent.
1889. ‡Hatch, F. H., Ph.D., F.G.S. 28 Jermyn-street, S.W.
1893. ‡Hatton, John L. S. People's Palace, Mile End-road, E.
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, S.W.
1897. §Hawksley, Charles. 60 Porchester-terrace, 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.

Year of
Election.

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, 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, Rev. F. C. The Rectory, Raheny, Dublin.
1896. ‡Hayes, William. Fernyhurst, Rathgar, Dublin.
1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1898. §§Hayman, C. A. Kingston Villa, Richmond Hill, Clifton, Bristol.
1858. *HAYWARD, R. B., M.A., F.R.S. Ashcombe, Shanklin, Isle of Wight.
1896. *Haywood, A. G. Rearsby, Merrilocks-road, Blundellsands.
1879. *Hazelhurst, George S. The Grange, Rockferry.
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. Oak Hill, Windermere.
1883. *Heap, Ralph. 1 Brick-court, Temple, 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. 195 Union-street, Plymouth.
1883. ‡Heath, Dr. 46 Hoghton-street, Southport.
1898. *Heath, Arthur J. 10 Grove Road, Redland, Bristol.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1898. §§Heath, R. S., M.A., D.Sc. Mason University College, Birmingham.
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.
1888. *Heawood, Edward, M.A. 3 Underhill-road, Lordship-lane, S.E.
1888. *Heawood, Percy J., 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.
1887. *HEDGES, KILLINGWORTH, M.Inst.C.E. Wootton Lodge, 39 Streatham-hill, S.W.
1881. *HELE-SHAW, H. S., LL.D., F.R.S., M.Inst.C.E., Professor of Engineering in University College, Liverpool. 27 Ullett-road, Liverpool.
1887. §Hembry, Frederick William, F.R.M.S. Langford, Sidcup, Kent.
1897. §Hemming, G. W., Q.C. 2 Earl's Court-square, S.W.
1899. §Hemsalech, G. A. Faculté des Sciences, Paris.
1867. ‡Henderson, Alexander. Dundee.
1873. *Henderson, A. L. Westmoor Hall, Brimsdown, Middlesex.
1883. ‡Henderson, Mrs. A. L. Westmoor Hall, Brimsdown, Middlesex.
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.

Year of Election.
1885. ‡Henderson, Sir William. Devanha House, Aberdeen.
1880. *Henderson, Captain W. H., R.N. 21 Albert Hall-mansions, Kensington, S.W.
1896. ‡Henderson, W. Saville, B.Sc. Beech Hill, Fairfield, Liverpool.
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, S.W. 34 Clarendon-road, Notting Hill, W.
Henry, Franklin. Portland-street, Manchester.
Henry, Mitchell. Stratheden House, Hyde Park, W.
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, W.
1890. ‡Hepper, J. 43 Cardigan-road, Headingley, Leeds.
1890. ‡Hepworth, Joseph. 25 Wellington-street, Leeds.
1892. *HERBERTSON, ANDREW J., F.R.G.S. Colinton, Midlothian.
1887. *HERDMAN, WILLIAM A., D.Sc., F.R.S., F.R.S.E., F.L.S., Professor of Natural History in University College, Liverpool. Croxteth Lodge, Sefton Park, Liverpool.
1893. *Herdman, Mrs. Croxteth Lodge, Sefton Park, 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.
1894. ‡Hewins, W. A. S., M.A., F.S.S. Professor of Political Economy in King's College, Strand, W.C.
1896. §Hewitt, David Basil. Oakleigh, Northwich, Cheshire.
1893. ‡Hewitt, Thomas P. Eccleston Park, Prescot, Lancashire.
1883. ‡Hewson, Thomas. Junior Constitutional Club, Piccadilly, W.
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. The Hollies, Banbury.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1897. ‡Heys, Thomas. 130 King-street West, Toronto, Canada.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
1879. ‡Heywood, Sir A. Percival, Bart. Duffield Bank, Derby.
1886. §HEYWOOD, HENRY, J.P., F.C.S. Witla Court, near Cardiff.
1887. ‡Heywood, Robert. Mayfield, Victoria Park, Manchester.
1888. ‡Hichens, James Harvey, M.A., F.G.S. The School House, Wolverhampton.
1875. ‡HICKS, H., M.D., F.R.S., F.G.S. Hendon Grove, Hendon, N.W.
1898. §Hicks, Henry B. 44 Pembroke-road, Clifton, Bristol.
1877. §HICKS, Professor W. M., M.A., D.Sc., F.R.S., Principal of University 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. The Castle, Barnstaple.

Year of Election.

1891. §HIGGS, HENRY, LL.B., F.S.S. 12 Lyndhurst-road, Hampstead, N.W.
1894. §Hill, Rev. A. Du Boulay. East Bridgford Rectory, Nottingham.
1885. *HILL, ALEXANDER, M.A., M.D. Downing College, Cambridge.
1898.§§Hill, Charles. Clevedon.
*Hill, Rev. Canon Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1881. *HILL, Rev. EDWIN, M.A., F.G.S. The Rectory, Cockfield, Bury St. Edmunds.
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, W.C.
1885. *Hill, Sidney. Langford House, Langford, Bristol.
1898. *Hill, Thomas 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. 16 Duchess-road, Edgbaston, Birmingham.
1886. §Hillier, Rev. E. J. Cardington Vicarage, near Bedford.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1887. ‡Hilton, Edwin. Oak Bank, Fallowfield, Manchester.
1870. ‡HINDE, G. J., Ph.D., F.R.S., F.G.S. Ivythorn, Avondale-road, South Croydon, Surrey.
1898. §Hinds, Henry. 57 Queen-street, Ramsgate.
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, Sir WILLIAM HALES, M.D., D.C.L. 37 Union-avenue, Montreal, Canada.
1884. ‡Hirschfilder, C. A. Toronto, Canada.
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1899. §Hobday, Henry. Hazelwood, Crabble Hill, Dover.
1879. ‡Hobkirk, Charles P., F.L.S. The Headlands, Scotland-lane, Horsforth, near Leeds.
1887. *Hobson, Bernard, B.Sc., F.G.S. Tapton Elms, Sheffield.
1883. ‡Hobson, Mrs. Carey. 5 Beaumont-crescent, West Kensington, 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. 18 Glencoe-road, Blackheath, S.E.
1884. ‡Hodgson, Jonathan. Montreal, Canada.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. 7 Sandhill, Newcastle-upon-Tyne.
1898. §Hodgson, T. V. Municipal Museum and Art Gallery, Plymouth.

Year of Election.

1896. ‡Hodgson, Dr. Wm., J.P. Helensville, Crewe.
1894. ‡Hogg, A. F., M.A. 13 Victoria-road, Darlington.
1894. §Holah, Ernest. 5 Crown-court, Cheapside, E.C.
1883. ‡Holden, Edward. Laurel Mount, Shipley, 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.
1887. *Holder, Henry William, M.A. Owens College, Manchester.
1896. ‡Holder, Thomas. 2 Tithebarn-street, Liverpool.
1887. *Holdsworth, C. J. Hill Top, near Kendal, Westmoreland.
1891. ‡Holgate, Benjamin, F.G.S. 4 Montpelier-terrace, Cliff-road, Leeds.
1879. ‡Holland, Calvert Bernard. Hazel Villa, Thicket-road, Anerley, S.E.
1896. §Holland, Mrs. Lowfields House, Hooton.
1898. §§Holland, Thomas H., F.G.S. Geological Survey Office, Calcutta.
1889. ‡Holländer, Bernard. King's College, Strand, W.C.
1886. ‡Holliday, J. R. 101 Harborne-road, Birmingham.
1883. ‡Hollingsworth, Dr. T. S. Elford Lodge, Spring Grove, Isleworth.
1883. *Holmes, Mrs. Basil. 5 Freeland-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. 24 Aberdare-gardens, West Hampstead, N.W.
1892. ‡Holmes, Matthew. Netherby, Lenzie, Scotland.
1882. *HOLMES, THOMAS VINCENT, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1896. ‡Holt, William Henry. 11 Ashville-road, Birkenhead.
1897. §§Holterman, R. F. Brantford, Ontario, Canada.
1891. *Hood, Archibald, M.Inst.C.E. 42 Newport-road, Cardiff.
1875. *Hood, John. Chesterton, Cirencester.
1847. ‡HOOKER, Sir JOSEPH DALTON, G.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, S.W.
1877. *Hooper, Rev. Samuel F., M.A. Lydlinch Rectory, Sturminster Newton, Dorset.
1856. ‡Hooton, Jonathan. 116 Great Ducie-street, Manchester.
1884. *HOPKINSON, CHARLES. The Limes, Didsbury, near Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Oakleigh, Timperley, Cheshire.
1871. *HOPKINSON, JOHN, F.L.S., F.G.S., F.R.Met.Soc. 34 Margaret-street, Cavendish-square, 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.
1898. *Hornby, R., M.A. The High School, Newcastle, Staffordshire.
1885. ‡HORNE, JOHN, F.R.S.E., F.G.S. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1875. *Horniman, F. J., M.P., F.R.G.S., F.L.S. Falmouth House, 20 Hyde Park-terrace, W.
1884. *Horsfall, Richard. Stoodley House, Halifax.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1893. *HORSLEY, VICTOR A. H., B.Sc., F.R.S., F.R.C.S. 25 Cavendish-square, W.
1884. *Hotblack, G. S. Bremdall, Norwich.
1899. §Hotblack, J. T. 45 Newmarket-road, Norwich.
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1896. *Hough, S. S. Royal Observatory, Cape Town.
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.

Year of Election.

1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, Surrey, S.E.

1893. ‡Howard, F. T., M.A., F.G.S. University College, Cardiff.

1899. §Howard-Hayward, H. Harbledown, 120 Queen's-road, Richmond, Surrey.

1883. ‡Howard, James Fielden, M.D., M.R.C.S. Sandycroft, Shaw.

1886. *HOWARD, JAMES L., D.Sc. 90 St. John's-road, Waterloo, near Liverpool.

1887. *Howard, S. S. 58 Albemarle-road, Beckenham, Kent.

1886. ‡Howatt, David. 3 Birmingham-road, Dudley.

1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.

1899. §Howden, Ian D. C. 6 Cambridge-terrace, Dover.

1889. §§Howden, Robert, M.B., Professor of Anatomy in the 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.

1898. §§Howell, J. H. 104 Pembroke-road, Clifton, Bristol.

1891. ‡Howell, Rev. William Charles, M.A. Holy Trinity Parsonage, High Cross, Tottenham, Middlesex.

1886. §HOWES, G. B., LL.D., F.R.S., F.L.S. Professor of Zoology in the Royal College of Science, South Kensington, 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. 7 Prince's Buildings, Clifton, Bristol.

1863. ‡HOWORTH, Sir H. H., K.C.I.E., M.P., D.C.L., F.R.S., F.S.A. 30 Collingham-place, Cromwell-road, S.W.

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.

1898. §HUDLESTON, W. H., M.A., F.R.S., F.G.S. 8 Stanhope-gardens, S.W.

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, S.W.

1858. *HUGGINS, Sir WILLIAM, K.C.B., D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. 90 Upper Tulse-hill, S.W.

1887. ‡Hughes, E. G. 4 Roman-place, Higher Broughton, Manchester.

1883. ‡Hughes, Miss E. P. Cambridge Teachers' College, Cambridge.

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. 18 Hills-road, Cambridge.

1891. ‡Hughes, Rev. W. Hawker. Jesus College, Oxford.

1865. ‡Hughes, W. R., F.L.S., Treasurer of the City of Birmingham. Birmingham.

1867. §HULL, EDWARD, M.A., LL.D., F.R.S., F.G.S. 20 Arundel-gardens, Notting Hill, W.

1897. ‡Hume, J. G., M.A., Ph.D. 650 Church-street, Toronto, Canada.

1887. *HUMMEL, Professor J. J. 152 Woodsley-road, Leeds.

Year of
Election.
1890. ‡Humphrey, Frank W. 63 Prince's-gate, 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. North Cote, 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.
1879. ‡HUNTINGTON, A. K., F.C.S., Professor of Metallurgy in King's College, W.C.
1885. ‡Huntly, The Most Hon. the Marquess of. Aboyne Castle, Aberdeenshire.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1898. §§Hurle, J. Cooke. Southfield House, Brislington, Bristol.
1869. ‡Hurst, George. Bedford.
1882. *Hurst, Walter, B.Sc. Kirkgate, Tadcaster, Yorkshire.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Co. Down, 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.
1896. ‡Hutchinson, W. B. 4 West-street, Southport.
Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, N.W.
1887. *Hutton, J. Arthur. The Woodlands, Alderley Edge, Cheshire.
1883. ‡Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Painswick, Stroud, Gloucestershire.

1883. §Idris, T. H. W. Pratt-street, Camden Town, 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.
1898. §Inskip, James. Clifton Park, Clifton, Bristol.
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 Vicarage, Bishop's Stortford, Herts.

Year of Election.
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, 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. 358 Collins-street, Melbourne, Australia.
1883. ‡*Jackson, Frank. 11 Park-crescent, Southport.*
1874. *Jackson, Frederick Arthur. Penalva Ranche, Millarville, Alberta, Calgary, N.W.T., Canada.
1883. *Jackson, F. J. 42 Whitworth-street, Manchester.
1883. ‡Jackson, Mrs. F. J. 42 Whitworth-street, Manchester.
1899. §Jackson, Geoffrey A. 31 Harrington-gardens, Kensington, S.W.
1885. ‡Jackson, Henry. 19 Golden-square, Aberdeen.
1866. ‡Jackson, H. W., F.R.A.S. 67 Upgate, Louth, Lincolnshire.
1897. §Jackson, James, F.R.Met.Soc. 34 Lonsdale-square, N.
1898. *Jackson, Sir John. 3 Victoria-street, S.W.
1869. §Jackson, Moses, J.P. The Orchards, Whitchurch, Hants.
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. 64 Park-place, Cardiff.
1891. *James, Charles Russell. 6 New-court, Lincoln's Inn, 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 Herbert. Howard House, Arundel-street, Strand, W.C.*
1891. ‡James, J. R., L.R.C.P. 158 Cowbridge-road, Canton, Cardiff.
1896. ‡James, O. S. 192 Jarvis-street, Toronto, Canada.
1858. ‡James, William C. Woodside, Plymouth.
1896. *Jameson, H. Lyster. Killencoole, Castlebellingham, Ireland.
1884. ‡Jameson, W. C. 48 Baker-street, Portman-square, 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., Ph.D., LL.D., F.R.S., V.P.C.S., Professor of Chemistry in the University of Aberdeen.
1896. *Jarmay, Gustav. Hartford Lodge, Hartford, Cheshire.
1870. ‡Jarrold, John James. London-street, Norwich.
1891. ‡Jefferies, Henry. Plas Newydd, Park-road, Penarth.
1855. *Jeffray, John. 9 Winton-drive, Kelvinside, Glasgow.
1897.§§Jeffrey, E. C., B.A. The University, Toronto, Canada.
1867. ‡Jeffreys, Howel, M.A. 61 Bedford-gardens, Kensington, W.
1894. ‡Jelly, Dr. W. Aveleanas, 11, Valencia, Spain.
1899. §Jenkins, Colonel T. M. Glen Tify, Westwood-road, Southampton.
1891. §Jenkins, Henry C., Assoc.M.Inst.C.E., F.C.S. Royal College of Science, South Kensington, S.W.

Year of
Election.

1873. §Jenkins, Major-General J. J. 16 St. James's-square, S.W.
1880. *JENKINS, Sir JOHN JONES, M.P. The Grange, Swansea.
1852. ‡Jennings, Francis M., M.R.I.A. Brown-street, Cork.
1893. §Jennings, G. E. Ashleigh, Ashleigh-road, Leicester.
1897. §Jennings, W. T. 34 St. Vincent-street, Toronto, Canada.
1878. ‡*Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.*
1899. §Jepson, Thomas. Evington, Northumberland-street, Higher Broughton, Manchester.
1887.§§JERVIS-SMITH, Rev. F. J., M.A., F.R.S. Trinity College, Oxford.
Jessop, William. 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, 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, N.
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.
1898. *Johnson, W. Claude, M.Inst.C.E. The Dignaries, Blackheath, S.E.
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.
1899. §Johnston, Colonel Duncan A., R.E. Ordnance Survey, Southampton.
1883. ‡JOHNSTON, Sir H. H., K.C.B., F.R.G.S. Queen Anne's Mansions, S.W.
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. ‡Jolly, Thomas. Park View-villas, Bath.
1871. ‡JOLLY, WILLIAM, F.R.S.E., F.G.S. St. Andrew's-road, Pollokshields, Glasgow.
1888. ‡Jolly, W. C. Home Lea, Lansdowne, Bath.
1896. *JOLY, C. J., M.A. The Observatory, Dunsink, Co. Dublin.
1888. ‡JOLY, JOHN, M.A., D.Sc., F.R.S., Professor of Geology and Mineralogy in the University of Dublin.
1898.§§Jones, Alfred L. Care of Messrs. Elder, Dempster, & Co., Liverpool.
1881. ‡*Jones, Alfred Orlando, M.D. Cardigan Villa, Harrogate.*

Year of Election.
1887. ‡Jones, D. E., B.Sc., H.M. Inspector of Schools. Science and Art Department, South Kensington, S.W.
1890. §JONES, Rev. EDWARD, F.G.S. Primrose Cottage, Embsay, Skipton.
1891. ‡Jones, Dr. Evan. Aberdare.
1896. ‡Jones, E. Taylor. University College, Bangor.
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, N.W.
1877. ‡Jones, Henry C., F.C.S. Royal College of Science, South Kensington, 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, E.C.
1880. ‡Jones, Thomas. 15 Gower-street, Swansea.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S. 17 Parson's Green, Fulham, 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.
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. 22 Cumberland-road, Kew.
1883. ‡Justice, Philip M. 14 Southampton-buildings, Chancery-lane, W.C.

1868. *Kaines, Joseph, M.A., D.Sc. 8 Osborne-road, Stroud Green-road, N.
1888. ‡Kapp, Gisbert, M.Inst.C.E., M.Inst.E.E. 3 Lindenallee, Westend, Berlin.
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.Z.S. 11 Queen's-gate, 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.*
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1864. *Kelly, W. M., M.D. Ermington, Taunton, Somerset.
1885. §KELTIE, J. SCOTT, LL.D., Sec. R.G.S., F.S.S. 1 Savile-row, W.
1847. *KELVIN, The Right Hon. Lord, G.C.V.O., M.A., LL.D., D.C.L., F.R.S., F.R.S.E., F.R.A.S. The University, Glasgow.

Year of Election.

1877. *Kelvin, Lady. The University, Glasgow.
1887. ‡Kemp, Harry. 55 Wilbraham-road, Chorlton-cum-Hardy, Manchester.
1898. *Kemp, John T., M.A. 61 Cotham Brow, Bristol.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.
1890. §Kempson, Augustus. Kildare, 17 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, W.
1897. §Kennedy, George, M.A., LL.D. Crown Lands Department, Toronto, Canada.
1884. ‡Kennedy, George T., 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.
1897. ‡Kenrick, Frank B. Knesebeckstr. 3iii., Charlottenburg, Berlin.
1886. ‡Kenrick, George Hamilton. Whetstone, Somerset-road, Edgbaston, Birmingham.
1893. §KENT, A. F. STANLEY, M.A., F.L.S., F.G.S., Professor of Physiology in University College, Bristol.
1886. §KENWARD, JAMES, F.S.A. 43 Streatham High-road, 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.
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.
1892. ‡Kerr, J. Graham. Christ's College, Cambridge.
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.
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. 12 Clarendon-place, Stirling.
1897. ‡Kiekelly, Dr. John, LL.D. 46 Upper Mount-street, Dublin.
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.

Year of Election.

1883. *King, Joseph. Lower Birtley, Witley, Godalming.
1860. *King, Mervyn Kersteman. 3 Clifton-park, Clifton, Bristol.
1899. §§KING, Sir GEORGE, K.C.I.E., F.R.S. Care of Messrs. Grindlay & Co., 55 Parliament-street, S.W.
1875. *King, Percy L. 2 Worcester-avenue, Clifton, Bristol.
1870. ‡King, William. 5 Beach Lawn, Waterloo, Liverpool.
1889. ‡King, Sir William. Stratford Lodge, Southsea.
1897. ‡Kingsmill, Nichol. Toronto, Canada.
1875. §KINGZETT, CHARLES T., F.C.S. Elmstead Knoll, Chislehurst.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1892. ‡Kinnear, The Hon. Lord, F.R.S.E. Blair Castle, Culross, N.B.
1899. *Kirby, Miss C. F. 74 Kensington Park-road, W.
1899. *Kirby, Miss M. A. Field House, Montpelier-road, Bristol.
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1890. *KITSON, Sir JAMES, Bart., M.P. Gledhow Hall, Leeds.
1886. ‡Klein, Rev. L. M. de Beaumont, D.Sc., F.L.S. 6 Devonshire-road, Liverpool.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1886. ‡Knight, J. McK., F.G.S. Bushwood, Wanstead, Essex.
1898. §KNOCKER, E. WOLLASTON, C.B. Castle Hill House, Dover.
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.
1897. ‡Knowlton, W. H. 36 King-street East, Toronto, Canada.
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.
1875. *Knubley, Rev. E. P., M.A. Steeple Ashton Vicarage, Trowbridge.
1883. ‡Knubley, Mrs. Steeple Ashton Vicarage, Trowbridge.
1892. ‡KOHN, CHARLES A., Ph.D. 20 Mulgrave-street, Liverpool.
1898. §Krauss, A. Hawthornden, Priory-road, Tyndall's Park, Clifton, Bristol.
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.
1870. ‡Kynaston, Josiah W., F.C.S. 3 Oak-terrace, Beech-street, Liverpool.

1858. ‡Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1884. ‡Laflamme, Rev. Professor J. C. K. Laval University, Quebec.
1885. *Laing, J. Gerard. 111 Church-street, Chelsea, S.W.
1897. ‡Laird, Professor G. J. Wesley College, Winnipeg, Canada.
1877. ‡Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. City Hall, Cork Hill, Dublin.
1889. *Lamb, Edmund, M.A. Borden Wood, Liphook, Hants.
1887. ‡LAMB, HORACE, M.A., F.R.S., Professor of Pure Mathematics in the Owens College, Manchester. 6 Wilbraham-road, Fallowfield, 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.

Year of Election.

1893. ‡LAMPLUGH, G. W., F.G.S. Geological Survey Office, Jermyn-street, 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, S.E.

1883. ‡Lang, Rev. Gavin. Mayfield, Inverness.

1859. ‡Lang, Rev. John Marshall, D.D. Barony, Glasgow.

1898. *Lang, William H. 10 Jedburgh-gardens, Kelvinside, Glasgow.

1886. *LANGLEY, J. N., M.A., D.Sc., F.R.S. Trinity College, Cambridge.

1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.

1865. ‡LANKESTER, E. RAY, M.A., LL.D., F.R.S., Director of the Natural History Museum, Cromwell-road, S.W.

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 University College, Birmingham. 28 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. 5 Pepy's-road, Wimbledon, Surrey.

1891. ‡Laurie, A. P. 49 Beaumont-square, E.

1892.§§Laurie, Malcolm, B.A., B.Sc., F.L.S., Professor of Zoology in St. Mungo's College, Glasgow.

1888. ‡Laurie, Colonel R. P., C.B. 79 Farringdon-street, E.C.

1883. ‡Laurie, Major-General. Oakfield, Nova Scotia, Canada.

1870. *Law, Channell. Ilsham Dene, Torquay.

1878. ‡Law, Henry, M.Inst.C.E. 9 Victoria-chambers, 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.

1889. §Laws, W. G., M.Inst.C.E. 65 Osborne-road, Newcastle-upon-Tyne.

1885. ‡Lawson, James. 8 Church-street, Huntly, N.B.

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, S.W.

1894. *Leahy, A. H., M.A., Professor of Mathematics in Firth College. 92 Ashdell-road, Sheffield.

1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.

1884. ‡Learmont, Joseph B. 120 Mackay-street, Montreal, Canada.

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, Canada.

Year of
Election.

1895. *Ledger, Rev. Edmund. Proted, Woods-road, Reigate.
1898. §LEE, ARTHUR, J.P. 10 Berkeley-square, Clifton, Bristol.
1861. ‡*Lee, Henry. Sedgeley Park, Manchester.*
1896. §Lee, Rev. H. J. Barton. South Park View, Ashburton, Devon.
1891. ‡Lee, Mark. The Cedars, Llandaff-road, Cardiff.
1894. *Lee, Mrs. W. Ashdown House, Forest-row.
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., D.Sc. Osborne, Belgrave-road, Oldham.
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. 18 Bryanston-square, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1892. ‡Lehfeldt, Robert A. 28 South Molton-street, W.
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, W.
1871. ‡LEONARD, HUGH, M.R.I.A. 24 Mount Merrion-avenue, Blackrock, Co. Dublin.
1874. ‡*Lepper, Charles W. Laurel Lodge, Belfast.*
1884. ‡Lesage, Louis. City Hall, Montreal, Canada.
1890. *Lester, Joseph Henry. Royal Exchange, Manchester.
1883. §Lester, Thomas. Fir Bank, Penrith.
1880. ‡LETCHER, R. J. Lansdowne-terrace, Walters-road, Swansea.
1894. ‡Leudesdorf, Charles. Pembroke College, Oxford.
1896. §Lever, W. H. Port Sunlight, Cheshire.
1887. *Levinstein, Ivan. Hawkesmoor, Fallowfield, Manchester.
1890. §Levy, J. H. 11 Abbeville-road, Clapham Park, 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, S.W.
1870. ‡LEWIS, ALFRED LIONEL. 54 Highbury-hill, N.
1891. ‡Lewis, D., J.P. 44 Park-place, Cardiff.
1891. §§Lewis, Professor D. Morgan, M.A. University College, Aberystwyth.
1899. §Lewis, Professor E. P. University of California, Berkeley, U.S.A.
1897. §§Lewis, Rev. J. Pitt, M.A. Care of G. A. Mackenzie, Esq., 18 Toronto-street, Toronto, Canada.
1899. §Lewis, Thomas. 9 Hubert-terrace, Dover.
1891. ‡*Lewis, W. Lyncombe Villa, Cowbridge-road, Cardiff.*
1891. ‡Lewis, W. 22 Duke-street, Cardiff.

Year of Election.

1891. ‡Lewis, W. Henry. Bryn Rhos, Llanishen, Cardiff.
1884. *Lewis, Sir W. T., Bart. The Mardy, Aberdare.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1878. ‡Lincolne, William. Ely, Cambridgeshire.
1881. *Lindley, William, M.Inst.C.E., F.G.S. 74 Shooters Hill-road, Blackheath, S.E.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
1898. §Lippincott, R. C. Cann. Over Court, near Bristol.
1883. ‡Lisle, H. Claud. Nantwich.
1895. *LISTER, The Right Hon. Lord, D.C.L., Pres.R.S. 12 Park-crescent, Portland-place, W.
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.
1880. ‡LLEWELYN, Sir JOHN T. D., Bart., M.P. Penllegare, Swansea.
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., F.R.S.E 49A Grove-street, Liverpool.
1886. ‡Lloyd, Samuel. Farm, Sparkbrook, Birmingham.
1865. *Lloyd, Wilson, F.R.G.S. Park Lane House, Woodgreen, Wednesbury.
1897. §Lloyd-Verney, J. H. 14 Hinde-street, Manchester-square, W.
1854. *LOBLEY, JAMES LOGAN, F.G.S. City of London College, Moorgate-street, E.C.
1892. §Loch, C. S., B.A. 15A Buckingham-street, W.C.
1867. *Locke, John. 144 St. Olaf's-road, Fulham, S.W.
1892. ‡Lockhart, Robert Arthur. 10 Polwarth-terrace, Edinburgh.
1863. ‡LOCKYER, Sir J. NORMAN, K.C.B., F.R.S. Royal College of Science, South Kensington, 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.
1899. §Loncq, Emile. 6 Rue de la Plaine, Laon, Aisne, France.
1876. ‡Long, H. A. Brisbane, Queensland.
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. Lowestoft.
1898. *Longfield, Miss Gertrude. High Halston Rectory, Rochester.
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.
1899. *Longstaff, Tom G., B.A., F.R.Met.Soc. Ridgelands, Wimbledon, Surrey.
1883. *Longton, E. J., M.D. Brown House, Blawith, *viâ* Ulverston.

Year of Election.

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.
1897. ‡LOUDON, JAMES, LL.D., President of the University of Toronto, Canada.
1883. *Louis, D. A., F.C.S. 77 Shirland-gardens, W.
1896. §Louis, Henry, Professor of Mining, Durham College of Science, Newcastle-on-Tyne.
1887. *LOVE, Professor A. E. H., M.A., F.R.S. Oxford.
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, 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, W.
1867. *Low, James F. Seaview, Monifieth, by Dundee.
1885. §Lowdell, Sydney Poole. Baldwin's Hill, East Grinstead, Sussex.
1891. §Lowdon, John. St. Hilda's, Barry, Glamorgan.
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. Lansoar, 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.
1897. ‡*Lowry, George. Manchester.*
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, W.
1870. ‡Lubbock, Montague, M.D. 19 Grosvenor-street, W.
1889. ‡Lucas, John. 1 Carlton-terrace, Low Fell, Gateshead.
1878. ‡Lucas, Joseph. Tooting Graveney, S.W.
1889. ‡Luckley, George. The Grove, Jesmond, Newcastle-upon-Tyne.
1891. *Lucovich, Count A. The Rise, Llandaff.
1881. ‡Luden, C. M. 4 Bootham-terrace, York.
1897. ‡Lumsden, George E., F.R.A.S. 57 Elm-avenue, Toronto, Canada.
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, W.
1900. §LUPTON, W. C. (LOCAL TREASURER), Mayor of Bradford.
1864. *Lutley, John. Brockhampton Park, Worcester.
1898. §Luxmore, Dr. C. M. Reading College, Reading.
1871. ‡Lyell, Sir Leonard, Bart., M.P., F.G.S. 48 Eaton-place, S.W.
1899. §Lyle, Professor Thomas R. The University, Melbourne.
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.

Year of Election.

1896. ‡LYSTER, GEORGE F. Plas Isaf, Ruthin.
1862. *LYTE, F. MAXWELL, F.C.S. 60 Finborough-road, S.W.
1854. *MACADAM, STEVENSON, Ph.D., F.R.S.E., F.I.C., F.C.S., Professor of Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, 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, W.C.
1897. ‡McAllister, Samuel. 99 Wilcox-street, Toronto, Canada.
1896. §MACALLUM, Professor A. B., Ph.D. The University, Toronto, Canada.
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. 79 Holland-park, W.
1896. ‡McArthur, Charles. Villa Marina, New Brighton, Cheshire.
1884. ‡Macarthur, D. Winnipeg, Canada.
1896. *Macaulay, F. S., M.A. 19 Dewhurst-road, W.
1834. MACAULAY, JAMES, A.M., M.D. 4 Wynnstay-gardens, W.
1896. ‡MACBRIDE, Professor E. W., M.A. McGill University, Montreal, Canada.
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.
1868. ‡M'CLINTOCK, Admiral Sir FRANCIS L., R.N., K.C.B., F.R.S., F.R.G.S. United Service Club, Pall Mall, S.W.
1872. *McClure, J. H., F.R.G.S. Whiston, Prescot.
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.*
1899. §McDiarmid, Jabez. The Elms, Stanmore, Middlesex.
1890. *MacDonald, Mrs. J. R. 3 Lincoln's Inn Fields, W.C.
1886. ‡McDonald, John Allen. Hillsboro' House, Derby.
1884. ‡MacDonald, Kenneth. Town Hall, Inverness.
1884. *McDonald, Sir 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.*
1884. ‡McDougall, John. 35 St. François Xavier-street, Montreal, Canada.
1897. ‡McEwen, William C. 9 South Charlotte-street, Edinburgh.
1881. ‡Macfarlane, Alexander, D.Sc., F.R.S.E., Professor of Physics in the University of Texas. Austin, Texas, U.S.A.
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.
1897. ‡McFarlane, Murray, M.D. 32 Carlton-street, Toronto, Canada.

Year of Election.

1867. *M'Gavin, Robert. Ballumbie, Dundee.
1897. ‡McGaw, Thomas. Queen's Hotel, Toronto, Canada.
1888 ‡MacGeorge, James. 67 Marloes-road, Kensington, W.
1884. ‡MacGillivray, James. 42 Cathcart-street, Montreal, Canada.
1884. ‡MacGoun, Archibald, jun., B.A., B.C.L. Dunavon, Westmount, Montreal, Canada.
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. ***McIntosh, 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, A. H., B.Sc., LL.D., Superintendent of Education. Education Office, Halifax, Nova Scotia, Canada.
1885. §**Mackay, John Yule**, M.D., Professor of Anatomy in University College, Dundee.
1897. ‡McKay, T. W G., M.D. Oshawa, Ontario, Canada.
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.
1897. ‡McKenzie, John J. 61 Madison-avenue, Toronto, Canada.
1884. ‡McKenzie, Stephen, M.D. 26 Finsbury-circus, E.C.
1884. ‡McKenzie, Thomas, B.A. School of Science, Toronto, Canada.
1883. ‡Mackeson, Henry. Hythe, Kent.
1872. *Mackey, J. A. 175 Grange-road, S.E.
1867. ‡**Mackie, Samuel Joseph.** 17 Howley-place, W.
1884. ‡McKilligan, John B. 387 Main-street, Winnipeg, Canada.
1887. ‡**Mackinder, H. J.**, M.A., F.R.G.S. Christ Church, Oxford.
1867. *Mackinlay, David. 6 Great Western-terrace, Hillhead, Glasgow.
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 R. D. St. Catherine's, Liberton, Midlothian.
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.
1897. ‡MacLaren, J. F. 380 Victoria-street, Toronto, Canada.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1897. ‡MacLaren, Rev. Wm., D.D. 57 St. George-street, Toronto, Canada.
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.

Year of Election.

1884. ‡McLennan, John. Lancaster, Ontario, Canada.
1868. §McLEOD, HERBERT, F.R.S., Professor of Chemistry in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1892. ‡Macleod, W. Bowman. 16 George-square, Edinburgh.
1861. *Maclure, Sir John William, Bart., M.P., F.R.G.S., F.S.S. Whalley Range, Manchester.
1883. *McMAHON, Lieut.-General C. A., F.R.S., F.G.S. 20 Nevern-square, South Kensington, S.W.
1883. ‡MACMAHON, Major PERCY A., R.A., F.R.S. 52 Shaftesbury-avenue, 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. University of Michigan, Ann Arbor, Michigan, U.S.A.
1867. ‡M'Neill, John. Balhousie House, Perth.
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, 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.
1899. §Makarius, Saleem. 'Al Mokattam,' Cairo.
1887. ‡Mainprice, W. S. Longcroft, Altrincham, Cheshire.
1883. ‡Maitland, P. C. 136 Great Portland-street, W.
1881. ‡Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1889. ‡Maling, C. T. 14 Ellison-place, Newcastle-upon-Tyne.
1857. ‡MALLET, JOHN WILLIAM, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, Albemarle Co., U.S.A.
1896. *Manbré, Alexandre. 15 Alexandra-drive, Liverpool.
1897.§§MANCE, Sir H. C. 32 Earl's Court-square, S.W.
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.
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.
1887. *March, Henry Colley, M.D., F.S.A. Portesham, Dorchester, Dorsetshire.
1870. ‡Marcoartu, His Excellency Don Arturo de. Madrid.
1898. *Mardon, Heber. 2 Litfield-place, Clifton, Bristol.
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., Pres.R.G.S., F.S.A. 21 Eccleston-square, S.W.
1894. ‡*Markoff, Dr. Anatolius. 44 Museum-street, W.C.*
1863. ‡Marley, John. Mining Office, Darlington.

Year of Election.
1888. ‡Marling, W. J. Stanley Park, Stroud, Gloucestershire.
1888. ‡Marling, Lady. Stanley Park, Stroud, Gloucestershire.
1881. *MARR, J. E., M.A., F.R.S., F.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. 5 Ladywood-road, 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. 2 Strattan-street, 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.
1891. *Martin, Edward P., J.P. Dowlais, Glamorgan.
1899. §Martin, Miss A. M. Park View, Bayham-road, Sevenoaks.
1887. *Martin, Rev. H. A. Grosvenor Club, London, S.W.
1884. §Martin, N. H., J.P., F.L.S. Ravenswood, Low Fell, Gateshead-on-Tyne.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Northdene, New Barnet, Herts.
1890. §Martindale, William, F.L.S. 19 Devonshire-street, Portland-place, W.
*Martineau, Rev. James, LL.D., D.D. 35 Gordon-square, 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, 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. University of Melbourne, Victoria, Australia.
1898. §Masterman, A. T. University of St. Andrews, N.B.
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.
1898. §Mathews, E. R. Norris. Cotham-road, Cotham, Bristol.
1894. ‡MATHEWS, G. B., M.A., F.R.S. University College, Bangor.
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1889. ‡Mathews, John Hitchcock. 1 Queen's-gardens, Hyde Park, W.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 21 Augustus-road, Edgbaston, Birmingham.

Year of Election.

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.
1899. §**Matthews, William**, M.Inst.C.E. 9 Victoria-street, S.W.
1893. ‡Mavor, Professor James, M.A., LL.D. 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. Northfield, St. Mary Cray, Kent.
1883. ‡Mayall, George. Clairville, Birkdale, Southport.
1884. *Maybury, A. C., D.Sc. 19 Bloomsbury-square, 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, 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, W.C.
1867. ‡**Meldrum, Charles**, C.M.G., LL.D., F.R.S., F.R.A.S. Marine House, Beach-road, St. Luke's, Jersey.
1883. ‡Mellis, Rev. James. 23 Park-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡**Mello**, Rev. J. M., M.A., F.G.S. Mapperley Vicarage, Derby.
1883. §Mello, Mrs. J. M. Mapperley Vicarage, Derby.
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, S.W.
1862. ‡**Mennell, Henry T.** St. Dunstan's-buildings, Great Tower-street, E.C.
1879. ‡**Merivale, John Herman**, M.A. Togston Hall, Acklington.
1899. *Merrett, William H. Royal Mint, Tower Hill, E.
1880. ‡Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1899. §Merryweather, J. C. 4 Whitehall-court, S.W.
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. 46 Windsor-road, Ealing, W.
1894. ***Miers, H. A.**, M.A., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. Magdalen College, Oxford.

Year of Election.

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. 22 Gloucester-place, Portman-square, W.
1889. *Millar, Robert Cockburn. 30 York-place, Edinburgh.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1875. ‡Miller, George. Brentry, near Bristol.
1895. ‡Miller, Henry, M.Inst.C.E. Bosmere House, Norwich-road, Ipswich.
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.
1895. §Miller, Thomas, M.Inst.C.E. 9 Thoroughfare, Ipswich.
1884. ‡Miller, T. F., B.Ap.Sc. Napanee, Ontario, Canada.
1876. ‡Miller, Thomas Paterson. Cairns, Cambuslang, N.B.
1897. ‡Miller, Willet G., Professor of Geology in Queen's University, Kingston, Ontario, Canada.
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. Sherwood Hall, Mansfield.
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, William. 40 Albyn-place, Aberdeen.
1887. ‡Milne-Redhead, R., F.L.S. Holden Clough, Clitheroe.
1898. *Milner, S. Roslington, B.Sc. Owens College, Manchester.
1882. ‡Milnes, Alfred, M.A., F.S.S. 22a Goldhurst-terrace, South Hampstead, 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, W.
1883. ‡Mitchell, Mrs. Charles T. 41 Addison-gardens North, Kensington, W.
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. 77 Inverness-terrace, W.
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, Right 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, N.W.
1891. *Mond, Robert Ludwig, M.A., F.R.S.E., F.G.S. 20 Avenue-road, Regent's Park, N.W.
1882. *Montagu, Sir Samuel, Bart., M.P. 12 Kensington Palace-gardens, W.
1892. ‡Montgomery, Very Rev. J. F. 17 Athole-crescent, Edinburgh.
1872. ‡Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, W.

Year of
Election.
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, Harold E. 41 Bedford-row, W.C.
1891. ‡Moore, John. Lindenwood, Park-place, Cardiff.
1890. ‡Moore, Major, R.E. School of Military Engineering, Chatham.
1857. **Moore, Rev. William Prior. Carrickmore, Galway, Ireland.*
1896. *Mordey, W. M. Princes-mansions, Victoria-street, S.W.
1891. ‡Morel, P. Lavernock House, near Cardiff.
1881. ‡MORGAN, ALFRED. 50 West Bay-street, Jacksonville, Florida, U.S.A.
1895.§§MORGAN, C. LLOYD, F.R.S., F.G.S., Principal of University College, Bristol. 16 Canynge-road, Clifton, Bristol.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, South Kensington, 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.
1892. ‡Morison, John, M.D., F.G.S. Victoria-street, St. Albans.
1889. §Morison, J. Rutherford, M.D. 14 Saville-row, Newcastle-upon-Tyne.
1893. ‡Morland, John, J.P. Glastonbury.
1891. ‡Morley, H. The Gas Works, Cardiff.
1883. *MORLEY, HENRY FORSTER, M.A., D.Sc., F.C.S. 47 Broadhurst-gardens, South Hampstead, N.W.
1889. ‡MORLEY, The Right Hon. JOHN, M.A., LL.D., M.P., F.R.S. 95 Elm Park-gardens, S.W.
1896. ‡Morrell, R. S. Caius College, Cambridge.
1881. ‡Morrell, W. W. York City and County Bank, York.
1883. ‡Morris, C. S. Millbrook Iron Works, Landore, South Wales.
1892. ‡MORRIS, DANIEL, C.M.G., M.A., D.Sc., F.L.S. Barbados, West Indies.
1899. §Morris, G. Harris, Ph.D., F.I.C. 18 Gwendwr-road, West Kensington, W.
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.*
1899. §Morrow, Captain John, M.Sc. 7 Rockleaze-avenue, Sneyd Park, Bristol.
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.
1887. ‡Morton, Percy, M.A. Illtyd House, Brecon, South Wales.
1886. *Morton, P. F. Hockliffe Grange, Leighton Buzzard.
1896. *Morton, William B., M.A., Professor of Natural Philosophy in Queen's College, 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.

Year of Election.

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., M.A. 19 Peak-hill, Sydenham, S.E.

1866. ‡MOTT, FREDERICK T., F.R.G.S. Crescent House, Leicester.

1856. ‡Mould, Rev. J. G., B.D. Roseland, Meadfoot, Torquay.

1878. *MOULTON, J. FLETCHER, M.A., Q.C., M.P., F.R.S. 57 Onslow-square, 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.

1899. §Mowll, Martyn. Chaldercot, Leyburne-road, Dover.

1887. ‡Moxon, Thomas B. County Bank, Manchester.

1888. ‡Moyle, R. E., M.A., F.C.S. Heightley, Chudleigh, Devon.

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.

1899. *Muff, Herbert B. Aston Mount, Heaton, Bradford, Yorkshire.

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.

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. 14 Kerrsland-street, Hillhead, Glasgow.

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, N.W.

1880. ‡Muller, Hugo M. 1 Grünanger-gasse, Vienna.

1897. ‡Mullins, W. E. Preshute House, Marlborough, Wilts.

1898. §Mumford, C. E. Bury St. Edmunds.

Munby, Arthur Joseph. 6 Fig-tree-court, Temple, E.C.

1876. ‡Munro, Donald, M.D., F.C.S. The University, Glasgow.

1898.§§Munro, John, Professor of Mechanical Engineering in the Merchant Venturers' Technical College, Bristol.

1883. *MUNRO, ROBERT, M.A., M.D. 48 Manor-place, Edinburgh.

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. Marcus-square, Newry, Ireland.

1887. ‡Murray, A. Hazeldean, Kersal, Manchester.

1891. ‡MURRAY, G. R. M., F.R.S., F.R.S.E., F.L.S. British Museum (Natural History), South Kensington, S.W.

1859. ‡Murray, John, M.D. Forres, Scotland.

1884. ‡MURRAY, Sir JOHN, K.C.B., LL.D., Ph.D., F.R.S., F.R.S.E. Challenger Lodge, Wardie, 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.

Year of Election.
1892. ‡Murray, T. S. 1 Nelson-street, Dundee.
1863. ‡Murray, William, M.D. 9 Ellison-place, Newcastle-on-Tyne.
1874. §Musgrave, Sir James, Bart., J.P. Drumglass House, Belfast.
1897. ‡Musgrave, James, M.D. 511 Bloor-street West, Toronto, Canada.
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. Trinity College, Oxford.
1892. *Nairn, Michael B. Ronkielor, Springfield, Fife.
1890. §Nalder, Francis Henry. 34 Queen-street, 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. 11 Claremont-road, Surbiton.
1887. ‡Nason, Professor Henry B., Ph.D. Troy, New York, U.S.A.
1896. ‡Neal, James E., U.S. Consul. 26 Chapel-street, Liverpool.
1887. §Neild, Charles. 19 Chapel Walks, Manchester.
1883. *Neild, Theodore, B.A. The Vista, Leominster.
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.
1897. ‡Nesbitt, Beattie S. A., M.D. 71 Grosvenor-street, Toronto, Canada.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1898. §Nevill, Rev. J. H. N. The Vicarage, Stoke Gabriel, South Devon.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. ‡NEVILLE, F. H., M.A., F.R.S. Sidney College, Cambridge.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1889. *Newall, H. Frank. Madingley Rise, Cambridge.
1886. ‡Newbolt, F. G. Oakley Lodge, Weybridge, Surrey.
1889. §Newstead, A. H. L., B.A. Rose Villa, Prospect-road, Snakes-lane, Woodford.
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, S.W.
1867. ‡Nicholl, Thomas. Dundee.
1866. ‡NICHOLSON, Sir CHARLES, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.
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.
1893. ‡Nickolls, John B., F.C.S. The Laboratory, Guernsey.
1887. ‡Nickson, William. Shelton, Sibson-road, Sale, Manchester.
1885.§§Nicol, W. W. J., 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, Old Aberdeen.
1877. ‡Niven, Professor James, M.A. King's College, Aberdeen.

Year of
Election.

1874. ‡Nixon, Randal C. J., M.A. Royal Academical Institution, Belfast.
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. 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., LL.D., F.R.S., F.L.S. The Red House, Berkhamsted.
1888. ‡Norman, George. 12 Brock-street, Bath.
1865. ‡NORRIS, RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1883. *Norris, William G. Dale House, Coalbrookdale, R.S.O., Shropshire.
NORTON, The Right Hon. Lord, K.C.M.G. 35 Eaton-place, S.W.; and Hamshall, Birmingham.
1886. ‡Norton, Lady. 35 Eaton-place, S.W.; and Hamshall, Birmingham.
1894.§§NOTCUTT, S. A., LL.M., B.A., B.Sc. 98 Anglesea-road, Ipswich.
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.*

1898. *O'Brien, Neville Forth. Queen Anne's-mansions, S.W.
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.
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. Royal Colonial Institute, Northumberland-avenue, 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, 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.

Year of Election.
1887. ‡OLIVER, F. W., D.Sc., F.L.S., Professor of Botany in University College, London. The Tower House, Tite-street, Chelsea, S.W.
1883. §Oliver, Samuel A. Bellingham House, Wigan, Lancashire.
1889. §Oliver, Professor T., M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §Olsen, O. T., F.L 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, 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 in the University of Berlin.
1867. ‡*Orchar, James G. 9 William-street, Forebank, Dundee.*
1883. ‡*Ord, Miss Maria. Fern Lea, Park-crescent, Southport.*
1880. ‡O'Reilly, J. P., Professor of Mining and Mineralogy in the Royal College of Science, Dublin.
1899. §Orling, Axel. Moorgate Station-chambers, E.C.
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.
1884. *Orpen, Rev. T. H., M.A. Binnbrooke, Cambridge.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1899. §Osborn, Dr. F. A. The Châlet, Dover.
1897. ‡Osborne, James K. 40 St. Joseph-street, Toronto, Canada.
1887. §O'Shea, L. T., B.Sc. University College, Sheffield.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1897. ‡Osler, E. B., M.P. Rosedale, Toronto, Canada
1865. *Osler, Henry F. Coppy Hill, Linthurst, near Bromsgrove, Birmingham.
1884. ‡OSLER, Professor WILLIAM, M.D., F.R.S. 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.

1889. ‡Page, Dr. F. 1 Saville-place, Newcastle-upon-Tyne.
1883. ‡Page, George W. Fakenham, Norfolk.
1883. ‡Page, Joseph Edward. 12 Saunders-street, Southport.
1894. ‡Paget, Octavius. 158 Fenchurch-street, E.C.
1898. §Paget, The Right Hon. Sir R. H., Bart. Cranmore Hall, Shepton Mallet.
1884. ‡Paine, Cyrus F. Rochester, New York, U.S.A.
1875. ‡Paine, William Henry, M.D. Stroud, Gloucestershire.
1870. *PALGRAVE, R. H. INGLIS, F.R.S., F.S.S. Belton, Great Yarmouth.
1896. ‡Pallis, Alexander. Tatoi, Aigburth-drive, Liverpool.
1889. ‡PALMER, Sir CHARLES MARK, Bart., M.P. Grinkle Park, Yorkshire.
1878. *Palmer, Joseph Edward. Rose Lawn, Ballybrack, Co. Dublin.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
1872. *Palmer, W. R. 49 Tierney-road, Streatham Hill, S.W.
1883. ‡Pant, F. J. Van der. Clifton Lodge, Kingston-on-Thames.

Year of Election.

1886. ‡Panton, George A., F.R.S.E. 73 Westfield-road, Edgbaston, Birmingham.
1883. ‡Park, Henry. Wigan.
1883. ‡Park, Mrs. Wigan.
1880. *Parke, George Henry, F.L.S., F.G.S. St. John's, Wakefield, Yorkshire.
1898. §§Parker, G., M.D. 14 Pembroke-road, Clifton, Bristol.
1863. ‡Parker, Henry. Low Elswick, Newcastle-upon-Tyne.
1886. ‡Parker, Lawley. Chad Lodge, Edgbaston, Birmingham.
1899. §Parker, Mark. 30 Upper Fant-road, Maidstone.
1891. ‡Parker, William Newton, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1899. *Parkin, John. Blaithwaite, Carlisle.
1879. ‡Parkin, William. The Mount, Sheffield.
1887. §Parkinson, James. Greystones, Langho, Blackburn.
1859. ‡Parkinson, Robert, Ph.D. Yewbarrow House, Grange-over-Sands.
1862. *Parnell, John, M.A. Hadham House, Upper Clapton, N.E.
1883. ‡Parson, T. Cooke, M.R.C.S. Atherston House, Clifton, Bristol.
1865. *Parsons, Charles Thomas. Mountlands, Norfolk-road, Edgbaston, Birmingham.
1878. ‡PARSONS, Hon. C. A., F.R.S., M.Inst.C.E. Holeyn Hall, Wylam-on-Tyne.
1883. ‡Part, Isabella. Rudleth, Watford, Herts.
1898. *Partridge, Miss Josephine M. Girton College, Cambridge.
1898. §§Pass, Alfred C. Clifton Down, Bristol.
1881. ‡Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.
1887. ‡PATERSON, A. M., M.D., Professor of Anatomy in University College, Liverpool.
1897. ‡Paterson, John A. 23 Walmer-road, Toronto, Canada.
1896. ‡Paton, A. A. Greenbank-drive, Wavertree, Liverpool.
1897. §§PATON, D. Noël, M.D. 33 George-square, Edinburgh.
1883. *Paton, Henry, M.A. 32 Shandon-crescent, Edinburgh.
1884. *Paton, Hugh. Care of the Sheddon Co., Montreal, Canada.
1871. **Patterson, A. Henry.* 16 *Ashburn-place, 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.
1867. ‡*Pattison, Samuel Rowles.* 11 *Queen Victoria-street, E.C.*
1879. *Patzer, F. R. Clayton Lodge, Newcastle, Staffordshire.
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, 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, 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, W.*
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, W.C.

Year of Election.

1881. *PEARCE, HORACE, F.R.A.S., F.L.S., F.G.S. The Limes, Stourbridge.
1886. *Pearce, Mrs. Horace. The Limes, Stourbridge.
1884. ‡Pearce, William. Winnipeg, Canada.
1886. ‡Pearsall, Howard D. 19 Willow-road, Hampstead, N.W.
1883. ‡Pearson, Arthur A. Colonial Office, S.W.
1891. ‡Pearson, B. Dowlais Hotel, Cardiff.
1893. *Pearson, Charles E. Chilwell House, Nottinghamshire.
1898. §Pearson, George. Baldwin-street, Bristol.
1883. ‡Pearson, Miss Helen E. 69 Alexandra-road, Southport.
1881. ‡Pearson, John. Glentworth House, The Mount, York.
1883. ‡Pearson, Mrs. Glentworth House, The Mount, York.
1872. *Pearson, Joseph. Grove Farm, Merlin, Raleigh, Ontario, Canada.
1892. ‡Pearson, J. M. John Dickie-street, Kilmarnock.
1881. ‡Pearson, Richard. 57 Bootham, York.
1883. **Pearson, Thomas H. Redclyffe, Newton-le-Willows, Lancashire.*
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, Sir CUTHBERT E., Bart., M.A., F.S.A. 22 Belgrave-square, S.W.
1878. *Peek, William. The Manor House, Kemp Town, Brighton.
1881. ‡Peggs, J. Wallace. 21 Queen Anne's-gate, S.W.
1861. *Peile, George. Greenwood, Shotley Bridge, Co. Durham.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, W.C.
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.
1897. ‡PENHALLOW, Professor D. P., M.A. McGill University, Montreal, Canada.
1896.§§Pennant, P. P. Nantlys, St. Asaph.
1898.§§Pentecost, Harold, B.A. Clifton College, Bristol.
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.
1898.§§Percival, Francis W., M.A., F.R.G.S. 2 Southwick-place, W.
1895. §Percival, John, M.A., Professor of Botany in the South-Eastern Agricultural College, Wye, Kent.
*Perigal, Frederick. Lower 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.
1898. *Perman, E. P. University College, Cardiff.
1885. ‡Perrin, Miss Emily. 31 St John's Wood Park, N.W.
1886. ‡Perrin, Henry S. 31 St. John's Wood Park, N.W.

Year of Election.
1886. ‡Perrin, Mrs. 31 St. John's Wood Park, N.W.
1874. *PERRY, JOHN, M.E., D.Sc., F.R.S., Professor of Mechanics and Mathematics in the Royal College of Science, S.W.
1883. ‡Perry, Ottley L., F.R.G.S. Bolton-le-Moors, Lancashire.
1883. ‡Perry, Russell R. 34 Duke-street, Brighton.
1897. ‡Peters, Dr. George A. 171 College-street, Toronto, Canada.
1898. §Pethick, William. Woodside, Stoke Bishop, Bristol.
1883. ‡Petrie, Miss Isabella. Stone Hill, Rochdale.
1895. §PETRIE, W. M. FLINDERS, D.C.L., Professor of Egyptology in University College, W.C.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 13 Fourth-avenue, Brighton.
1886. ‡Phelps, Major-General A. 23 Augustus-road, Edgbaston, Birmingham.
1886. ‡Phelps, Hon. E. J. American Legation, Members' Mansions, Victoria-street, S.W.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, S.W.
1896. §§Philip, George, jun. Weldon, Bidston, Cheshire.
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.
1883. ‡Phillips, Arthur G. 20 Canning-street, Liverpool.
1899. §Phillips, Charles E. S. Castle House, Shooter's Hill, Kent.
1894. §Phillips, Staff-Commander E. C. D., R.N., F.R.G.S. 14 Hargreaves-buildings, Chapel-street, Liverpool.
1887. ‡Phillips, H. Harcourt, F C.S. 183 Moss-lane East, Manchester.
1892. §Phillips, J. H. Poole, Dorset.
1890. §Phillips, R. W., M.A., D.Sc., Professor of Biology in University College, Bangor.
1883. ‡Phillips, S. Rees. Wonford House, Exeter.
1881. ‡Phillips, William. 9 Bootham-terrace, York.
1898. §§Philps, Captain Lambe. 7 Royal-terrace, Weston-super-Mare.
1868. ‡*Phipson, T. L., Ph.D., F.C.S. 4 The Cedars, Putney, Surrey, S.W.*
1884. *Pickard, Rev. H. Adair, M.A. Airedale, Oxford.
1883. *Pickard, Joseph William. Oatlands, Lancaster.
1894. ‡PICKARD-CAMBRIDGE, Rev. O., M.A., F.R.S. Bloxworth Rectory, Wareham.
1885. *PICKERING, SPENCER P. U., M.A., F.R.S. Harpenden, Herts.
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, W.
1871. ‡Pigot, Thomas F., M.R.I.A. Royal College of Science, Dublin.
1884. ‡Pike, L. G., M.A., F.Z.S. 12 King's Bench-walk, Temple, E.C.
1865. ‡PIKE, L. OWEN. 4A Marlborough-gate, Hyde Park, W.
1873. ‡Pike, W. H., M.A., Ph.D., Professor of Chemistry in the University of Toronto, Canada.
1896. *Pilkington, A. C. The Hazels, Prescot, Lancashire.
1896. *Pilling, William. Rosario, Keene-road, West Worthing.
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.
1887. ‡Pitkin, James. 56 Red Lion-street, Clerkenwell, E.C.
1875. ‡Pitman, John. Redcliff Hill, Bristol.

Year of Election.
1883. ‡Pitt, George Newton, M.A., M.D. 24 St. Thomas-street, S.E.
1864. ‡*Pitt, R. 5 Widcomb-terrace, Bath.*
1883. ‡Pitt, Sydney. 16 St. Andrew's-street, Holborn-circus, 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. Rushmore, Salisbury.
1884. *Playfair, W. S., M.D., LL.D., Professor of Midwifery in King's College, London. 38 Grosvenor-street, W.
1898. §Playne, H. C. 28 College-road, Clifton, Bristol.
1883. *Plimpton, R. T., M.D. 23 Lansdowne-road, Clapham-road, S.W.
1893. ‡Plowright, Henry J. Brampton Foundries, Chesterfield.
1897. ‡Plummer, J. H. Bank of Commerce, Toronto, Canada.
1898. §Plummer, W. E. The Observatory, Bidston, Birkenhead.
1899. §Plumptre, Fitzwalter. Goodnestone, Dover.
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, S.W.
1896. ‡Pollard, James. High Down, Hitchin, Herts.
1898. §POLLEN, Rev. G. C. H., F.G.S. St. Beuno's College, St. Asaph, North Wales.
1896. *Pollex, Albert. Dale End, Cavendish Park, Rockferry.
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., Assoc.M.Inst.C.E. Yorkshire College, Leeds.
1868. ‡PORTAL, WYNDHAM S. Malshanger, Basingstoke.
1883. *Porter, Rev. C. T., LL.D., D.D. All Saints' Vicarage, Southport.
1883. ‡Postgate, Professor J. P., M.A. Trinity College, Cambridge.
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 Highbury, 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.
1898. *Poulton, Edward Palmer. 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, W.
1887. *Powell, Horatio Gibbs. Wood Villa, Tettenhall Wood, Wolverhampton.
1883. ‡Powell, John. Brynmill-crescent, Swansea.
1894. *Powell, Sir Richard Douglas, Bart., M.D. 62 Wimpole-street, 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 University College, Birmingham.
1884. *Prankerd, A. A., D.C.L. 66 Banbury-road, Oxford.
1869. *PREECE, Sir WILLIAM HENRY, K.C.B., F.R.S., M.Inst.C.E. Gothic Lodge, Wimbledon Common, Surrey; and 13 Queen Anne's Gate, S.W.
1888. *Preece, W. Llewellyn. Tan-y-bryn, Rusholme-road, Putney Heath, S.W.

Year of
Election.
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. Journal-chambers, Pelham-street, Nottingham.
1893. §PRESTON, Professor THOMAS, M.A., F.R.S. Bardowie, Orwell Park, Dublin.
1884. *Prevost, Major L. de T., 2nd Battalion Argyll and Sutherland Highlanders.
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.
1897. *Price, W. A., M.A. Teign House, Westcombe Park-road, S.E.
1897. ‡Primrose, Dr. Alexander. 196 Simcoe-street, Toronto, Canada.
1892. ‡Prince, Professor Edward E., B.A. Ottawa, Canada.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, N.W.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. 45 St. Giles, Norwich.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 26 Wimpole-street, W.
1888. ‡Probyn, Leslie C. Onslow-square, S.W.
1881. §Procter, John William. Ashcroft, York.
1863. ‡Proctor, R. S. Grey-street, Newcastle-upon-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1884. *Proudfoot, Alexander, M.D. 2 Phillips-place, Montreal, Canada.
1879. *Prouse, Oswald Milton, F.G.S. Alvington, Slade-road, Ilfracombe.
1872. *Pryor, M. Robert. Weston Park, Stevenage, Herts.
1871. *Puckle, Rev. T. J. Chestnut House, Huntingdon-road, Cambridge.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1899. §Pullar, Frederick P. The Lea, Bridge of Allan, N.B.
1867. *Pullar, Sir Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Brahan, Perth.
1891. ‡Pullen, W. W. F. University College, Cardiff.
1842. *Pumphrey, Charles. Castlewood, Park-road, Moseley, 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.
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, W.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1898. *Pye, Miss E. St. Mary's Hall, Rochester.
1883. §Pye-Smith, Arnold. Willesley, Park Hill Rise, Croydon.
1883. §Pye-Smith, Mrs. Willesley, Park Hill Rise, Croydon.
1868. ‡PYE-SMITH, P. H., M.D., F.R.S. 48 Brook-street, W.; and Guy's Hospital, 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 W. J. University of Missouri, Columbia, U.S.A.

Year of Election.

1870. ‡Rabbits, W. T. 6 Cadogan-gardens, S.W.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
1896. §Radcliffe, Herbert. Balderstone Hall, Rochdale.
1877. ‡*Radford, George D. Mannamead, Plymouth.*
*Radford, William, M.D. Sidmount, Sidmouth.
1855. *Radstock, The Right Hon. Lord. Mayfield, Woolston, Southampton.
1887. *Ragdale, John Rowland. The Beeches, Whitefield, Manchester.
1864. ‡Rainey, James T. 3 Kent-gardens, Ealing, W.
1898. *Raisin, Miss Catherine A., D.Sc. Bedford College, York-place, Baker-street, W.
1896. *Ramage, Hugh. St. John's College, Cambridge.
1894. *RAMBAUT, ARTHUR A., M.A., D.Sc., F.R.A.S., M.R.I.A., Radcliffe Observatory, Oxford.
1863. ‡RAMSAY, ALEXANDER. 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.
1885. ‡Ramsay, Major. Straloch, N.B.
1889. ‡Ramsay, Major R. G. W. Bonnyrigg, Edinburgh.
1876. *RAMSAY, WILLIAM, Ph.D., F.R.S., Professor of Chemistry in University College, London. 12 Arundel-gardens, W.
1883. ‡Ramsay, Mrs. 12 Arundel-gardens, W.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, West Kensington, 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. Sunnyhurst, Deane Park, Bournemouth.
Ransome, Thomas. Hest Bank, near Lancaster.
1889. §Rapkin, J. B. Sidcup, Kent.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, 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. 2 York-mansions, Battersea Park, S.W.
1889. ‡Rawlings, Edward. Richmond House, Wimbledon Common, Surrey.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
1866. *RAWLINSON, Rev. Canon GEORGE, M.A. The Oaks, Precincts, Canterbury.
1887. ‡Rawson, Harry. Earlswood, Ellesmere Park, Eccles, Manchester.
1886. ‡Rawson, W. Stepney, M.A. 68 Cornwall-gardens, Queen's-gate, S.W.
1868. *RAYLEIGH, The Right Hon. Lord, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Natural Philosophy in the Royal Institution. Terling Place, Witham, Essex.
1895. §§Raynbird, Hugh, jun. Garrison Gateway Cottage, Old Basing, Basingstoke.
1883. *Rayne, Charles A., M.D., M.R.C.S. St. Mary's Gate, Lancaster.
1897. *Rayner, Edwin Hartree. Teviot Dale, Stockport.
1896. §READ, CHARLES H., F.S.A. British Museum, W.C.
1870. ‡READE, THOMAS MELLARD, F.G.S. Blundellsands, Liverpool.
1884. §Readman, J. B., D.Sc., F.R.S.E. 4 Lindsay-place, Edinburgh.
1899. §Reaster, James William. 68 Linden-grove, Nunhead, S.E.
1852. *REDFERN, Professor PETER, M.D. 4 Lower-crescent, Belfast.

Year of Election.

1892. ‡Redgrave, Gilbert R., Assoc.Inst.C.E. The Elms, Westgate-road, Beckenham, Kent.
1889. ‡Redmayne, J. M. Harewood, Gateshead.
1889. ‡Redmayne, Norman. 26 Grey-street, Newcastle-upon-Tyne.
1890. *Redwood, Boverton, F.R.S.E., F.C.S. Glen Wathen, Church End, Finchley, N.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. ‡REED, Sir EDWARD JAMES, K.C.B., F.R.S. Broadway-chambers, Westminster, 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, W.C.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1897. ‡Reeve, Richard A. 22 Shuter-street, Toronto, Canada.
1881. §Reid, Arthur S., M.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *REID, CLEMENT, F.R.S., F.L.S., F.G.S. 28 Jermyn-street, S.W.
1892. ‡REID, E. WAYMOUTH, B.A., F.R.S., Professor of Physiology in University College, Dundee.
1889. ‡Reid, G., Belgian Consul. Leazes House, Newcastle-upon-Tyne.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1897.§§Reid, T. Whitehead, M.D. St. George's House, Canterbury.
1892. ‡Reid, Thomas. University College, Dundee.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
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, Rev. G. H., M.A. Charterhouse, Godalming.
1891. *Rendell, Rev. James Robson, B.A. Whinside, Whalley-road, Accrington.
1885. ‡Rennett, Dr. 12 Golden-square, Aberdeen.
1889. *Rennie, George B. 20 Lowndes-street, S.W.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1883. *Reynolds, A. H. Bank House, 135 Lord-street, Southport.
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. 19 Lady Barn-road, Fallowfield, Manchester.
1858. §REYNOLDS, RICHARD, F.C.S. Cliff Lodge, Hyde Park, Leeds.
1896. ‡Reynolds, Richard S. 73 Smithdown-lane, Liverpool.
1896. §Rhodes, Albert. Field Hurst, Liversidge, Yorkshire.
1883. ‡Rhodes, Dr. James. 25 Victoria-street, Glossop.
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, S.W.*
1890. ‡Rhodes, J. M., M.D. Ivy Lodge, Didsbury.
1884. ‡Rhodes, Lieut.-Colonel William. Quebec, Canada.
1899. *RHYS, Professor JOHN, M.A. Jesus College, Oxford.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Riva Muro, 14, Modena, Italy.

Year of Election.
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.
1869. *Richardson, Charles. 6 The Avenue, Bedford Park, Chiswick.
1882. §Richardson, Rev. George, M.A. Walcote, Winchester.
1884. *Richardson, George Straker. Isthmian Club, Piccadilly, W.
1889. ‡Richardson, Hugh. Bootham School, York.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1896. *Richardson, Nelson Moore, B.A., F.E.S. 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. Harry. 8 Park-grove, Cardiff.
1886. §Richmond, Robert. Heathwood, 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-street, S.W.
1894. §RIDLEY, E. P. 6 Paget-road, Ipswich.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, N.W.
1889. ‡Ridley, Thomas D. Coatham, Redcar.
1884. ‡Ridout, Thomas. Ottawa, Canada.
1881. *Rigg, Arthur. 152 Blomfield-terrace, W.
1883. *RIGG, EDWARD, M.A. Royal Mint, E.
1892. ‡Rintoul, D., M.A. Clifton College, Bristol.
1873. ‡Ripley, Sir Edward, Bart. Acacia, Apperley, near Leeds.
*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, 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.*
1898. §Robb, Alfred A. Lisnabreeny House, Belfast.
1869. *ROBBINS, JOHN, F.C.S. 57 Warrington-crescent, Maida Vale, 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.
1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. 17 Charterhouse-square, E.C.
1879. ‡Roberts, Samuel. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1896. §Roberts, Thomas J. 33 Serpentine-road, Liscard, Cheshire.
1868. *ROBERTS-AUSTEN, Sir W. CHANDLER, K.C.B., D.C.L., F.R.S., V.P.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal College of Science, London. (GENERAL SECRETARY.) Royal Mint, E.
1883. ‡Robertson, Alexander. Montreal, Canada.
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.

Year of Election.

1897. §ROBERTSON, Sir GEORGE S., K.C.S.I. Care of Messrs. Wm. Watson & Co., 7 Waterloo-place, S.W.
1897. §Robertson, Professor J. W. Department of Agriculture, Ottawa, Canada.
1892. ‡Robertson, W. W. 3 Parliament-square, Edinburgh.
1888. **Robins, Edward Cookworthy, F.S.A. 8 Marlborough-road, St. John's Wood, N.W.*
1886. *Robinson, C. R. 27 Elvetham-road, Birmingham.
1898. §Robinson, Charles E., M.Inst.C.E. Richmond Lodge, Torquay.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1897. ‡Robinson, Haynes. St. Giles's Plain, Norwich.
1887. §Robinson, Henry, M.Inst.C.E. 13 Victoria-street, 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.
1899. *Robinson, Mark, M.Inst.C.E. Overslade, Bilton, near Rugby.
1887. §Robinson, Richard. Bellfield Mill, Rochdale.
1881. ‡Robinson, Richard Atkinson. 195 Brompton-road, S.W.
1875. *Robinson, Robert, M.Inst.C.E. 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, 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. E. S. Talbot, D.D., Lord Bishop of. Kennington Park, S.E.
1896. §Rock, W. H. 73 Park-road East, Birkenhead.
1896. ‡Rodger, Alexander M. The Museum, Tay Street, Perth.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1885. *Rodriguez, Epifanio. New Adelphi Chambers, Adelphi, W.C.
1866. ‡Roe, Sir Thomas. Grove-villas, Litchurch.
1898. §§ROGERS, BERTRAM, M.D. 11 York-place, Clifton, Bristol.
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. Canon Saltren, M.A. Tresleigh, St. Austell, Cornwall.
1884. *Rogers, Walter. Hill House, St. Leonards.
1889. ‡Rogerson, John. Croxdale Hall, Durham.
1897. ‡Rogerson, John. Barrie, Ontario, Canada.
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. 12 Cumberland-place, Southampton.
1869. ‡*Roper, C. H. Magdalen-street, Exeter.*
1881. *Roper, W. O. Bank-buildings, Lancaster.
1855. *ROSCOE, Sir HENRY ENFIELD, B.A., Ph.D., LL.D., D.C.L., F.R.S. 10 Bramham-gardens, S.W.
1883. *Rose, J. Holland, M.A. 11 Endlesham-road, Balham, S.W.
1894. *Rose, T. K., D.Sc. 9 Royal Mint, E.
1885. ‡Ross, Alexander. Riverfield, Inverness.

Year of Election.

1897. ‡Ross, Hon. Alexander M. 3 Walmer-road, Toronto, Canada.
1887. ‡Ross, Edward. Marple, Cheshire.
1880. ‡Ross, Captain G. E. A., F.G.S. 8 Collingham-gardens, Cromwell-road, S.W.
1897. §Ross, Hon. G.W. Toronto, Canada.
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 Prescot-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.
1899. *Round, J. C., M.R.C.S. 19 Crescent-road, Sydenham Hill, S.E.
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.
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.
1885. ‡Roy, John. 33 Belvidere-street, Aberdeen.
1899. §Rubie, G. S. Belgrave House, Folkestone-road, Dover.
1875. *RÜCKER, A. W., M.A., D.Sc., Sec.R.S., Professor of Physics in the Royal College of Science, London. 19 Gledhow-gardens, South Kensington, S.W.
1892. §Rücker, Mrs. Levetleigh, Dane-road, St. Leonards-on-Sea.
1869. §RUDLER, F. W., F.G.S. The Museum, Jermyn-street, S.W.
1882. ‡Rumball, Thomas, M.Inst.C.E. 8 Union-court Chambers, Old Broad-street, E.C.
1896. *Rundell, T. W., F.R.Met.Soc. 25 Castle-street, Liverpool.
1887. ‡Ruscoe, John. 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, S.E.
Russell, John. 39 Mountjoy-square, Dublin.
1890. ‡Russell, J. A., M.B. Woodville, Canaan-lane, Edinburgh.
1883. *Russell, J. W. 16 Bardwell-road, Oxford.
1852. *Russell, Norman Scott. Arts Club, Hanover-square, 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. 34 Upper Hamilton-terrace, St. John's Wood, N.W.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1897. ‡Rutherford, A. Toronto, Canada.
1891. §Rutherford, George. Dulwich House, Pencisely-road, Cardiff.
1887. ‡Rutherford, William. 7 Vine-grove, Chapman-street, Hulme, Manchester.

Year of Election.

1879. ‡*Ruxton, Vice-Admiral, Fitzherbert R.N. 41 Cromwell-gardens, S. W.*
1875. ‡*Ryalls, Charles Wagner, LL.D. 3 Brick-court, Temple, E.C.*
1889. ‡Ryder, W. J. H. 52 Jesmond-road, Newcastle-upon-Tyne.
1897. ‡Ryerson, G. S., M.D. Toronto, Canada.
1898. §Ryland, C. J. Southerndon House, Clifton, Bristol.
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, E.C.
1885. ‡*Saint, W. Johnston. 11 Queen's-road, Aberdeen.*
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, 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.
1887. ‡Samson, C. L. Carmona, Kersal, Manchester.
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, S.W.
1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.
1883. ‡Sanderson, Deputy Surgeon-General Alfred. East India United Service Club, St. James's-square, S.W.
1893. ‡Sanderson, F. W., M.A. The School, Oundle.
1872. §SANDERSON, Sir J. S. BURDON, Bart., 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, Lady Burdon. 64 Banbury-road, Oxford.
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. Tylehurst, 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, 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, Dr. 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. Canon E. B., M.A., F.S.A. St. Thomas' Vicarage, 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.

Year of Election.

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., LL.D., F.R.S., M.R.C.S., Professor of Physiology in the University of Edinburgh. (General Secretary.)
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, 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. Ivy Dene, Oak-road, Sale, Cheshire.
Schunck, Edward, Ph.D., F.R.S., F.C.S. Oaklands, Kersal Moor, Manchester.
1873. *Schuster, Arthur, Ph.D., F.R.S., F.R.A.S., Professor of Physics in the Owens College, Manchester.
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, 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., F.R.S. Royal Institution, Albemarle-street, W.
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. Bryn Mawr College, Pennsylvania, U.S.A.
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.
1897.§§Scott, James. 173 Jameson-avenue, Toronto, Canada.
1857. *Scott, Robert H., M.A., F.R.S., F.R.Met.S., 6 Elm Park-gardens, S.W.
1884. *Scott, Sydney C. 28 The Avenue, Gipsy Hill, S.E.
1869. ‡Scott, William Bower. Chudleigh, Devon.
1895.§§Scott-Elliot, 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. The Pines, 10 Langland-gardens, Finchley-road, N.W.
1890. §Searle, G. F. C., M.A. Peterhouse, Cambridge.
1859. ‡Seaton, John Love. The Park, Hull.
1880. ‡Sedgwick, Adam, M.A., F.R.S. Trinity College and 4 Craven-road, 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, W.
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, E.C.

Year of Election.

1897. ‡Selous, F. C., F.R.G.S. Alpine Lodge, Worplesden, Surrey.
1884. ‡SELWYN, A. R. C., C.M.G., F.R.S., F.G.S. Ottawa, Canada.
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.
1888. *SENIER, ALFRED, M.D., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.
1888. *Sennett, Alfred R., A.M.Inst.C.E. The Chalet, Portinscale-road, Putney, S.W.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1892. ‡Seton, Miss Jane. 37 Candlemaker-row, Edinburgh.
1895. *Seton-Karr, H. W. Spencer House, Wimbledon, Surrey.
1892. §SEWARD, A. C., M.A., F.R.S., F.G.S. Westfield, Huntingdon-road, Cambridge.
1891. ‡Seward, Edwin. 55 Newport-road, Cardiff.
1868. ‡Sewell, Philip E. Catton, Norwich.
1899. §Seymour, Henry, J. 16 Wellington-road, Dublin.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1888. ‡Shackles, Charles F. Hornsea, near Hull.
1883. ‡Shadwell, John Lancelot. 30 St. Charles-square, Ladbroke Grove-road, W.
1871. *Shand, James. Parkholme, Elm Park-gardens, S.W.
1867. ‡Shanks, James. Dens Iron Works, Arbroath, N.B.
1881. ‡Shann, George, M.D. Petergate, York.
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. 7 Fishergate, Preston.
1870. ‡Shaw, Duncan. Cordova, Spain.
1896. ‡Shaw, Frank. Ellerslie, Aigburth-drive, Liverpool.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1870. ‡Shaw, John. 21 St. James's-road, Liverpool.
1891. ‡Shaw, Joseph. 1 Temple-gardens, 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. Meteorological Office, Victoria-street, S.W.
1883. ‡Shaw, Mrs. W. N. Meteorological Office, Victoria-street, S.W.
1891. ‡Sheen, Dr. Alfred. 23 Newport-road, Cardiff.
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., F.R.S. Clifton College, Bristol.
1885. ‡Shepherd, Rev. Alexander. Ecclesmechen, Uphall, Edinburgh.
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-park, Liverpool.
1888. *Shickle, Rev. C. W., M.A. Langridge Rectory, Bath.
1886. ‡Shield, Arthur H. 35A Great George-street, S.W.
1892. ‡Shields, John, D.Sc., Ph.D. Dolphingston, Tranent, Scotland.

Year of
Election.

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. 47 Victoria-street, S.W.
1888. ‡Shoppee, C. H. 22 John-street, Bedford-row, W.C.
1897. ‡Shore, Dr. Lewis E. St. John's College, Cambridge.
1875. ‡SHORE, THOMAS W., F.G.S. 105 Ritherdon-road, Upper Tooting, S.W.
1882. ‡SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital. Heathfield, Alleyn Park, Dulwich, S.E.
1897. ‡Shortt, Professor Adam, M.A. Queen's University, Kingston, Ontario, Canada.
1889. ‡Sibley, Walter K., B.A., M.B. 8 Duke Street-mansions, Grosvenor-square, W.
1883. ‡Sibly, Miss Martha Agnes. Flook House, Taunton.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1883. *Sidebotham, James Nasmyth. Parkfield, Altrincham, Cheshire.
1877. *Sidebotham, Joseph Watson, M.P. The Thorns, 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, 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.
1898. §§Simmons, Henry. Kingsland House, Whiteladies-road, Clifton, Bristol.
1862. ‡Simms, James. 138 Fleet-street, E.C.
1874. ‡Simms, William. Upper Queen-street, Belfast.
1876. ‡Simon, Frederick. 24 Sutherland-gardens, W.
1847. ‡SIMON, Sir JOHN, K.C.B., M.D., D.C.L., F.R.S. 40 Kensington-square, 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, W.
1894. §Simpson, Thomas, F.R.G.S. Fennymere, Castle Bar, Ealing, 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.
1897. §Sinnott, James. Bank of England-chambers, 12 Broad-street, Bristol.
1864. *Sircar, The Hon. Mahendra Lal, M.D., C.I.E. 51 Sankaritola, Calcutta.

Year of Election.

1892. ‡Sisley, Richard, M.D. 11 York-street, Portman-square, 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.
1898. §Skinner, Sidney. Cromwell House, Trumpington, Cambridgeshire.
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, S.W.; and Northbrook Park, near Exeter.
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. 65 Pembroke-road, 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. The Mount, Radbourne-street, Derby.
1887. §Small, William. Lincoln-circus, The Park, Nottingham.
1885. ‡Smart, James. Valley Works, Brechin, N.B.
1889. *Smart, William, LL.D. Nunholme, Dowanhill, Glasgow.
1898.§§Smeeth, W. F., M.A., F.G.S. Mysore, India.
1876. ‡Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1890. ‡Smethurst, Charles. Palace House, Harpurhey, Manchester.
1876. ‡Smieton, James. Panmure Villa, Broughty Ferry, Dundee.
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.
1897. ‡Smith, Andrew, Principal of the Veterinary College, Toronto, Canada.
1872. *SMITH, BASIL WOODD, F.R.A.S. Branch Hill Lodge, Hampstead Heath, N.W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, 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, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1897. §Smith, Sir Frank. 54 King-street East, Toronto, Canada.
1885. ‡Smith, Rev. G. A., M.A. 21 Sardinia-terrace, Glasgow.
1897.§§Smith, G. Elliot, M.D. St. John's College, Cambridge.
1860. *Smith, Heywood, M.A., M.D. 18 Harley-street, Cavendish-square, W.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
1889. *Smith, H. Llewellyn, B.A., B.Sc., F.S.S. 4 Harcourt-buildings, Inner Temple, E.C.

Year of Election.

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., Assoc.M.Inst.C.E. 52 Victoria-street, S.W.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1873. ‡Smith, Sir 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. 14 Calverley-park, Tunbridge Wells.
1884. ‡Smith, Vernon. 127 Metcalfe-street, Ottawa, Canada.
1892. ‡Smith, Walter A. 120 Princes-street, Edinburgh.
1885. *Smith, Watson. University College, Gower-street, W.C.
1896. *Smith, Rev. W. Hodson. 31 Esplanade-gardens, Scarborough.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1875. *Smith, William. Sundon House, Clifton Down, 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.
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, N.W.
1878. §Snell, H. Saxon. 22 Southampton-buildings, W.C.
1889. ‡Snell, W. H. Lamorna, Oxford-road, Putney, S.W.
1898. §Snook, Miss L. B. V. 13 Clare-road, Cotham, Bristol.
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 Oxford. 169 Woodstock-road, Oxford.
1892. *SOMERVAIL, ALEXANDER. The Museum, Torquay.
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.
1887. §Sowerbutts, Eli, F.R.G.S. 16 St. Mary's Parsonage, 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.
1887. ‡Spencer, F. M. Fernhill, Knutsford.

Year of
Election.

1884. ‡Spencer, John, M.Inst.M.E. Globe Tube Works, Wednesbury.
1889. *Spencer, John. Newbiggin House, Kenton, Newcastle-upon-Tyne.
1891. *Spencer, Richard Evans. The Old House, Llandaff.
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, N.
1894. ‡Spiers, A. H. Newton College, South Devon.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, N.
1864. *Spottiswoode, W. Hugh, F.C.S. 107 Sloane-street, S.W.
1854. *SPRAGUE, THOMAS BOND, M.A., LL.D., F.R.S.E. 29 Buckingham-terrace, Edinburgh.
1883. ‡Spratling, W. J., B.Sc., F.G.S. Maythorpe, 74 Wickham-road, Brockley, S.E.
1888. ‡Spreat, John Henry. Care of Messrs. Vines & Froom, 75 Aldersgate-street, E.C.
1884. *Spruce, Samuel, F.G.S. Beech House, Tamworth.
1897. ‡Squire, W. Stevens, Ph.D. Charendon House, St. John's Wood Park, N.W.
1888. *Stacy, J. Sargeant. 15 Wolseley-road, Crouch End, N.
1897. ‡Stafford, Joseph. Morrisburg, Ontario, Canada.
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, S.E.
1883. ‡Stanley, Mrs. Cumberlow, South Norwood, S.E.
1894. *STANSFIELD, ALFRED, D.Sc. Royal College of Science, S.W.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1899. §§STARLING, E. H., M.D., F.R.S., Professor of Physiology in University College, London. 8 Park-square West, N.W.
1876. ‡Starling, John Henry, F.C.S. 32 Craven-street, Strand, W.C.
1899. §Statham, William. The Redings, Totteridge, Herts.
1898. §§Stather, J. W., F.G.S. 16 Louis-street, Hull.
Staveley, T. K. Ripon, Yorkshire.
1894. ‡Stavert, Rev. W. J., M.A. Burnsall Rectory, Skipton-in-Craven, Yorkshire.
1873. *Stead, Charles. Red Barns, Freshfield, Liverpool.
1881. ‡Stead, W. H. Orchard-place, Blackwall, E.
1881. ‡Stead, Mrs. W. H. Orchard-place, Blackwall, 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., F.G.S. 169 Gloucester-terrace, W.
1891. ‡Steeds, A. P. 15 St. Helen's-road, Swansea.
1873. ‡Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1884. ‡Stephen, George. 140 Drummond-street, Montreal, Canada.
1884. ‡Stephen, Mrs. George. 140 Drummond-street, Montreal, Canada.
1884. *Stephens, W. Hudson. Low-Ville, Lewis County, New York, U.S.A.
1879. *STEPHENSON, Sir HENRY, J.P. The Glen, Sheffield.
1880. *Stevens, J. Edward, LL.B. Le Mayals, near Swansea.
1900. §STEVENS, FREDERICK (LOCAL SECRETARY), Town Clerk's Office, Bradford.
1892. ‡Stevenson, D. A., B.Sc., F.R.S.E., M.Inst.C.E. 84 George-street, Edinburgh.

Year of Election.

1863. *STEVENSON, JAMES C. Westoe, South Shields.
1890. *Steward, Rev. Charles J., F.R.M.S. The Cedars, Anglesea-road, Ipswich.
1885. *Stewart, Rev. Alexander, M.D., LL.D. Heathcot, Aberdeen.
1864. ‡STEWART, CHARLES, M.A., F.R.S., F.L.S., Hunterian Professor of Anatomy and Conservator of the Museum, Royal College of Surgeons, Lincoln's Inn Fields, W.C.
1892. ‡Stewart, C. Hunter. 3 Carlton-terrace, Edinburgh.
1885. ‡Stewart, David. Banchory House, Aberdeen.
1886. *Stewart, Duncan. 14 Windsor-terrace West, Glasgow.
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.
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.
1898. §§Stoddart, F. Wallis, F.I.C. Grafton Lodge, Sneyd Park, Bristol.
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.
1898. *Stokes, Professor George J., M.A. Riversdale, Sunday's Well, Cork.
1887. ‡*Stone, E. D., F.C.S. 19 Lever-street, Piccadilly, Manchester.*
1899. §Stone, F. J. Chazey Farm, Mapledurham, Reading.
1888. ‡STONE, JOHN. 15 Royal-crescent, Bath.
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, E.C.
1876. ‡Stone, Octavius C., F.R.G.S. Rothbury House, Westcliff-gardens, Bournemouth.
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, N.
1878. *Stoney, G. Gerald. 7 Roxburgh-place, Heaton, Newcastle-upon-Tyne.
1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. 8 Upper Hornsey Rise, N.
1876. §Stopes, Henry. 25 Denning-road, Hampstead, N.W.
1883. ‡Stopes, Mrs. 25 Denning-road, Hampstead, N.W.
1887. *Storey, H. L. Lancaster.
1884. §Storrs, George H. Gorse Hall, Stalybridge.
1888. *Stothert, Percy K. 3 Park-lane, Bath.
1874. ‡Stott, William. Scar Bottom, Greetland, near Halifax, Yorkshire.
1871. *STRACHEY, Lieut.-General SIR RICHARD, R.E., G.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, 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.*

Year of
Election.

1882. ‡Strange, Rev. Cresswell, M.A. Edgbaston Vicarage, Birmingham.
1898. §§Strangeways, C. Fox. Leicester.
1881. ‡STRANGWAYS, C. FOX, F.G.S. Geological Museum, Jermyn-street, S.W.
1889. ‡Streatfeild, H. S., F.G.S. Ryhope, near Sunderland.
1879. ‡Strickland, Sir Charles W., Bart., 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.
1898. *Strong, W. M. Helstonleigh, Champion Park, Denmark Hill, S.E.
1887. *Stroud, H., M.A., D.Sc., Professor of Physics in the College of Science, Newcastle-upon-Tyne.
1887. *STROUD, WILLIAM, D.Sc., Professor of Physics in the Yorkshire College, Leeds.
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, 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.
1897. ‡Stupart, R. F. The Observatory, Toronto, Canada.
1879. *Styring, Robert. 64 Crescent-road, Sheffield.
1891. *Sudborough, J. J., Ph.D., B.Sc. University College, Nottingham.
1898. §Sully, T. N. Avalon House, Priory-road, Tyndall's Park, Clifton, Bristol.
1884. ‡Sumner, George. 107 Stanley-street, Montreal, Canada.
1887. ‡Sumpner, W. E. 37 Pennyfields, Poplar, 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.
1898. §Sutton, William, M.D. 6 Camden-crescent, Dover.
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, W.
1897. §Swanston, William, F.G.S. Mount Collyer Factory, Belfast.
1879. ‡Swanwick, Frederick. Whittington, Chesterfield.
1887. §SWINBURNE, JAMES, M.Inst.C.E. 82 Victoria-street, S.W.
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., F.L.S. Avenue House, Oxford.
1891. ‡Swinnerton, R. W., Assoc.M.Inst.C.E. Bolarum, Dekkan, India.
1873. ‡Sykes, Benjamin Clifford, M.D. St. John's House, Cleckheaton.
1895. ‡Sykes, E. R. 3 Gray's Inn-place, W.C.

Year of Election.

1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. Glencoe, Elmbourne-road, Tooting Common, S.W.
1896. *Sykes, Mark L., F.R.M.S. 19 Manor-street, Ardwick, Manchester.
1887. *Sykes, T. H. Cringle House, Cheadle, Cheshire.
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.*
1859. §SYMONS, G. J., F.R.S., Sec.R.Met.Soc. 62 Camden-square, N.W.
1855. *SYMONS, WILLIAM. Dragon House, Bilbrook, Washford, Taunton.
1886.§§Symons, W. H., M.D. (Brux.), M.R.C.P., F.I.C. Guildhall, Bath.

1896. §Tabor, J. M. 20 Petherton-road, Canonbury, N.
1898.§§Tagart, Francis. 199 Queen's-gate, S.W.
1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, Forfarshire.
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. 6 Rossetti-mansions, Cheyne-walk, S.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.
1890. ‡TANNER, H. W. LLOYD, M.A., F.R.S., Professor of Mathematics and Astronomy in University College, Cardiff.
1897. ‡Tanner, Professor J. H. Ithaca, New York, U.S.A.
1892. *Tansley, Arthur G. 49 Gordon Mansions, W.C.
1883. *Tapscott, R. Lethbridge, Assoc.M.Inst.C.E., F.G.S., F.R.A.S. 62 Croxteth-road, Liverpool.
1878. ‡TARPEY, HUGH. Dublin.
1861. *Tarratt, Henry W. 190 Old Christchurch-road, Bournemouth.
1857. *Tate, Alexander. Rantalard, Whitehouse, Belfast.
1893. ‡Tate, George, Ph.D. College of Chemistry, Duke-street, Liverpool.
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.
1898. §Taylor, Lieut.-Colonel G. L. Le M. 6 College-lawn, Cheltenham.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
1887. ‡Taylor, George Spratt. 13 Queen's-terrace, St. John's Wood, N.W.
1881. *Taylor, H. A. 69 Addison-road, Kensington, W.
1884. *TAYLOR, H. M., M.A., F.R.S. 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. 32 Bruton-street, W.
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1898. §Taylor, Robert H., M.Inst.C.E. 5 Maison Dieu-road, Dover.
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.

Year of Election.

1895. ‡Taylor, W. A., M.A., F.R.S.E. Royal Scottish Geographical Society, Edinburgh.
1893. ‡Taylor, W. F. Bhootan, Whitehorse-road, Croydon, Surrey.
1894. *Taylor, W. W. 30 Banbury-road, 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.
1898. §Tebb, Robert Palmer. Enderfield, Chislehurst, Kent.
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.S., F.R.G.S. Athenæum Club, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-upon-Tyne.
1889. ‡Tennant, James. Saltwell, Gateshead.
1894. §§Terras, J. A., B.Sc. 40 Findhorn-place, Edinburgh.
1882. ‡Terrill, William. 42 St. George's-terrace, Swansea.
1896. *Terry, Rev. T. R., M.A., F.R.A.S. The Rectory, East Ilsley, Newbury, 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, W.C.
1889. ‡Thetford, The Right Rev. A. T. Lloyd, Bishop of, D.D. North Creake Rectory, Fakenham, Norfolk.
1885. ‡Thin, Dr. George. 22 Queen Anne-street, W.
1871. ‡*Thin, James. 7 Rillbank-terrace, Edinburgh.*
1871. ‡THISELTON-DYER, Sir W. T., K.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.
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.
1884. ‡THOMAS, F. WOLFERSTAN. Molson's Bank, Montreal, Canada.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1875. ‡Thomas, Herbert. Ivor House, Redland, Bristol.
1881. ‡THOMAS, J. BLOUNT. Southampton.
1869. ‡Thomas, J. Henwood, F.R.G.S. 86 Breakspear's-road, Brockley, S.E.
1880. *Thomas, Joseph William, F.C.S. 2 Hampstead Hill-mansions, N.W.
1899. *Thomas, Mrs. J. W. 2 Hampstead Hill-mansions, N.W.
1898. §§Thomas, Rev. U. Bristol School Board, Guildhall, Bristol.
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, 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.

Year of Election.

1885. ‡Thompson, D'Arcy W., B.A., C.B., 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.
1893. *Thompson, Harry J., M.Inst.C.E., Madras. Care of Messrs. Grindlay & Co., Parliament-street, S.W.
1870. ‡THOMPSON, Sir HENRY, Bart. 35 Wimpole-street, W.
1883. *Thompson, Henry G., M.D. 86 Lower Addiscombe-road, Croydon.
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.
1897. ‡Thompson, J. Barclay. 37 St. Giles's, Oxford.
1891. ‡Thompson, J. Tatham, M.B. 23 Charles-street, Cardiff.
1861. *THOMPSON, JOSEPH. Riversdale, Wilmslow, Cheshire.
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. Redlynch 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, W.
1896. ‡Thomson, John. 3 Derwent-square, Stonycroft, Liverpool.
1890. §THOMSON, Professor J. ARTHUR, M.A., F.R.S.E. Castleton House, Old Aberdeen.
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, LL.D., F.R.S., Sec.C.S., Professor of Chemistry in King's College, London. 85 Addison-road, W.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1897. ‡Thorburn, James, M.D. Toronto, Canada.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1887. ‡Thornton, John. 3 Park-street, Bolton.
1867. ‡Thornton, Sir Thomas. Dundee.
1898. §Thornton, W. M. The Durham College of Science, Newcastle-on-Tyne.
1883. ‡Thorowgood, Samuel. Castle-square, Brighton.
1881. ‡Thorp, Fielden. Blossom-street, York.
1881. *Thorp, Josiah. Undercliffe, Holmfirth.
1898. §Thorp, Thomas. Moss Bank, Whitefield, Manchester.
1864. *THORP, WILLIAM, B.Sc., F.C.S. 22 Sinclair-gardens, West Kensington, W.
1871. ‡THORPE, T. E., Ph.D., LL.D., F.R.S., F.R.S.E., Pres.C.S., Principal of the Government Laboratories, Clement's Inn-passage, W.C.
1898. §Thorpe, Jocelyn Field, Ph.D. Owens College, Manchester.

Year of
Election.

1883. §Threlfall, Henry Singleton, J.P. 1 London-street, Southport.
1899. §Threlfall, Richard. 259 Hagley-road, Birmingham.
1896. §Thrift, William Edward. 80 Grosvenor-square, Rathmines, 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.
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, 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, Yorkshire.
1899. §Tims, H. W. Marett, M.D., F.L.S. Fairseat Cottage, Warwick-road, Ealing, W.
1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, S.E.
1891. ‡Todd, Richard Rees. Portuguese Consulate, Cardiff.
1897. ‡Todhunter, James. 85 Wellesley-street, Toronto, Canada.
1889. §Toll, John M. 49 Newsham-drive, Liverpool.
1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.
1896. ‡Toms, Frederick. 1 Ambleside-avenue, Streatham, S.W.
1888. ‡Tomkins, Rev. Henry George. Park Lodge, Weston-super-Mare.
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, S.W.
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.
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.

Year of
Election.

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.
1871. ‡TRIMEN, ROLAND, M.A., F.R.S., F.L.S., F.Z.S. Water Hall, St. Aldate's, Oxford.
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. 10 Randolph-crescent, Edinburgh.
1891. ‡Trounce, W. J. 67 Newport-road, Cardiff.
1887. *TROUTON, FREDERICK T., M.A., D.Sc., F.R.S. Trinity College, Dublin.
1898. §Trow, Albert Howard. Glanhafren, Penarth.
1896. §Truell, Henry Pomeroy, M.B., F.R.C.S.I. Clonmannon, Ashford, Co. Wicklow.
1885. *Tubby, A. H., F.R.C.S. 25 Weymouth-street, Portland-place, W.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1888. ‡Tuckett, William Fothergill, M.D. 18 Daniel-street, Bath.
1871. ‡Tuke, Sir 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. Ottawa, Canada.
1892. ‡Turnbull, Alexander R. Ormiston House, Hawick.
1855. ‡Turnbull, John. 37 West George-street, Glasgow.
1896. ‡*Turner, Alfred. Elmswood Hall, Aigburgh, 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., F.R.S., F.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 (PRESIDENT ELECT.) 6 Eton-terrace, Edinburgh.
1893. ‡TURNEY, Sir JOHN, J.P. Alexandra Park, Nottingham.
1890. *Turpin, G. S., M.A., D.Sc. School House, Swansea.
1884. *Tutin, Thomas. The Orchard, Chellaston, Derby.
1886. *Twigg, G. H. 56 Claremont-road, Handsworth, Birmingham.
1898. §Twiggs, H. W. 65 Victoria-street, Bristol.
1899. §Twisden, John R., M.A. 14 Gray's Inn-square, W.C.
1888. §§Tyack, Llewelyn 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 University Museum, Oxford.
1883. ‡Tyrer, Thomas, F.C.S. Stirling Chemical Works, Abbey-lane, Stratford, E.
1897. ‡Tyrrell, J. B., M.A., B.Sc. Ottawa, Canada.
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. 1 Newton-grove, Bedford Park, Chiswick.
1883. §Unwin, John. Eastcliffe Lodge, Southport.

Year of Election.

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, W.
1887. ‡Upton, Francis R. Orange, New Jersey, U.S.A.
1872. ‡Upward, Alfred. 150 Holland-road, W.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1898. §§Usher, Thomas. 3 Elmgrove-road, Cotham, Bristol.
1880. ‡USSHER, W. A. E., F.G.S. 28 Jermyn-street, 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, N.
1865. *VARLEY, S. ALFRED. 5 Gayton-road, Hampstead, N.W.
1870. ‡Varley, Mrs. S. A. 5 Gayton-road, Hampstead, N.W.
1869. ‡Varwell, P. Alphington-street, Exeter.
1884. ‡Vasey, Charles. 112 Cambridge-gardens, W.
1895. §Vaughan, D. T. Gwynne. Howry Hall, Llandrindod, Radnorshire.
1887. *VAUGHAN, His Eminence Cardinal. Carlisle-place, Westminster S.W.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. ‡Vaughan, William. 42 Sussex-road, Southport.
1881. §VELEY, V. H., M.A., F.R.S., F.C.S. 20 Bradmore-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, Lieut.-Colonel R. de, R.E. 55 Queensborough-terrace, W.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1899. *VINCENT, SWALE, M.B. Physiological Laboratory, University College, W.C.
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 Spa.
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. Bank View, Chapel Allerton, Leeds.
1896. ‡*Wailes, Miss 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.

Year of Election.

1886. ‡Waite, J. W. The Cedars, Bestcot, Walsall.
1870. ‡WAKE, CHARLES STANILAND. Welton, near Brough, East Yorkshire.
1892. ‡*Walcot, John. 50 Northumberland-street, Edinburgh.*
1884. ‡Waldstein, Professor C., M.A., Ph.D. King's College, 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.
1885. ‡Walker, Mr. Baillie. 52 Victoria-street, Aberdeen.
1893. §Walker, Alfred O., F.L.S. Ulcombe-place, Maidstone, Kent.
1890. ‡Walker, A. Tannett. Hunslet, Leeds.
1897. *WALKER, B. E., F.G.S. Canadian Bank of Commerce, Toronto.
1883. ‡Walker, Mrs. Emma. 13 Lendal, York.
1883. ‡Walker, E. R. Pagefield Ironworks, Wigan.
1891. ‡Walker, Frederick W. Hunslet, Leeds.
1897. §Walker, George Blake. Tankersley Grange, near Barnsley.
1894. *WALKER, G. T., M.A. Trinity College, Cambridge.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1896. ‡Walker, Horace. Belvidere-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.
1886. *Walker, Major Philip Billingsley. Sydney, New South Wales.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1884. ‡Walker, Samuel. Woodbury, Sydenham Hill, S.E.
1888. ‡Walker, Sydney F. 195 Severn-road, Cardiff.
1887. ‡Walker, T. A. 15 Great George-street, S.W.
1883. ‡Walker, Thomas A. 66 Leyland-road, Southport.
Walker, William. 47 Northumberland-street, Edinburgh.
1895. §WALKER, WILLIAM G., A.M.Inst.C.E. 47 Victoria-street, S.W.
1896. §Walker, Colonel William Hall. Gateacre, Liverpool.
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.
1897. ‡Wallace, Chancellor. Victoria University, Toronto, Canada.
1892. ‡Wallace, Robert W. 14 Frederick-street, Edinburgh.
1887. *WALLER, AUGUSTUS D., M.D., F.R.S. Weston Lodge, 16 Grove End-road, 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, 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, Birmingham.
1894. *WALMISLEY, A. T., M.Inst.C.E. Engineer's Office, Dover Harbour.
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.*
1895. §WALSINGHAM, The Right Hon. Lord, LL.D., F.R.S. Merton Hall, Thetford.
1881. ‡Walton, Thomas, M.A. Oliver's Mount School, Scarborough.
1884. ‡Wanless, John, M.D. 88 Union-avenue, Montreal, Canada.
1887. ‡Ward, A. W., M.A., Litt.D.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.

Year of Election.
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.
1887. ‡Ward, Thomas. Brookfield House, Northwich.
1882. ‡Ward, William. Cleveland Cottage, Hill-lane, Southampton.
1867. ‡Warden, Alexander J. 23 Panmure-street, Dundee.
1858. ‡Wardle, Sir Thomas, F.G.S. St. Edward-street, Leek, Staffordshire.
1884. ‡Wardwell, George J. 31 Grove-street, Rutland, Vermont, U.S.A.
1887. *Waring, Richard S. Standard Underground Cable Co., 16th-street, Pittsburg, Pennsylvania, U.S.A.
1878. §**Warington, Robert**, F.R.S., F.C.S. 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
1896. ‡*Warr, A. F. 4 Livingstone-drive North, Liverpool.*
1896. ‡Warrand, Major-General, R.E. Westhorpe, Southwell, Middlesex.
1875. ‡*Warren, Algernon. Downgate, Portishead.*
1887. ‡**Warren**, Major-General Sir **Charles**, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. Athenæum Club, S.W.
1898. §§Warrington, Arthur W. University College, Aberystwith.
1893. ‡Warwick, W. D. Balderton House, Newark-on-Trent.
1875. *Waterhouse, Major-Colonel J. Oak Lodge, Court-road, 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, 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, W.C.
1892. §Watson, G., Assoc.M.Inst.C.E. 21 Springfield-mount, Leeds.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1882. ‡**Watson**, Rev. **Henry W.**, D.Sc., F.R.S. The Rectory, Berkeswell, Coventry.
1884. ‡Watson, John. Queen's University, Kingston, Ontario, Canada.
1889. ‡Watson, John, F.I.C. P.O. Box 317, Johannesberg, South Africa.
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.
1894. ***Watson, W.**, B.Sc. 7 Upper Cheyne-row, S.W.
1892. §Watson, William, M.D. Waverley House, Slateford, Midlothian.
1879. ***Watson, William Henry**, F.C.S., F.G.S. Braystones, Cumberland.
1882. ‡*Watt, Alexander. 19 Brompton-avenue, Sefton Park, Liverpool.*
1884. ‡Watt, D. A. P. 284 Upper Stanley-street, Montreal, Canada.
1869. ‡Watt, Robert B. E. 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. Little Don Waterworks, Langsett, near Penistone.
1896. ‡Watts, W. H. Elm Hall, Wavertree, Liverpool.

Year of Election.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.
1883. *WATTS, W. W., M.A., Sec. G.S., Assistant Professor of Geology in the Mason Science College, Birmingham.
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, N.W.*
1886. ‡WEBBER, Major-General C. E., C.B., M.Inst.C.E. 17 Egerton-gardens, S.W.
1891. §Webber, Thomas. Kensington Villa, 6 Salisbury-road, Cardiff.
1859. ‡Webster, John. Edgehill, Aberdeen.
1882. *Webster, Sir Richard Everard, LL.D., Q.C., M.P. Hornton Lodge, Hornton-street, Kensington, S.W.
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, S.W.
1894. §Weld, Miss. Conal More, Norham-gardens, Oxford.
1876. *WELDON, Professor W. F. R., M.A., F.R.S., F.L.S. The Museum, Oxford.
1880. *Weldon, Mrs. Oxford.
1897. ‡Welford, A. B., M.B. Woodstock, Ontario, Canada.
1881. §Wellcome, Henry S. Snow Hill Buildings, E.C.
1879. §WELLS, CHARLES A., A.I.E.E. 219 High-street, Lewes.
1881. §Wells, Rev. Edward, M.A. West Dean Rectory, Salisbury.
1894. ‡Wells, J. G. Selwood House, Shobnall-street, Burton-on-Trent.
1883. ‡Welsh, Miss. Girton College, Cambridge.
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., Principal of and Professor of Chemistry in the Merchant Venturers' Technical College, Bristol.
1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1898. §§West, Charles D. Imperial University, Tokyo, Japan.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1897. ‡Western, Alfred E. 36 Lancaster-gate, W.
1882. *Westlake, Ernest, F.G.S. Vale Lodge, Vale of Health, Hampstead, N.W.
1882. ‡Westlake, Richard. Portswood, Southampton.
1882. ‡WETHERED, EDWARD B., F.G.S. 4 St. Margaret's-terrace, Cheltenham.
1885. *WHARTON, Admiral Sir W. J. L., K.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.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1884. ‡Wheeler, Claude L., M.D. 251 West 52nd-street, New York City, U.S.A.

Year of Election.

1878. *Wheeler, W. H., M.Inst.C.E. Wyncote, Boston, Lincolnshire.
1888. §Whelen, John Leman. 18 Frognal, Hampstead, N.W.
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. The Priory, Westbury-on-Trym, near Bristol.
1898. *Whipple, Robert S. Scientific Instrument Company, Cambridge.
1874. ‡Whitaker, Henry, M.D. Fortwilliam Terrace, Belfast.
1883. *Whitaker, T. Walton House, Burley-in-Wharfedale.
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.
1897. §Whitcombe, George. The Wotton Elms, Wotton, Gloucester.
1886. ‡White, Alderman, J.P. Sir Harry's-road, Edgbaston, Birmingham.
1876. ‡White, Angus. Easdale, Argyllshire.
1886. ‡White, A. Silva. 47 Clanricarde-gardens, W.
1883. ‡White, Charles. 23 Alexandra-road, Southport.
1898.§§White, George. Clare-street House, Bristol.
1882. ‡White, Rev. George Cecil, M.A. Nutshalling Rectory, Southampton.
1885. *White, J. Martin. Balruddery, 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. 6 Southwell-gardens, S.W.
1895. ‡White, Philip J., M.B., Professor of Zoology in University College, Bangor, North Wales.
1884. ‡White, R. 'Gazette' Office, Montreal, Canada.
1898.§§White, Samuel. Clare-street House, Bristol.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 66 Cambridge-gardens, Notting Hill, W.
1883. *White, Mrs. 66 Cambridge-gardens, Notting Hill, W.
1886. *White, William. The Ruskin Museum, Sheffield.
1897. *WHITE, Sir W. H., K.C.B., F.R.S. The Admiralty, Whitehall, S.W.
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.
1891. §Whitmell, Charles T., M.A., B.Sc. Invermay, Headingley, Leeds.
1897. §Whittaker, E. T., M.A. Trinity College, Cambridge.
1896. §Whitney, Colonel C. A. The Grange, Fulwood Park, Liverpool.
1857. *WHITTY, Rev. JOHN IRWINE, M.A., D.C.L., LL.D. 11 Poplar-road, Ramsgate.
1887 ‡Whitwell, William. Overdene, Saltburn-by-the-Sea.
1874. *Whitwill, Mark. 1 Berkeley-square, Clifton, Bristol.
1883. ‡Whitworth, James. 88 Portland-street, Southport.
1870. ‡Whitworth, Rev. W. Allen, M.A. 7 Margaret-street, W.
1892. §Whyte, Peter, M.Inst.C.E. 3 Clifton-terrace, Edinburgh.
1897. ‡Wickett, M., Ph.D. 339 Berkeley-street, Toronto, Canada.
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.

Year of Election.

1896. ‡Wigglesworth, J. County Asylum, Rainhill, Liverpool.
1883. ‡Wigglesworth, Mrs. 23 Westbourne-grove, Scarborough.
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., M.A. Barley Rectory, Royston, Herts.
1886. *Wilkinson, J. H. Elmhurst Hall, Lichfield.
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.
1872. ‡WILLETT, HENRY. Arnold House, Brighton.
1894. ‡Willey, Arthur. New Museums, Cambridge.
1891. ‡Williams, Arthur J., M.P. Coedymwstwr, near Bridgend.
1861. *Williams, Charles Theodore, M.A., M.B. 2 Upper Brook-street, Grosvenor-square, 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.
1888. ‡Williams, James. Bladud Villa, Entry Hill, Bath.
1891. §Williams, J. A. B., M.Inst.C.E. Lingfield Grange, Branksome Park, Bournemouth.
1887. ‡Williams, J. Francis, Ph.D. Salem, New York, U.S.A.
1888. *Williams, Miss Katharine T. Llandaff House, Pembroke Vale, Clifton, Bristol.
1875. *Williams, M. B. Killay House, near Swansea.
1879. ‡*Williams, Matthew W.* 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.
1877. *WILLIAMS, W. CARLETON, F.C.S. University College, Sheffield.
1883. ‡Williamson, Miss. Sunnybank, Ripon, Yorkshire.
1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.D., LL.D., D.C.L., F.R.S., 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., Director of the Royal Botanical Gardens, Ceylon.
1896. §WILLISON, J. S. Toronto, Canada.
1882. ‡Willmore, Charles. Queenwood College, near Stockbridge, Hants.
1859. *Wills, The Hon. Sir Alfred. Chelsea Lodge, Tite-street, S.W.
1886. ‡Wills, A. W. Wylde Green, Erdington, Birmingham.
1898. §Wills, H. H. Barley Wood, Wrington, R.S.O., Somerset.
1886. ‡Wilson, Alexander B. Holywood, Belfast.
1885. ‡Wilson, Alexander H. 2 Albyn-place, Aberdeen.

Year of Election.

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. 14 Old 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, S.W.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1890. ‡Wilson, Edmund. Denison Hall, Leeds.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 99 Albany-street, N.W.
1899. §Wilson, George. The Rosary, Wendover, Tring.
1899. §Wilson, Mrs. George. The Rosary, Wendover, Tring.
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, Farnborough, 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.
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.
1896. ‡*Wilson, John H., D.Sc., F.R.S.E., Professor of Botany, Yorkshire College, Leeds.*
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
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. Hillocks of Terpersie, by Alford, Aberdeenshire.
1871. *WILSON, WILLIAM E., F.R.S. Daramona House, Streete, Rathowen, Ireland.
1861. *WILTSHIRE, Rev. THOMAS, M.A., D.Sc., F.G.S., F.L.S., F.R.A.S., Professor of Geology and Mineralogy in King's College, London. 25 Granville-park, Lewisham, S.E.
1877. ‡Windeatt, T. W. Dart View, Totnes.
1886. ‡WINDLE, BERTRAM C. A., M.A., M.D., D.Sc., F.R.S., Professor of Anatomy in Mason College, Birmingham.
1887. ‡*Windsor, William Tessimond. Sandiway, Ashton-on-Mersey.*
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1888. ‡WODEHOUSE, Right Hon. E. R., M.P. 56 Chester-square, S.W.
1875. ‡WOLFE-BARRY, Sir JOHN, K.C.B., F.R.S., M.Inst.C.E. 21 Delahay-street, Westminster, S.W.
1883. ‡Wolfenden, Samuel. Cowley Hill, St. Helens, Lancashire.
1898.§§Wollaston, G. H Clifton College, Bristol.
1884. ‡Womack, Frederick, M.A., B.Sc., 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.
1883. ‡Wood, Miss Emily F. Egerton Lodge, near Bolton, Lancashire.

Year of Election.

1875. *Wood, George William Rayner. Singleton, Manchester.
1878. ‡WOOD, Sir H. TRUEMAN, M.A. Society of Arts, John-street, Adelphi, W.C.
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.
1871. ‡Wood, Provost T. Baileyfield, Portobello, Edinburgh.
1899. *Wood, W. Hoffman. Ben Rhydding, Yorks.
1872. ‡Wood, William Robert. Carlisle House, Brighton.
1845. *Wood, Rev. William Spicer, M.A., D.D. Waldington, Combe Park, Bath.
1863. *WOODALL, JOHN WOODALL, M.A., F.G.S. 5 Queen's-mansions, Victoria-street, S.W.
1884. ‡Woodbury, C. J. H. 31 Milk-street, Boston, U.S.A.
1883. ‡Woodcock, Herbert S. The Elms, Wigan.
1884. ‡Woodd, Arthur B. Woodlands, Hampstead, N.W.
1896. §WOODHEAD, Professor G. SIMS, M.D. Pathological Laboratory, Cambridge.
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, S.W.
WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, E.C.
1888. ‡Woodthorpe, Colonel. Care of Messrs. King & Co., 45 Pall Mall, 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, 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, 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, S.W.
1870. ‡WOODWARD, HORACE B., F.R.S., F.G.S. Geological Museum, Jermyn-street, S.W.
1894. *Woodward, John Harold. 13 Queen Anne's-gate, Westminster, S.W.
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. South Collingham, Newark.
1874. ‡*Workman, Charles. Ceara, Windsor, Belfast.*
1899. §Workman, Thomas. Craigdarragh, Co. Down.
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.
1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, N.W.
1884. ‡Wragge, Edmund. 109 Wellesley-street, Toronto, Canada.
1896. ‡Wrench, Edward M., F.R.C.S. Park Lodge, Bastow.
1879. ‡Wrentmore, Francis. 34 Holland Villas-road, Kensington, S.W.
1883. *Wright, Rev. Arthur, M.A. Queen's College, Cambridge.

Year of Election.

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. University College, Toronto, Canada.
1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.
1871. ‡WRIGHTSON, THOMAS, M.P., M.Inst.C.E., F.G.S. Neasham Hall, Darlington.
1898.§§Wrong, Professor George M. The University, Toronto, Canada.
1897. ‡Wyld, Frederick. 127 St. George-street, Toronto, Canada.
1883. §Wyllie, Andrew. Sandown, Southport.
1885. ‡Wyness, James D., M.D. 349 Union-street, Aberdeen.
1871. ‡Wynn, Mrs. Williams. Plas-yn-Cefn, St. Asaph.
1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S. Geological Survey Office, 14 Hume-street, Dublin.
1899. §WYNNE, W. P., D.Sc., F.R.S. 10 Selwood-terrace, South Kensington, S.W.

1875. ‡Yabbicom, Thomas Henry. 23 Oakfield-road, Clifton, Bristol.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1894. *Yarrow, A. F. Poplar, E.
1883.§§Yates, James. Public Library, Leeds.
1896. ‡Yates, Rev. S. A. Thompson. 43 Phillimore-gardens, S.W.
1867. ‡Yeaman, James. Dundee.
1887. ‡Yeats, Dr. Chepstow.
1884. ‡Yee, Fung. Care of R. E. C. Fittock, Esq., Shanghai, China.
1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1891. ‡Yorath, Alderman T. V. Cardiff.
1884. ‡York, Frederick. 87 Lancaster-road, Notting Hill, W.
1891. §Young, Alfred C., F.C.S. 64 Tyrwhitt-road, St. John's, S.E.
1886. *YOUNG, A. H., M.B., F.R.C.S., Professor of Anatomy in Owens College, Manchester.
1884. ‡Young, Sir Frederick, K.C.M.G. 5 Queensberry-place, S.W.
1894. *Young, George, Ph.D. Firth College, Sheffield.
1884. ‡Young, Professor George Paxton. 121 Bloor-street, Toronto, Canada.
1876. ‡YOUNG, JOHN, M.D., Professor of Natural History in the University of Glasgow. 38 Cecil-street, Hillhead, Glasgow.
1896. ‡Young, J. Denholm. 88 Canning-street, Liverpool.
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, 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, U.S.A.
1892. Professor Svante Arrhenius. The University, Stockholm. (Bergsgatan 18).
1881. Professor G. F. Barker. University of Pennsylvania, Philadelphia, U.S.A. (3909, Locust-street).
1897. Professor Carl Barus. Brown University, Providence, R.I., U.S.A.
1894. Professor F. Beilstein. 8th Line, No. 17, St. Petersburg.
1894. Professor E. van Beneden. 50 quai des Pêcheurs, Liége, Belgium.
1887. Professor A. Bernthsen, Ph.D. Mannheim, L 11, 4, Germany.
1892. Professor M. Bertrand. L'École des Mines, Paris.
1894. Deputy Surgeon-General J. S. Billings. 40 Lafayette Place, New York, U.S.A.
1893. Professor Christian Bohr. Bredgade 62, Copenhagen, Denmark.
1880. Professor Ludwig Boltzmann. IX/I. Türkenstrasse 3, Vienna.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, U.S.A.
1884. Professor H. P. Bowditch, M.D. Harvard Medical School, Boston, Massachusetts, U.S.A.
1890. Professor Dr. L. Brentano. Maximilian-platz 1, München.
1893. Professor Dr. W. C. Brögger. Universitets Mineralogske Institute, Kristiania, Norway.
1887. Professor J. W. Brühl. Heidelberg.
1884. Professor George J. Brush. Yale College, New Haven, Conn., U.S.A.
1894. Professor D. H. Campbell. Stanford University, Palo Alto, California, United States.
1897. M. C. de Candolle. 3 Cour de St. Pierre, Geneva, Switzerland.
1887. Professor G. Capellini. 65 Via Zamboni, Bologna.
1887. Hofrath Dr. H. Caro. C. 8, No. 9, Mannheim.
1894. Emile Cartailhac. 5 Rue de la Chaîne, Toulouse, France.
1861. Professor Dr. J. Victor Carus. Universitätstrasse 15, Leipzig.
1894. Dr. A. Chauveau. Rue Cuvier 7, Paris.
1887. F. W. Clarke. United States Geological Survey, Washington, U.S.A.
1873. Professor Guido Cora. Via Goito 2, Rome.
1880. Professor Cornu. Rue de Grenelle 9, Paris.
1870. J. M. Crafts, M.D. L'École des Mines, Paris.
1876. Professor Luigi Cremona. 5 Piazza S. Pietro in Vincoli, Rome.
1889. W. H. Dall. United States Geological Survey, Washington, D.C., U.S.A.
1872. Professor G. Dewalque. Liége, Belgium.

Year of Election.

1870. Dr. Anton Dohrn, D.C.L. Naples.
1890. Professor V. Dwelshauvers-Dery. 5 Quai Marcellis, Liége, Belgium.
1876. Professor Alberto Eccher. Florence.
1894. Professor Dr. W. Einthoven. Leiden, Netherlands.
1892. Professor F. Elfving. Helsingfors, Finland.
1894. Professor T. W. W. Engelmann. Neue Wilhelmstrasse 15, Berlin, N.W.
1892. Professor Léo Errera. 38 Rue de la Loi, Brussels.
1874. Dr. W. Feddersen. 9 Carolinenstrasse, Leipzig.
1886. Dr. Otto Finsch. Leiden, Netherlands.
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 20, Liége, Belgium.
1887. Professor Dr. Anton Fritsch. 66 Wenzelsplatz, Prague.
1892. Professor Dr. Gustav Fritsch. Roon Strasse 10, Berlin.
1881. Professor C. M. Gariel. 6 Rue Edouard Detaille, Paris.
1866. Dr. Gaudry. 7 bis Rue des Saints Pères, Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1884. Professor J. Willard Gibbs. Yale University, New Haven, Conn., U.S.A.
1884. Professor Wolcott Gibbs. Newport, Rhode Island, United States.
1889. G. K. Gilbert. United States Geological Survey, Washington, D.C., U.S.A.
1892. Daniel C. Gilman. President of the Johns Hopkins University, Baltimore, U.S.A.
1870. William Gilpin. Denver, Colorado, U.S.A.
1889. Professor Gustave Gilson. l'Université, Louvain.
1889. A. Gobert. 222 Chaussée de Charleroi, Brussels.
1884. General A. W. Greely, LL.D. War Department, Washington, D.C., U.S.A.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1876. Professor Ernst Haeckel. Jena.
1881. Dr. Edwin H. Hall. 37 Gorham-street, Cambridge, Mass., U.S.A.
1895. Professor Dr. Emil Chr. Hansen. Carlsberg Laboratorium, Copenhagen, Denmark.
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. Zoologisches Institut, Alte Akademie, Munich.
1893. Professor Hildebrand. Stockholm.
1897. Dr. G. W. Hill. West Nyack, N.Y., U.S.A.
1887. Professor W. His. Königstrasse 22, Leipzig.
1881. Professor A. A. W. Hubrecht, LL.D., C.M.Z.S. The University, Utrecht, Netherlands.
1887. Dr. Oliver W. Huntington. Cloyne House, Newport, Rhode Island, U.S.A.
1884. Professor C. Loring Jackson. 6 Boylston Hall, Cambridge, Massachusetts, U.S.A.
1867. Dr. J. Janssen, LL.D. L'Observatoire, 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.
1887. Professor C. Julin. Liége.

Year of Election.

1876. Dr. Giuseppe Jung. 9 Via Borgonuovo, Milan.
1884. Professor Dairoku Kikuchi, M.A. Imperial University, Tōkyō, Japan.
1873. Professor Dr. Felix Klein. Wilhelm-Weberstrasse 3, Göttingen.
1894. Professor Dr. L. Kny. Kaiser-Allee 92, Wilmersdorf, bei Berlin.
1896. Dr. Kohlrausch. Physikalisch-technische Reichsanstalt, Charlottenburg, Berlin.
1856. Professor A. von Kölliker. Würzburg, Bavaria.
1894. Professor J. Kollmann. St. Johann 88, Basel, Switzerland.
1887. Professor Dr. Arthur König. Physiological Institute, The University, Berlin, N.W.
1894. Maxime Kovalevsky. Beaulieu-sur-Mer, Alpes-Maritimes.
1887. Professor W. Krause. Knesebeckstrasse, 17/I, Charlottenburg, bei Berlin.
1877. Dr. Hugo Kronecker, Professor of Physiology. The University, Bern, Switzerland.
1887. Professor A. Ladenburg. Kaiser Wilhelm Str. 108, Breslau.
1887. Professor J. W. Langley. 77 Cornell Street, Cleveland, Ohio, U.S.A.
1882. Dr. S. P. Langley, D.C.L., Secretary of the Smithsonian Institution. Washington, U.S.A.
1887. Dr. Leeds, Professor of Chemistry at the Stevens Institute, Hoboken, New Jersey, U.S.A.
1872. M. Georges Lemoine. 76 Rue Notre Dame des Changes, Paris.
1887. Professor A. Lieben. IX. Wasagasse 9, Vienna.
1883. Dr. F. Lindemann. Franz-Josefstrasse 12/I, 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-in-Breisgau, Germany.
1871. Professor Dr. Lütken. Nörregade 10, Copenhagen, Denmark.
1894. Dr. Otto Maas. Wurzerstrasse 1b, Munich.
1887. Dr. Henry C. McCook. 3,700 Chestnut-street, Philadelphia, U.S.A.
1867. Professor Mannheim. 1 Boulevard Beausejour, Paris.
1887. Dr. C. A. Martius. Voss Strasse 8, Berlin, W.
1890. Professor E. Mascart, Membre de l'Institut. 176 Rue de l'Université, Paris.
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, U.S.A.
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, France.
1894. Dr. Edmund von Mojsisovics. Strohgasse 26, Vienna, III/3.
1897. Professor Oskar Montelius. St. Paulsgatan 11, Stockholm, Sweden.
1897. Professor E. W. Morley. Adelbert College, Cleveland, Ohio, U.S.A.
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. Lysaker, Norway.
1894. Professor R. Nasini. Istituto Chimico dell' Università, Padova, Italy.
1864. Dr. G. Neumayer. Deutsche Seewarte, Hamburg.
1884. Professor Simon Newcomb. 1620 P.-street, Washington, D.C., U.S.A.
1887. Professor Emilio Noelting. Mühlhausen, Elsass, Germany.

Year of Election.

1894. Professor H. F. Osborn. Columbia College, New York, U.S.A.
1894. Baron Osten-Sacken. Heidelberg.
1890. Professor W. Ostwald. Linnestrasse 2/8, Leipzig.
1889. Professor A. S. Packard. Brown University, Providence, Rhode Island, U.S.A.
1890. Maffeo Pantaleoni. 20 Route de Malagrou, Geneva.
1895. Professor F. Paschen. Nelkenstrasse 14, Hannover.
1887. Dr. Pauli. Feldbergstrasse 49, Frankfurt a. M., Germany.
1890. Professor Otto Pettersson. Stockhoms Hogskola, Stockholm.
1894. Professor W. Pfeffer, D.C.L. The University, Leipzig.
1870. Professor Felix Plateau. 152 Chaussée de Courtrai, Gand, Belgium.
1884. Major J. W. Powell, Director of the Geological Survey of the United States. Washington, D.C., U.S.A.
1886. Professor Putnam. Harvard University, Cambridge, Massachusetts, U.S.A.
1887. Professor Georg Quincke. Hauptstrasse 47, Friederichsbau, Heidelberg.
1868. L. Radlkofer, Professor of Botany in the University of Munich (Sonnenstrasse 7).
1895. Professor Ira Remsen. Johns Hopkins University, Baltimore, U.S.A.
1886. Rev. A. Renard. 6 Rue du Roger, Gand, Belgium.
1897. Professor Dr. C. Richet. 15 Rue de l'Université, Paris, France.
1873. Professor Baron von Richthofen. Kurfürstenstrasse 117, Berlin, W.
1896. Dr. van Rijckevorsel. Parklaan 7, Rotterdam, Netherlands.
1892. Professor Rosenthal, M.D. Erlangen, Bavaria.
1890. A. Lawrence Rotch. Blue Hill Observatory, Readville, Mass., U.S.A.
1881. Professor Henry A. Rowland. Baltimore, U.S.A.
1895. Professsr Karl Runge. Körnerstrasse 19A, Hannover.
1894. Professor P. H. Schoute. The University, Groningen, Netherlands.
1897. Professor W. B. Scott. Princeton, N.J., U.S.A.
1883. Dr. Ernst Schröder. Gottesanerstrasse 9, Karlsruhe in Baden.
1874. Dr. G. Schweinfurth. Potsdamerstrasse 75A, Berlin.
1846. Baron de Selys-Longchamps. Liége, Belgium.
1873. Dr. A. Shafarik. Vinokrady 422, Prague.
1892. Dr. Maurits Snellen, Chief Director of the Royal Meteorological Institute of the Netherlands, de Bilt, near Utrecht.
1887. Professor H. Graf Solms. Bot. Garten, Strassburg.
1887. Ernest Solvay. 25 Rue du Prince Albert, Brussels.
1888. Dr. Alfred Springer. 32 East 2nd St., Cincinnati, Ohio, U.S.A.
1889. Professor G. Stefanescu. Stradaverde 8, 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. Cornell University, Ithaca, New York, U.S.A.
1864. Dr. Otto Torell, Professor of Geology in the University of Lund, Sweden.
1887. Dr. T. M. Treub. Buitenzorg, Java.
1887. Professor John Trowbridge. Harvard University, Cambridge, Massachusetts, U.S.A.
Arminius Vámbéry, Professor of Oriental Languages in the University of Pesth, Hungary.
1890. Professor Dr. J. H. van't Hoff. Uhlandstrasse 2, Charlottenburg, Berlin.
1889. Wladimir Vernadsky. Mineralogical Museum, Moscow.
1886. Professor Jules Vuylsteke. 59 Rue du Congres, Brussels, Belgium.
1887. Professor H. F. Weber. Zurich.

Year of Election.	
1887.	Professor Dr. Leonhard Weber. Moltke Strasse 60, Kiel.
1887.	Professor August Weismann. Freiburg-in-Breisgau, Baden.
1887.	Dr. H. C. White. Athens, Georgia, United States.
1881.	Professor H. M. Whitney. Beloit College, Wisconsin, U.S.A.
1887.	Professor E. Wiedemann. Erlangen. [C/o T. A. Barth, Johannisgasse, Leipzig.]
1887.	Professor Dr. R. Wiedersheim. Hansastrasse 3, Freiburg-im-Breisgau, Baden.
1887.	Professor Dr. J. Wislicenus. Liebigstrasse 18, Leipzig.
1887.	Dr. Otto N. Witt. 21 Siegmundshof, Berlin, N.W. 23.
1876.	Professor Adolph Wüllner. Aureliusstrasse 9, Aachen.
1887.	Professor C. A. Young. Princeton College, New Jersey, U.S.A.
1896.	Professor E. Zacharias. Botanischer Garten, Hamburg.
1887.	Professor F. Zirkel. Thalstrasse 33, Leipzig.

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——, 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.
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Glasgow Philosophical Society.
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——, Royal Institution.
——, Royal Meteorological Society.
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——	Geological Society.
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——	Collegio Romano.
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Madras	The Observatory.
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——	Smithsonian Institution.
——	The Naval Observatory.
——	United States Geological Survey of the Territories.

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Brisbane	Queensland Museum.
Sydney	Public Works Department.
Victoria	The Colonial Government.

NEW ZEALAND.

Canterbury Museum.

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